# ON USING AMOS, EQS, LISREL, Mx, RAMONA \& SEPATH 

FOR

# STRUCTURAL EQUATION MODELING <br> by 

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by

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[^0]
## DEDICATION

I dedicate this work to the memories of:
My late father, Mark Kofi Asante
My late brother and friend, Kwabena Amponsah Moses
and
My late friend, Edmund Ofori Ayeh.

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## SUMMARY

Structural Equation Modeling is a common name for the statistical analysis of Structural Equation Models. Structural Equation Models are models that specify relationships between a set of variables and can be specified by means of path diagrams. A number of Structural Equation Modeling programs have been developed. These include, amongst others, AMOS, EQS, LISREL, Mx, RAMONA and SEPATH. A number of studies have been published on the use of some of the applications mentioned above. They include, amongst others, Brown (1986), Waller (1993) and Kano (1997). Structural Equation Models are increasingly being used in the social, economic and behavioral sciences. More and more people are therefore making use of one or more of the Structural Equation Modeling applications on the market. This study is performed with the aim of using each of the Structural Equation Modeling applications AMOS, EQS, LISREL, Mx, RAMONA and SEPATH for the first time and document the experience, joy and the difficulties encountered while using them. This treatise is different from the comparisons already published in that it is based on the use of AMOS, EQS, LISREL, Mx, RAMONA and SEPATH to fit a Structural Equation Model for peer influences on ambition, which is specified for data obtained by Duncan, Haller and Portes (1971), by myself as a first time user of each of the programs mentioned. The impressive features as well as the difficulties encountered are listed for each application. Recommendations for possible improvements to the various applications are also proposed. Finally, recommendations for future studies on the use of Structural Equation Modeling programs are made.

## OPSOMMING

Strukturele Vergelykingsmodellering is ' n algemene term vir die statistiese ontleding van Strukturele Vergelykingsmodelle. Hierdie modelle spesifiseer verwantskappe tussen 'n stel veranderlikes en kan deur middel van pyldiagramme voorgestel word. Verskeie programme vir Strukturele Vergelykingsmodellering is ontwikkel. Hierdie programme sluit, onder andere, AMOS, EQS, LISREL, Mx, RAMONA en SEPATH in. Verskeie artikels oor die gebruik van hierdie programme is reeds gepubliseer (Brown 1986, Waller 1993, Kano 1997). Strukturele Vergelykingsmodelle word toenemend in die sosiale, ekonomiese en gedragswetenskappe gebruik. Gevolglik word ' $n$ positiewe toename in die gebruik van een of meer programme vir Strukturele Vergelykingsmodellering in die praktyk ondervind. Hierdie studie is gemik op die aanvanklike gebruik van sekere programme vir Strukturele Vergelykingsmodellering, naamlik AMOS, EQS, LISREL, Mx, RAMONA en SEPATH. Dit dokumenteer die suksesse en probleme wat ondervind word met die gebruik daarvan deur ' $n$ nuwe gebruiker. Hierdie verhandeling verskil ten opsigte van die vergelykings, wat alreeds gepubliseer is, aangesien dit gebaseer is op die gebruik van AMOS, EQS, LISREL, Mx, RAMONA en SEPATH deur ' n nuwe gebruiker. Ek, as ' n nuwe gebruiker, pas ' n Strukturele Vergelykingsmodel vir portuur-invloede op ambisie op data, wat deur van Duncan, Haller en Portes (1971) versamel is, met behulp van elk van die ses programme. My persoonlike indrukwekkende eienskappe, sowel as die probleme wat ek ondervind het, word vir elke program verskaf. Voorstelle vir moontlike verbeterings vir die verskillende programme word gemaak. Ten slotte, word aanbevelings vir toekomstige studies oor die gebruik van die programme vir Strukturele Vergelykingsmodellering ook voorgestel.

## CHAPTER 1

## INTRODUCTION

### 1.1 INTRODUCTORY BACKGROUND

Structural Equation Modeling is a common name for the statistical analysis of Structural Equation Models. Structural Equation Models are models that specify relationships between a set of variables. A nice aspect of structural equation models is that they can be represented as a path diagram. A path diagram is a fairly simple graphical display of a structural equation model on which the relationships between all the structural equation model variables are indicated by means of uni-directional (for dependence relationships) and bi-directional (for covariances, variances and correlations) arrows. In a path diagram rectangles or squares are used to represent the observed or manifest variables and circles or ellipses are used to represent unobserved or latent variables.

Every Structural Equation Model can be specified by means of a mathematical model(s) which specifies the statistical relationships between the variables of the model. For example, the manifest variable $\mathbf{X}$ may be modeled as a measurement of the latent variable $\mathbf{Y}$, with an error term E1. This relationship is shown in Figure 1.1 below.


Figure 1.1: The measurement path between $\mathbf{X}$ and $\mathbf{Y}$

The measurement equation for the model depicted in Figure 1.1 is:

$$
\mathbf{X}=\lambda \mathbf{Y}+\mathrm{E} 1
$$

where $\lambda$ is the measurement strength of $\mathbf{X}$ as a measurement of $\mathbf{Y}$.

Several general mathematical models have been proposed for the specification of Structural Equation Models. The mathematical models differ from each other merely in the way the variables in the general Structural Equation Modeling framework (system) are partitioned. The first general mathematical model for the specification of Structural Equation Models is known as the LISREL
model (Jöreskog 1973, 1977; Jöreskog \& Sörbom 1979, 1981; Wiley 1973). This model consists of a measurement model for the endogenous (receiving at least one uni-directional arrow) latent variables, a measurement model for the exogenous (emitting at least one uni-directional arrow) latent variables and a latent variable model. Adapting the measurement model incorporates endogenous manifest variables (excluding measurements of latent variables) for the endogenous latent variables using duplicated endogenous latent variables. A similar adaptation of the measurement model for the exogenous latent variables is used to incorporate exogenous manifest variables.

The mathematical models for Structural Equation Modeling with Latent Variables can not be analyzed directly since no observations on the latent variables are available. However, the mathematical models which describe the relationships between the variables (manifest and latent) in the Structural Equation Modeling system lead to a structural model for the population covariance or correlation matrix of the manifest variables, i.e., to a covariance or correlation structure for the manifest variables, respectively. Consequently, statistical methods (estimation and measures of goodness-of-fit) for the analysis of Covariance and Correlation Structures (cf. Jöreskog, 1970, 1978; Browne, 1974, 1982, 1984; Bentler, 1983; Shapiro, 1983, 1985, 1986, 1987; Mels, 1988, 2000) can be used to fit Structural Equation Models to observed data.

Several statistical software packages have been developed for the analysis of Structural Equation Models. The first commercial version of such an application, LISREL (Linear Structural RELations), was developed by Jöreskog and Sörbom (1981). The general LISREL model leads to a Covariance Structure, which contains eight parameter matrices. Initially, a user had to specify his/her model in terms of these eight parameter matrices.

The next Structural Equation Modeling application after LISREL was BENWEE developed by Browne and Cudeck (1983). BENWEE was based on a general model specification for Structural Equation Models known as the Bentler and Weeks' model proposed by Bentler and Weeks (1980). The user of BENWEE had to specify his/her model in terms of the three large sparse parameter matrices of the Bentler and Weeks model.

An alternative method to represent Structural Equation Models is by using structural equations such as measurement and regression equations. The Structural Equation Modeling application EQS
(Bentler, 1985) utilizes this representation in the sense that the model is specified as a set of structural equations. EQS implements the Bentler and Weeks model (Bentler \& Weeks, 1980).

Mels (1988) introduced the Structural Equation Modeling application RAMONA as part of his Masters dissertation in Statistics at the University of South Africa. The program RAMONA implements the RAMONA model (Mels, 1988) which is a minor adaptation of the Recticular Action Model proposed by McArdle and McDonald (1984). RAMONA was developed using Steiger's suggestion of the use of the ASCII symbols <--: for dependence paths and <--> for covariance/variance paths to create ASCII representations of path diagrams of Structural Equation Models. The use of the ASCII symbols allows users to specify their models in terms of text path diagrams instead of matrices. RAMONA was the first program of its kind to yield correct results whenever the sample correlation matrix instead of the sample covariance matrix is analyzed. The program also addressed the problems with negative variance and out of bound estimates.

Steiger (1989) developed the Structural Equation Modeling program EzPATH as a module of a statistical software package SYSTAT. This program was strongly influenced by Steiger's ideas for user-machine communication. Steiger left SYSTAT and joined forces with the statistical software package STATISTICA to develop the SEM program known as SEPATH (Steiger, 1995) for Windows. This program is strongly influenced by the conventions used in RAMONA and the ideas contained in Mels (1988).

An alternative method for specifying a structural equation model, different from the ones mentioned above, is by means of a graphics file of the path diagram of the model. The structural equation model application AMOS (Arbuckle, 1994), was the first program of its kind to use a graphics file of a path diagram to specify the model and to display the parameter estimates on the path diagram. It is equipped with powerful path diagram drawing tools that allow a user to specify his/her model by creating a graphics file for the path diagram graphically. The AMOS graphics input file makes no references to matrices or any ASCII symbols.

Mx (Neale, 1994) is a combination of a matrix algebra interpreter and a numerical optimizer. It enables exploration of matrix algebra through a variety of operations and functions. There are many built-in functions, which enables Mx to handle Structural Equation Modeling and other statistical modeling of data. The input script file in Mx is created by entering the required entries of the three
parameter matrices of the RAM model. Complex nonstandard models are easy to specify. For further general applicability, it allows users to specify their own fit functions, and optimization may be performed subject to linear and non-linear equality or boundary constraints.

The first version of each of the applications mentioned above has been updated more than once. The table below gives the name of the applications, the date of the latest version and the author(s) of the latest version.

Table 1.1: Name, date of latest release and authors of the six programs to be reviewed.

|  | Name of program | Date of release <br> of latest version | Author(s) |
| :---: | :--- | :---: | :--- |
| 1 | AMOS | 1996 | Jim Arbuckle |
| 2 | EQS | 1995 | Peter M. Bentler |
| 3 | LISREL | 1999 | Karl Jöreskog \& Dag Sörbom |

There are other Structural Equations Modeling applications which are not considered in this study. These include, amongst others, COSAN (Fraser \& McDonald, 1988), LINCS (Schoenberg and Arminger, 1988), LISCOMP (Muthen, 1987), MECOSA 3 (Arminger, 1997), SAS PROC CALIS (SAS Institute, 1990), and a program using SAS Interactive Matrix Language (IML) by Cudeck, Klebe and Henly (1993).

In the next section, a brief account of the Duncan, Haller and Portes (1971) Structural Equations Modeling application is given. The path diagram of the application, Figure 1.2 below, is also used to introduce the basic concepts involved in Structural Equation Modeling.

### 1.2 A MODEL FOR PEER INFLUENCES ON AMBITION



Sociologists have often called attention to the way in which one's peers- e.g., best friends- influence one's decisions- e.g., choice of occupation. They have recognized that the relation must be reciprocal- if my best friend influences my choice, I must influence his. The model depicted in figure 1.2 , is based on data by Duncan, Haller, \& Portes (1971). The data was collected from a study conducted using a sample of 329 Michigan high-school students paired with their best friends. The model was analyzed by Jöreskog (1977) by using fixed path coefficients rather than constrained variances. In Figure 1.2, the descriptive names for the variables and their full names are:

REPAP Respondent's parental aspiration.
REINT Respondent's intelligence.
RESOE Respondent's socioeconomic status.
REOAP Respondent's occupational aspiration.
REEAP Respondent's educational aspiration.
BFINT Best friend's intelligence.
BFPAP Best friend's parental aspiration.
BFSOE Best friend's socioeconomic status.
BFOAP Best friend's occupational aspiration.
BFEAP Best friend's educational aspiration.

The path diagram in Figure 1.2 will now be used to introduce the basic concepts involved in Structural Equation Modeling.

## Latent variables:

A latent variable is an unobservable variable that is indicated by circle (ellipse) on a path diagram. The latent variables of the model depicted in Figure 1.2 are REAMB and BFAMB.

Latent variables can, however, be measured by using measuring instruments. A measuring instrument consists of common measurements (items, tests, questions, etc) of the latent variable of interest. A summary of the measuring instruments for the latent variables of the model depicted in Figure 1.2 is found in Table 1.2.

Table 1.2: Measuring Instruments of the Latent Variables in Figure 1.2

| Latent Variable | Measuring Instrument |
| :--- | :--- |
| REAMB | REOAP, REEAP |
| BFAMB | BFEAP, BFOAP |

## Measuring Instruments

A measuring instrument (scale) for a latent variable consists of a set of measurements. Each measurement is a manifest (observable) variable and is usually psychometric test, a questionnaire item or physical measurement. A measurement error is associated with each individual measurement. These measurement errors are latent variables, which emits only one uni-directional arrow. In Figure 1.2, E1, E2, E3 and E4 denote measurement errors.

## Manifest Variables

Manifest variables are observable variables. On a path diagram a square or rectangle box indicates manifest variable. In the model depicted in Figure 1.2, REOAP, REEAP, REPAP, REINT, RESOE, BFEAP, BFOAP, BFSOE, BFINT and BFPAP are manifest variables.

## Dependence Paths

The variables of Structural Equation Models are classified as being endogenous or exogenous. An endogenous variable receives at least one uni-directional arrow while an exogenous variable only emits unidirectional arrows. From Figure 1.2, REOAP, REEAP, REAMB, BFAMB, BFEAP and BFOAP are all endogenous variables while REPAP, REINT, RESOE, BFSOE, BFINT, BFPAP, E1, $\mathrm{E} 2, \mathrm{E} 3, \mathrm{E} 4, \mathrm{Z} 1$ and Z 2 are exogenous variables.
Dependence paths are used for defining the relationships between endogenous and exogenous variables and are indicated on a path diagram by means of a uni-directional arrow. For example, the dependence path between RESOE, REAMB and the error term Z 1 taken from Figure 1.2 is as shown in Figure 1.3 below.


Figure 1.3: The dependence path between REAMB, RESOE and Z1

## Variance and Covariance Paths

A variance or covariance path is used to indicate the variance of a variable as well as the covariance or correlation between two variables and is represented on a path diagram by means of a bidirectional arrow. In Figure 1.2, the variance of the error terms, the measurement errors, the latent variables and the six manifest variables: REPAP, REINT, RESOE, BFSOE, BFINT and BFPAP are covariance paths. The correlations between the six manifest variables: REPAP, REINT, RESOE, BFSOE, BFINT and BFPAP are shown on clearly in Figure 1.2. The variances of the error terms and the measurement errors are usually unknown parameters while the variances of the latent variables are frequently fixed or constrained at unity.

## The Parameters

Structural Equation Models contain known (fixed) and unknown (free) parameters. Fixed parameters are usually shown on a path diagram by displaying their values along the corresponding paths while no values are usually indicated on paths associated with free parameters. In Figure 1.2, the coefficients of the measurement errors and the error terms as well as all the variances are fixed at unity. The measurement strengths of the measurements REOAP, REEAP, BFEAP, BFOAP, the strength of the linear influences of REPAP, REINT, RESOE, BFSOE, BFINT and BFPAP and the correlations between REPAP, REINT, RESOE, BFSOE, BFINT and BFPAP represent the unknown parameters of the Structural Equation Model shown in Figure 1.2.

## The Statistical Methods

The Statistical Methods for the analysis of Structural Equation Models consist of methods to estimate the unknown (free) parameters of the model and methods to assess the goodness-of-fit of the model to the data.

The table below was the sample correlation matrix obtained by Duncan, Haller and Portes (1971) for the sample of 329 students. The descriptive names of the variables are given full meaning in Section 1.2 above.

Table 1.3: The correlation matrix for the Duncan, Haller and Portes' Application given in lower triangular format.

| REINT | 1.0000 |  |  |  |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :--- |
| REPAP | .1839 | 1.0000 |  |  |  |  |  |  |  |  |  |  |
| RESOE | .2220 | .0489 | 1.0000 |  |  |  |  |  |  |  |  |  |
| REOAP | .4105 | .2137 | .3240 | 1.0000 |  |  |  |  |  |  |  |  |
| REEAP | .4043 | .2742 | .4047 | .6247 | 1.0000 |  |  |  |  |  |  |  |
| BFINT | .3355 | .0782 | .2302 | .2995 | .2863 | 1.0000 |  |  |  |  |  |  |
| BFPAP | .1021 | .147 | .0931 | .0760 | .0702 | .2087 | 1.0000 |  |  |  |  |  |
| BFSOE | .1861 | .0186 | .2707 | .2930 | .2407 | .2950 | -.0438 | 1.0000 |  |  |  |  |
| BFOAP | .2598 | .0839 | .2786 | .4216 | .3275 | .5007 | .1988 | .3607 | 1.0000 |  |  |  |
| BFEAP | .2903 | .1124 | .3054 | .3269 | .3669 | .5191 | .2784 | .4105 | .6404 | 1.0000 |  |  |

Standard deviations are not given in Duncan, Haller, \& Portes (1971).

### 1.3 MOTIVATION

A number of studies have been published on the use of some of the applications mentioned above. These include, amongst others, Brown (1986), Waller (1993) and Kano (1997). Each of these authors used a different approach to investigate the use of the Structural Equation Modeling applications. Brown (1986) published a paper on the comparison of LISREL and EQS for obtaining parameter estimates in confirmatory factor analysis. He focused on the computational accuracy of the parameter estimates of the two programs. Waller (1993), reviews seven confirmatory factor analysis programs that run on a personal computer: EQS, EzPATH, LINCS, LISCOMP, LISREL, SIMPLIS, and CALIS along five dimensions: (1) clarity of documentation, (2) ease of use, (3) computational accuracy and estimator options, (4) error diagnostics and assessment of model fit, and (5) model flexibility. Kano (1997) is the latest publication of the review of Structural Equation Modeling applications. He invited eleven authors of Structural Equation Modeling applications to write a description of their own program and to answer the questionnaire enclosed. Seven responses were received from the authors of the following programs: AMOS, COSAN, EQS, LISREL, MECOSA 3, RAMONA and SEPATH. The answers to the questionnaire were summarized in tables under the following headings: (1) author affiliation, (2) version (date of release), (3) working circumstance, (4) name, the full meaning of the software name, (5) manual, (6) data import, (7) basic statistics and plots, (8) data manipulation, (9) path diagram and matrix algebra, (10) estimation method, (11) variable type, (12) starting value, (13) constraint, (14) goodness-of-fit index, (15) LM
(Lagrange multiplier test) and Wald statistics, (16) improper solution, (17) multiple populations and mean structure, (18) simulation, (19) user support and (20) address.

Structural Equation Models are increasingly being used in the social, economic and behavioral sciences. More and more people are therefore making use of one or more of the Structural Equation Modeling applications. As is the case of everything in this world, there is always a first time at which one comes to use one of the Structural Equation Modeling applications. The study is done with the aim of using each of the Structural Equation Modeling applications AMOS, EQS, LISREL, Mx, RAMONA and SEPATH for the first time and document the experiences, joys and the difficulties encountered while using them.

This treatise is different from the comparisons already published in that it is based on the use of AMOS, EQS, LISREL, Mx, RAMONA and SEPATH to fit the Structural Equation Model depicted in Figure 1.2 to the data in Table 1.3 by myself as a first time user of each of the programs mentioned, working by trial and error to fit the model to the data. Notes were made on the experiences, joys and difficulties encountered and the ways in which they were solved so that each of the programs would run finally. I also noted the complexities in the model specifications in each of the programs. The time it took for the start of each program to the time an output file was produced was also noted. This was done to have an idea of how long it will take a first time user to use each of the programs.

Based on the brief discussions above, the following objectives for the study on using AMOS, EQS, LISREL, Mx, RAMONA and SEPATH for Structural Equation Modeling as a first time user were formulated.

1. To review the use of AMOS, EQS, LISREL, Mx, RAMONA and SEPATH for Structural Equation Modeling.
2. To illustrate the use of AMOS, EQS, LISREL, Mx, RAMONA and SEPATH to fit the structural equation model in Figure 1.2 to the sample correlation matrix in Table 1.3.
3. To formulate positive impressions and difficulties encountered in fitting the model in Figure 1.2 to the sample correlation matrix in Table 1.3 (for each application).
4. To formulate recommendations for the program author(s) to improve the applications to suite first users.

The model depicted in Figure 1.2 represents a special case of Jöreskog's (1977, Figure 2) very well known path analysis model for data of Duncan, Haller and Portes (1971) on peer influence on ambition. It has the same structure as the model employed in Table IV of Jöreskog (1977). The only difference is the manner in which the scales of the latent variables REAMB and BFAMB are set.

The model, depicted in Figure 1.2, was chosen for this study for the following reasons: 1) It consists of most of the different types of variables one encounters in Structural Equation Models. The only exception is exogenous latent variables (excluding error variables). 2) The data to be analyzed is a correlation matrix. In Kano (1997), it is claimed that RAMONA is one of the few Structural Equation Modeling programs that can fit the model in Figure 1.2 correctly to the sample correlation matrix provided in Table 1.3. Consequently, this example may be used to compare the results produced by the SEM programs with the ability to analyze the sample correlation matrix correctly with those produced by the programs that treat correlation structures as if they were covariance structures.

### 1.4 SUMMARY OF CONTENTS

In Chapter Two, the use of AMOS is illustrated by describing the creation of a path diagram for the Duncan, Haller and Portes' application. The use of the path diagram to fit the model in Figure 1.2 to the Sample Correlation Matrix in Table 1.3 with AMOS is then outlined. A description of the entries of the AMOS output file for the Duncan, Haller and Portes' application concludes the contents of the chapter.

In Chapter Three, the use of EQS is illustrated by describing how to specify the Duncan, Haller and Portes' application in terms of structural equations. The use of the input file created to fit the model in Figure 1.2 to the Sample Correlation Matrix in Table 1.3 with EQS is then outlined. A description of the entries of the EQS output file for the Duncan, Haller and Portes' application concludes the contents of the chapter.

In Chapter Four, the use of LISREL is illustrated by describing the specification of the Duncan, Haller and Portes' application in terms of the LISREL eight parameter matrices of the LISREL model, the use of the SIMPLIS command language to specify the same model and the creation of a
path diagram for the Duncan, Haller and Portes' application. The use of the path diagram to fit the model in Figure 1.2 to the Sample Correlation Matrix in Table 1.3 with LISREL is then outlined. A description of the entries of the LISREL output file for the Duncan, Haller and Portes' application concludes the contents of the chapter.

In Chapter Five, the use of Mx is illustrated by describing how to specify the Duncan, Haller and Portes' application in terms of the RAM model. The creation of a Mx input script file for the model depicted in Figure 1.2 by using the path diagram is also illustrated. The use of the input file created to fit the model in Figure 1.2 to the Sample Correlation Matrix in Table 1.3 with Mx is then outlined. A description of the entries of the Mx output file for the Duncan, Haller and Portes' application concludes the contents of the chapter.

In Chapter Six, the use of RAMONA is illustrated by describing how to specify the Duncan, Haller and Portes' application by using the ASCII symbols of <--: for dependence paths and <--> for variance/covariance paths. The use of the input file created to fit the model in Figure 1.2. to the Sample Correlation Matrix in Table 1.3 with RAMONA is then outlined. A description of the entries of the RAMONA output file for the Duncan, Haller and Portes' application concludes the contents of the chapter.

In Chapter Seven, the use of SEPATH is illustrated by describing how to specify the Duncan, Haller and Portes' application by using the ASCII symbols of <-- for dependence paths and -- for variance/covariance paths. The use of the input file created to fit the model in Figure 1.2. to the Sample Correlation Matrix in Table 1.3 with SEPATH is then outlined. A description of the entries of the SEPATH output file for the Duncan, Haller and Portes' application concludes the contents of the chapter.

Chapter Eight deals with my personal positive impressions about each of the applications used to fit the model depicted in Figure 1.2 to the Sample Correlation Matrix in Table 1.3 and the difficulties I encountered as a first time user of each application. In addition, a comparison of the parameter estimates produced by the SEM programs with the ability to analyze the sample correlation matrix correctly is made with those produced by the programs that treat correlation structures as if they were covariance structures. The chapter is concluded with some proposed recommendations for each application based on my experience of using each of them.

# CHAPTER 2 <br> AMOS 

### 2.1 HISTORICAL BACKGROUND

The acronym AMOS stands for Analysis of MOment Structures. The first version of AMOS was developed by Jim Arbuckle in 1994. AMOS is a graphically based program for covariance structure analysis that has the ability to calculate maximum likelihood estimates in the presence of missing data, to compare multiple models, and to perform extensive bootstrap and Monte-Carlo analyses. The graphical interface allows a structural equation model to be specified by drawing its path diagram. The program then displays parameter estimates, including means and intercepts in regression equations, directly on the path diagram. The path diagrams are of presentation quality. They can be printed directly, and can be imported into other applications such as word processors or desktop publishing programs, and general purpose graphics programs.

AMOS can fit multiple models in a single analysis. The program examines every pair of models for which one model can be obtained by replacing restrictions on the parameters of the other. AMOS reports several statistics appropriate for comparing such nested models. In common with other programs for covariance structure analysis, AMOS allows multiple-group analyses.

AMOS was originally intended as a tool for teaching. For this reason, ease of use was a primary design goal. Two features are specifically provided for pedagogical purposes.
(1) It is possible to display the degrees of freedom for a model at any time during the course of drawing its path diagram. Students can use this feature to observe the change in degrees of freedom as new elements are added to a path diagram or as parameter constraints are modified.
(2) The modeling laboratory allows the student to enter an arbitrary choice of parameter values, and then observe the resulting implied moments and the resulting value of the discrepancy function. This capability allows the student to try out one set of parameter values after another in an attempt to make the implied moments resemble the sample moments.

The 1994 version of AMOS was updated in 1996. The new version accommodates the use of kanji characters in path diagrams. Even complex structural equation models are specified and evaluated
graphically, as path diagrams. Several intelligent drawing aids are built into the program to make graphical modeling easy. The program also has an online manual which can be accessed any time. A demonstration version of AMOS is available from the worldwide web site http://www.smallwaters.com.

### 2.2 THE AMOS INPUT SYSTEM

There are two ways of fitting a structural equation model to data with AMOS. These are:

1) To specify the structural equation model in an AMOS input file by using the appropriate AMOS commands. This input file is a text file with extension ".ami" and can be prepared manually by using text editor such as Notepad or Wordpad. Once the input file is prepared, the model is fitted to the data by running AMOSWIND.EXE.
2) To use AMOSGRAF to draw the path diagram of the structural equation model to create an AMOS graphics file. This graphics file is saved with file extension ".amw". The model is then fitted to the data by using the "Model-Fit" menu of AMOSGRAF.EXE

The data to be analyzed is provided in an AMOS data file. An AMOS data file is a text file that contains the raw data matrix, the sample covariance matrix or sample correlation matrix with standard deviations in free format.

## GENERAL RULES FOR TYPING AMOS INPUT FILES

- $\quad$ Each section of the Input file is preceded by a dollar sign (\$).
- The exclamation (!) sign precedes comments added to the Input file.
- Each parameter name can be alphanumeric and as long as one desires.

An AMOS Input File may be divided into six sections. These are:

1. Model information
2. Model Specification
3. Estimation Methods
4. Data
5. Group name (optional) and
6. Output

### 2.2.1 MODEL INFORMATION

Model Information is specified in three paragraphs namely: Title paragraph, Observed variable paragraph and Unobserved variable paragraph.
(a) TITLE PARAGRAPH

This paragraph provides a description for the analysis to be performed. It is provided as a comment and may be left out without affecting the job to be run. The title paragraph ends in a full stop. For the model depicted in Figure 1.2, we may have the following title paragraph:

Duncan, Haller and Portes' Application
(b) OBSERVED (MANIFEST) PARAGRAPH

- An observed variable is represented by means of a rectangle or square on a path diagram.
- The observed variable paragraph allows the user to give descriptive names to the observed variables of a model.
- The observed variable paragraph starts with the word "Observed" preceeded by the dollar sign (\$).
- Each descriptive name of an observed variable may not exceed eight (8) characters.
- Descriptive names must be on separate lines.

For the model depicted in Figure 1.2, we may have an observed paragraph as shown below:
\$Observed
REINT
REPAP
RESOE
REOAP
REEAP
BFINT
BFPAP
BFSOE
BFOAP
BFEAP
(c) UNOBSERVED (LATENT) PARAGRAPH

- An unobserved variable is represented by means of a circle or an ellipse on a path diagram.
- The unobserved variable paragraph allows the user to give descriptive names to the unobserved variables of a model.
- The unobserved variable paragraph starts with the dollar sign (\$) followed by the word "Unobserved".
- The descriptive name of an unobserved variable may not exceed eight (8) characters.
- Each descriptive name is listed on a separate line.

For the model depicted in Figure 1.2, we may have an unobserved paragraph as shown below:
\$Unobserved
REAMB
BFAMB
E1
E2
E3
E4
Z1
Z2

### 2.2.2 MODEL SPECIFICATION

## THE STRUCTURE PARAGRAPH

This is the section of the input file where the path diagram of the model is coded directly with the use of the ASCII symbols <--- (for dependence paths) and <--> (for variance/covariance paths).

- The paragraph starts with the dollar sign (\$) followed by the word "Structure".
- The "Structure paragraph" consists of two sub-paragraphs; one for dependence paths and one for variance/covariance paths.
- Dependence paths and variance/covariance paths must be specified in separate subparagraphs and cannot be intermingled.
(a) DEPENDENCE PATHS

A dependence path is indicated by the ASCII symbol "<---" or "く" which relates directly to the single headed arrow employed in a path diagram. A dependence path is coded by using the following syntax:

## Dependent variable <--- Explanatory variable

If a parameter along a path is fixed, the fixed parameter value is provided in brackets after the explanatory variable.

For the model depicted in Figure 1.2, the endogenous observed variable REOAP receives single headed arrows from the unobserved variable REAMB and a measurement error E1. These paths are displayed in Figure 2.1 below.


Figure 2.1 Dependence paths between REOAP, E1 and REAMB

These dependence paths are coded as follows:

$$
\begin{aligned}
& \text { REOAP <--- REAMB } \\
& \text { REOAP <--- E1 (1) }
\end{aligned}
$$

When specifying dependence paths, bear in mind that:

1) Dependence paths can be specified in any order.
2) AMOS ignores dashes in "\$Structure" lines, so the number of dashes after "<" does not matter.

## (b) VARIANCE/COVARIANCE PATHS

A variance or covariance path is indicated by the symbol "<-->" or "<>" which relates directly to the double headed arrow in a path diagram. A variance/covariance path is specified in an input file by using the following syntax:

## Variable <--> the other variable

Unlike the dependence path, it does not matter which variable is given first.
For the model depicted in Figure 1.2, double headed arrows are employed from the observed variable REPAP to itself to specify a variance and to REINT and RESOE to specify covariances. These paths are shown in the diagram below.


Figure 2.2 Variance/covariance paths between REPAP, RESOE, and REINT

These paths are specified in the sentences below.

```
REPAP <--> REPAP
REPAP <--> REINT
REPAP <--> RESOE
REINT <--> REINT
REINT <--> RESOE
RESOE <--> RESOE
or
REPAP <>REINT
REPAP <>RESOE
REINT <>REINT
REINT <>RESOE
RESOE <>RESOE
```


### 2.2.3 ESTIMATION METHOD(S)

This is the section of the input file where the method or methods of estimation are specified. Each method is specified on a separate line and must be preceded by the dollar sign " $\$$ ".

The estimation methods available in AMOS are:
\$ml maximum likelihood estimation
\$gls generalized least squares estimates
\$adf asymptotic distribution-free estimation
\$sls scale free least squares estimation
\$uls unweighted least squares estimation

### 2.2.4 DATA

The name of the AMOS data file is specified in this section. The data file is a text file with the extension ".amd". The file name is specified after the key word "Include=" preceded by the dollar sign " $\$$ ". For the model depicted in Figure 1.2, the correlation matrix with standard deviations to be analyzed resides in a file "pep-dhp.amd". This is specified as:
\$Include = pep-dhp.amd

### 2.2.5 GROUP NAME (Optional)

When analyzing data by using more than one model, each model is treated as a group and then given a group name. The command, "\$groupname" is used to assign a name to a group as shown below.
\$groupname= "name"
where "name" is the name given to a group.
By default, AMOS assigns the names 'group number 1', 'group number 2', and so on. If this option is not included in the input file, AMOS assumes that there is only one model in the analysis and will therefore assign the group name 'group_number_1'. In the example depicted in Figure 1.2, the group is not specified since only one model is being used in the analysis. AMOS therefore gives the group name as "\$groupname= Group_number_1".

### 2.2.6 OUTPUT

The input file ends with the keyword "Output" preceded by a dollar sign (\$). The "\$output" command instructs AMOS to write selected output to an output file in a text format, that is suitable for reading by other programs. The new output file is given the same name as the input file, but with the extension ".amo" instead of ".ami".

### 2.2.7 INPUT FILE: EXAMPLE 2

The complete AMOS input file for the model depicted in Figure 1.2 is shown below.
\$Observed
REOAP
REEAP
BFEAP
BFOAP
REPAP
REINT

## RESOE

BFSOE
BFINT
BFPAP
\$Unobserved
REAMB
BFAMB
Z1
Z2
E2
E3
E4
E1
\$Structure
REAMB <--- Z1 (1)
BFAMB <--- Z2 (1)
REOAP <--- REAMB (1)
BFEAP <--- BFAMB
BFOAP <--- BFAMB (1)
REEAP <--- REAMB
REAMB <--- REPAP
REAMB <--- REINT
REAMB <--- RESOE
BFAMB <--- BFSOE
BFAMB <--- RESOE
REAMB <--- BFSOE
BFAMB <--- BFINT
BFAMB <--- BFPAP
REAMB <--- BFAMB
BFAMB <--- REAMB
REEAP <--- E2 (1)
BFEAP <--- E3 (1)
BFOAP <--- E4 (1)

```
    REOAP <--- E1 (1)
    REINT <--> REPAP
RESOE <--> REPAP
BFSOE <--> REPAP
BFINT <--> REPAP
BFPAP <--> REPAP
RESOE <--> REINT
BFSOE <--> REINT
BFINT <--> REINT
BFPAP <--> REINT
BFSOE <--> RESOE
BFINT <--> RESOE
BFPAP <--> RESOE
BFINT <--> BFSOE
BFPAP <--> BFSOE
BFPAP <--> BFINT
REPAP<--> REPAP
REINT <--> REINT
RESOE <--> RESOE
BFSOE <--> BFSOE
BFINT <--> BFINT
BFPAP <--> BFPAP
$Include = C:\AMOS\PEPRAH\PEPDHP.amd
$Group name = Group_number_1
$Output
```


### 2.3 ILLUSTRATIVE EXAMPLE. THE DUNCAN, HALLER AND PORTES' APPLICATION.

### 2.3.1 CREATING THE AMOS DATA FILE FOR THE DUNCAN, HALLER AND PORTES' APPLICATION.

The step by step methods of creating an AMOS data file for the Duncan, Haller and Portes' application are outlined below.

- Double click on the "Notepad" icon shown below.
- This action will open the window below.

- Type in the Input data to produce the window below.

- Click on the "Save As" option from the Notepad "File" menu to load the dialog box shown below.

- Type the file name into the "File name" string field to produce the dialog box shown below.

- Click the "Save" push button to open the window shown below.

- Close the window above.


## 2．3．2 CREATING AN AMOS GRAPHIC FILE FOR THE MODEL OF THE DUNCAN，HALLER AND PORTES’ APPLICATION．

The model information may also be specified in the form of a path diagram．The path diagram is drawn using the several intelligent drawing aids built into the program．In the model，depicted in Figure 1．2，the Latent variables REAMB（Respondents Ambition）and BFAMB（Best Friends Ambition）are modeled to influence one another．These paths are drawn as follows：
－Double click on the AMOS icon shown below．

The above action will open the＂Unnamed project＂window of AMOSGRAF，part of which is shown below．

－Click on the push button

－Click inside the graphic field on the right hand side of the set of push buttons to draw an ellipse（or circle）for a latent variable as shown below．


- Right click on the elliptic figure drawn to load the menu box below.

- Click on the "Variable Name" option to load the dialog box below.

- Type the variable name "REAMB" in the string field.
- Change the font size from 24 to 12 points to produce the dialog box below.

- Click on the "Close" push button to load the "Unnamed project" window shown below.

- Right click on the figure for "REAMB" to load the menu box below.

- Click on the "Duplicate" option of the menu options dialog box to reload the "Unnamed project" window or click on the push button

- Click on the latent variable "REAMB" and drag to a new position to duplicate the latent variable "REAMB" as shown below.

- Right click on the duplicated "REAMB" to change the variable name to "BFAMB" as shown below.

- Click on the push button

- Place it on the latent variable "REAMB" and drag it to the latent variable "BFAMB"
- Repeat the above action in the opposite direction.

The above actions produce the diagram shown below.


- Click on the push button

- Place this on the latent variables "REAMB" and "BFAMB".

- Right click on the error term placed on the latent variable "REAMB" and select the "variable name" option of the menu options dialog box to produce the window with part shown below.

- Click on the "Variable name" option of the menu options dialog box to load the "Variable name" dialog box shown below.

- Change the font size from 17 to 12 points.
- Type the error term name "Z1" in the string field of the "Variable name" dialog box as shown below.

- Click on the close push button to produce the diagram below.

- Repeat the above steps for the second error term to produce the "Unnamed project" window below.

- Click on the "Manifest Variables" push button

- Click inside the graphical field on the right hand side of the set of push buttons, to draw a rectangle for a manifest variable, at the left side of the two latent variables as shown below.


With the same steps as described above for the latent variables "REAMB and "BFAMB" one would be able to type in the name of the manifest variable and duplicate it to obtain as many manifest variables as required in the path diagram. Part of the resulting diagram drawn is shown below.


To check on the change in the degrees of freedom at any stage of the drawing of the path diagram, clicking on the push button
to load a dialog box shown below.

## df =-4

Parameters: 7
Free parameters: 5
Sample moments: 1


- Click on the "OK" push button to reload the "Unnamed project" window.

The steps outlined above could be followed to draw the complete path diagram for the Duncan, Haller and Portes' application as shown below.


The graphics file for the path diagram could be saved by following the steps below.

- Click on the "Save As" option from the AMOS "File" menu to load the dialog box shown below.

- Select the required subdirectory, if any.
- Type the name of the file in the "File name" string filed to produce the dialog box shown below.

- Click on the "OK" push button to reopen the window with the file name as specified in the "File name" string field as shown below.

- Click on the "Model-Fit" menu to load the menu box below.

| put |  |
| :---: | :---: |
| Hodel-Fit Global Help |  |
| Calculate Estimates | Ctrl+F9 |
| Groups/Models... | Ctrl+G |
| Enter '\$' Commands... | Ctri+D |
| Edit Configuration File... Edit Include File... View Text Output... |  |
| Analysis Description... |  |
| Heterogeneous Structures... <br> Means <br> Modeling Lab... <br> Parameter Constraints <br> Ioggle Observed/Unobserved |  |
| Degrees of Freedom... <br> View Spreadsheet... | F12 <br> Ctrl+R |

- Click on the "Enter "\$" Commands..." option of the "Model-Fit" menu to open the window shown below.

- Double click on the "Include" option in the "Commands" list box to load the dialog box below.

- Type the "Data" file's name in the string filed of the dialog box to produce the dialog box below.

- Click on the "OK" push button to produce the window shown below.

- Click on the close button to close the window above.
- Click on the "Model-Fit" menu to load the menu box below.

| $n$ Iext | Model-Fit Global Help |  |
| :---: | :---: | :---: |
|  | Calculate Estimates | Ctrl+F9 |
|  | Groups/Models... | Ctrl +G |
|  | Enter '\$' Commands... | $\mathrm{Ctr}+\mathrm{D}$ |
|  | Edit Configuration File... |  |
|  | Edit Include File... <br> View Text Output. |  |
|  | Analysis Description... |  |
|  | Heterogeneous Structures... |  |
|  | Modeling Lab... |  |
|  | Parameter Constraints |  |
|  | Ioggle Observed/Unobserved |  |
|  | Degrees of Freedom... | F12 |
|  | View Spreadsheet... | Ctri+R |

- Click on the "View Spreadsheet..." option of the "Model-Fit" menu to open the "View Spreadsheet" dialog box shown below.

- Check the entries in the spreadsheet to see if all the paths in the path diagram have been correctly specified.
- Click on the close button to close the "View Spreadsheet" dialog box above.


### 2.3.3 RUNNING AMOS

## To run AMOS:

- Click on the "Model-Fit" menu to load the menu box below.

- Click on the "Calculate Estimates" option of the "Model-Fit" menu to run the program.
- If there are no syntax errors, the program will run and the appearance of the window below indicates the end of the iterations.



### 2.3.4 THE AMOS OUTPUT FILE

(1)
(2)

Amos<br>Version 3.61 (w32)<br>by James L. Arbuckle

(3)

$$
\begin{gathered}
\text { Copyright } 1994-1997 \text { SmallWaters Corporation } \\
1507 \mathrm{E} .53 \mathrm{rd} \text { Street - \#452 } \\
\text { Chicago, IL } 60615 \text { USA } \\
773-667-8635 \\
\text { Fax: 773-955-6252 } \\
\text { http://www.smallwaters.com }
\end{gathered}
$$

(4)

(b) Serial number 55501773
(5)

Pepdhp: 14 November 2000 09:16 AM Page 1
(6)

User-selected options
(I)

Output:

> Maximum Likelihood

## (II)

Output format options:
Compressed output
(III)

```
Minimization options:
    Technical output
    Standardized estimates
    Squared multiple correlations
    Machine-readable output file
```

(IV)
Sample size: 329
(7)
Your model contains the following variables

| REOAP | observed endogenous <br> observed |
| :--- | :--- | :--- |
| BFEAP | endogenous |
| BFOAP | observed endogenous |
| REEAP | observed endogenous |
| REPAP | observed exogenous |
| REINT | observed exogenous |
| RESOE | observed exogenous |
| BFSOE | observed exogenous |
| BFINT | observed exogenous |
| BFPAP | observed exogenous |
| REAMB | unobserved endogenous |
| BFAMB | unobserved endogenous |
| Z1 |  |
| Z2 | unobserved exogenous |
| E2 | unobserved exogenous |
| E3 | unobserved exogenous |
| E4 | unobserved exogenous |
| E1 | unobserved exogenous |


| (8) | (I) | Number of variables in your model: | 18 |
| :--- | :--- | :--- | ---: |
|  | (II) | Number of observed variables: | 10 |
|  | (III) | Number of unobserved variables: | 8 |
|  | (IV) | Number of exogenous variables: | 12 |
|  | $(V)$ | Number of endogenous variables: | 6 |

(9)

|  |  | (I) | (II) | (III) | (IV) | (V) | (VI) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Weights | Covariances | Variances | Means | Intercepts | Total |
| (I) | Fixed: | 8 | 0 | 0 | 0 | 0 | 8 |
| (II) | Labeled: | 0 | 0 | 0 | 0 | 0 | 0 |
| (III) | Unlabeled: | 12 | 15 | 12 | 0 | 0 | 39 |
| (IV) | Total: | 20 | 15 | 12 | 0 | 0 | 47 |

The model is nonrecursive.

Model: Your_model

## (10)

Computation of Degrees of Freedom

(11)
(I)

| 0 e | 5 | $0.0 \mathrm{e}+00$ | $-2.5336 \mathrm{e}-01$ | $1.00 \mathrm{e}+04$ | $8.67208748849 \mathrm{e}+02$ | 0 | $1.00 \mathrm{e}+04$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 1 e | 2 | $0.0 \mathrm{e}+00$ | $-1.8075 \mathrm{e}-01$ | $1.52 \mathrm{e}+00$ | $2.54452125279 \mathrm{e}+02$ | 20 | $7.70 \mathrm{e}-01$ |
| 2 e | 0 | $4.2 \mathrm{e}+01$ | $0.0000 \mathrm{e}+00$ | $7.15 \mathrm{e}-01$ | $7.08474287408 \mathrm{e}+01$ | 4 | $7.32 \mathrm{e}-01$ |
| 3 e | 0 | $1.8 \mathrm{e}+01$ | $0.0000 \mathrm{e}+00$ | $5.00 \mathrm{e}-01$ | $4.33064717040 \mathrm{e}+01$ | 2 | $0.00 \mathrm{e}+00$ |
| 4 e | 0 | $2.3 \mathrm{e}+01$ | $0.0000 \mathrm{e}+00$ | $2.00 \mathrm{e}-01$ | $2.75318654279 \mathrm{e}+01$ | 1 | $1.08 \mathrm{e}+00$ |
| 5 e | 0 | $2.3 \mathrm{e}+01$ | $0.0000 \mathrm{e}+00$ | $6.77 \mathrm{e}-02$ | $2.68371552916 \mathrm{e}+01$ | 1 | $1.05 \mathrm{e}+00$ |
| 6 e | 0 | $2.3 \mathrm{e}+01$ | $0.0000 \mathrm{e}+00$ | $5.60 \mathrm{e}-03$ | $2.68303101130 \mathrm{e}+01$ | 1 | $1.01 \mathrm{e}+00$ |
| 7 e | 0 | $2.3 \mathrm{e}+01$ | $0.0000 \mathrm{e}+00$ | $1.03 \mathrm{e}-04$ | $2.68303082257 \mathrm{e}+01$ | 1 | $1.00 \mathrm{e}+00$ |

## (II)

Minimum was achieved

## (12)

(I) Chi-square $=26.830$
(II) Degrees of freedom $=16$
(III)Probability level = 0.043
(13)


| REEAP <---- REAMB | 1.060 | 0.090 | 11.819 |
| :--- | :--- | :--- | ---: | ---: |
| REAMB <---- BFAMB | 0.173 | 0.087 | 1.987 |
| BFAMB <---- REAMB | 0.190 | 0.081 | 2.352 |

(b)

| Standardized Regression Weights: | Estimate |
| ---: | ---: | ---: |
| (I) | (II) |
| REAMB <---- REPAP | 0.214 |
| REAMB <---- REINT | 0.333 |
| REAMB <---- RESOE | 0.290 |
| BFAMB <---- BFSOE | 0.282 |
| BFAMB <--- RESOE | 0.088 |
| REAMB <--- BFSOE | 0.104 |
| BFAMB <---- BFINT | 0.438 |
| BFAMB <---- BFPAP | 0.196 |
| REOAP <---- REAMB | 0.767 |
| BFEAP <---- BFAMB | 0.825 |
| BFOAP <---- BFAMB | 0.774 |
| REEAP <---- REAMB | 0.813 |
| REAMB <---- BFAMB | 0.174 |
| BFAMB $<----~ R E A M B ~$ | 0.184 |


| (c) |  | (I) |
| :---: | :---: | :---: |
| Covariances: |  |  |
|  | REPAP | <---> REINT |
|  | REPAP | <---> RESOE |
|  | REPAP | <---> BFSOE |
|  | REPAP | <---> BFINT |
|  | REPAP | <---> BFPAP |
|  | REINT | <---> RESOE |
|  | REINT | <---> BFSOE |
|  | REINT | <---> BFINT |
|  | REINT | <---> BFPAP |
|  | RESOE | <---> BFSOE |
|  | RESOE | <---> BFINT |
|  | RESOE | <---> BFPAP |
|  | BFSOE | <---> BFINT |
|  | BFSOE | <---> BFPAP |
|  | BFINT | <---> BFPAP |

(d)

Correlations:

## Estimate

## (I)

REPAP <---> REINT REPAP <---> RESOE REPAP <---> BFSOE REPAP <---> BFINT REPAP <---> BFPAP REINT <---> RESOE REINT <---> BFSOE REINT <---> BFINT REINT <---> BFPAP RESOE <---> BFSOE RESOE <---> BFINT RESOE <---> BFPAP

## (II)

0.184
0.049
0.019
0.078
0.115
0.222
0.186
0.336
0.102
0.271
0.230
0.093

| (II) | (III) | (IV) | (V) |
| :---: | :---: | :---: | :---: |
| Estimate | S.E. | C.R. | Label |
| 0.184 | 0.056 | 3.277 |  |
| 0.049 | 0.055 | 0.886 |  |
| 0.019 | 0.055 | 0.344 |  |
| 0.336 | 0.058 | 5.768 |  |
| 0.102 | 0.056 | 1.838 |  |
| 0.049 | 0.055 | 0.886 |  |
| 0.019 | 0.055 | 0.344 |  |
| 0.078 | 0.055 | 1.408 |  |
| 0.115 | 0.056 | 2.069 |  |
| 0.271 | 0.057 | 4.737 |  |
| 0.230 | 0.057 | 4.059 |  |
| 0.093 | 0.055 | 1.677 |  |
| 0.295 | 0.058 | 5.124 |  |
| 0.044 | 0.055 | 0.796 |  |
| 0.209 | 0.056 | 3.705 |  |


| (II) | (III) | (IV) | (V) |
| :---: | :---: | :---: | :---: |
| Estimate | S.E. | C.R. | Label |
| 0.184 | 0.056 | 3.277 |  |
| 0.049 | 0.055 | 0.886 |  |
| 0.019 | 0.055 | 0.344 |  |
| 0.336 | 0.058 | 5.768 |  |
| 0.102 | 0.056 | 1.838 |  |
| 0.049 | 0.055 | 0.886 |  |
| 0.019 | 0.055 | 0.344 |  |
| 0.078 | 0.055 | 1.408 |  |
| 0.115 | 0.056 | 2.069 |  |
| 0.271 | 0.057 | 4.737 |  |
| 0.230 | 0.057 | 4.059 |  |
| 0.093 | 0.055 | 1.677 |  |
| 0.295 | 0.058 | 5.124 |  |
| 0.044 | 0.055 | 0.796 |  |
| 0.209 | 0.056 | 3.705 |  |

## Estimate

(II)
0.214
0.333
0.290
0.088
0.104
0.438
0.196
0.825
0.774
0.813
0.184

```
BFSOE <---> BFINT 0.295
BFSOE <---> BFPAP 0.044
BFINT <---> BFPAP 0.209
```

(e)

Variances:
(I)

| (I) | (II) <br> Estimate <br> -------- | (III) <br> S.E. | (IV) <br> C.R. |
| :--- | :---: | :---: | :---: |
|  | 1.000 | 0.078 | 12.806 |
| REPAP | 1.000 | 0.078 | 12.806 |
| REINT | 1.000 | 0.078 | 12.806 |
| RESOE | 1.000 | 0.078 | 12.806 |
| BFSOE | 1.000 | 0.078 | 12.806 |
| BFINT | 1.000 | 0.078 | 12.806 |
| BFPAP | 0.282 | 0.047 | 6.018 |
| Z1 | 0.234 | 0.040 | 5.883 |
| Z2 | 0.338 | 0.052 | 6.528 |
| E2 | 0.318 | 0.046 | 6.892 |
| E3 | 0.400 | 0.046 | 8.628 |
| E4 | 0.411 | 0.051 | 8.052 |
| E1 |  |  |  |

## (I)

BFAMB
REAMB
REEAP BFOAP BFEAP REOAP

Estimate
(II)
0.609 0.521 0.662 0.599 0.681 0.589
(g)
Stability index for the following variables is 0.033
BFAMB
REAMB
(14)
(a)

| (I) | (II) | (III) | (IV) | (V) | (VI) |
| ---: | ---: | ---: | ---: | ---: | ---: |
| Model | NPAR | CMIN | DF | P | CMIN/DF |
| Your_model | 39 | 26.830 | 16 | 0.043 | 1.677 |
| Saturated model | 55 | 0.000 | 0 |  |  |
| Independence model | 10 | 862.753 | 45 | 0.000 | 19.172 |

(b)
(I)
Model
$--------------\quad$ Your_model
Saturated model
Independence model
(c)
(I)
Model
---------------
Your_model
Saturated model
Independence model
(d)
(I)
Model
----------------
Your_model
Saturated model
Independence model
(e)

(I)

(II)
RMR
-------
0.021
0.000
0.276
GFI
$-------\quad$
0.984
1.000
0.544

| $(\mathbf{I V})$ | $(\mathbf{V})$ |
| ---: | ---: |
| AGFI | PGFI |
| 0.946 | 0.350 |
| 0.443 | 0.445 |


| (IV) | (V) | (VI) |
| ---: | ---: | ---: |
|  |  |  |
| DELTA2 | RHO2 | CFI |
| IFI | TLI | 0.987 |
| 0.987 | 0.963 | 1.000 |
| 1.000 |  | 0.000 |

IV)

PCFI
0.351
0.000
0.000
(IV)
(III)

HI 90 ----------

L
III)

PNFI
PCFI
$------\quad 0.351$
0.000
0.000

H
29
90
-------
29.18
$0.000 \quad 0.000 \quad 0.000$
$817.753 \quad 726.062 \quad 916.858$
(f)


| Model | RMSEA | LO 90 | HI 90 | PCLOSE |
| ---: | ---: | ---: | ---: | ---: |
| Independence model | 0.045 | 0.008 | 0.075 | 0.563 |
| Your_model | 0.235 | 0.222 | 0.249 | 0.000 |
| (h) |  |  |  |  |
|  |  |  |  |  |
| (I) | (II) | (III) | (IV) | (V) |
| Model | AIC | BCC | BIC | CAIC |
| Independence model | 882.753 | 883.447 | 943.739 | 930.713 |

(i)

| (I) | (II) | (III) | (IV) | (V) |
| ---: | ---: | ---: | ---: | ---: |
| Model | ECVI | LO 90 | HI 90 | MECVI |
| Your_model | 0.320 | 0.288 | 0.376 | 0.328 |
| Saturated model | 0.335 | 0.335 | 0.335 | 0.347 |
| Independence model | 2.691 | 2.412 | 2.993 | 2.693 |

(j)


## (15)

Execution time summary:
(I) Minimization: 0.520
(II) Miscellaneous: 0.752
(III) Bootstrap: 0.000
(IV) Total: 1.272

## ENTRIES OF THE AMOS OUTPUT FILE

1. Date and time of the analysis.
2. The name, the version and the author of AMOS.
3. Information about the company with the right to distribute AMOS.
4. (a) Name of the input file used in the analysis and the date, day and time of the analysis.
(b) Serial number of the particular installation of AMOS.
5. Same as 4(a).

## 6. User-selected options

(I) The method of estimation used.
(II) The format in which the output file is to be provided.
(III) Minimization options
(IV) Size of the sample used in the analysis.
7. The list of descriptive names of all the variables of the model fitted to the data.
8. (I) The total number of variables of the model.
(II) The number of observed variables of the model.
(III) The number of unobserved variables of the model.
(IV) The number of exogenous variables of the model.
(V) The number of endogenous variables of the model.
9. Column (I): number of weights or parameters.

Column (II): number of covariances in the model.
Column (III): number of variances in the model
Column (IV): number of means provided in the data for the analysis.
Column (V): number of intercepts specified in the data for the analysis.
Column (VI): the total for each row.
$\operatorname{Row}(\mathbf{I}): \quad$ the number of the fixed parameters in the model.
$\operatorname{Row}(\mathbf{I I}): \quad$ the number of parameters of the model that are labeled.
$\operatorname{Row}($ III ): the number of parameters of the model are neither fixed nor labeled. These parameters are free to take on any value.

Row(IV): the total of each column.

## 10. Computation of Degrees of Freedom

$\operatorname{Row}(\mathbf{I}): \quad$ the number of distinct sample moments ( sample variances and nonduplicated covariances), usually denoted by $p$.
$\operatorname{Row}(\mathbf{I I}): \quad$ the number of distinct parameters to be estimated in the model, usually denoted by q .
Row(III): degrees of freedom is given by $\quad \mathrm{d}=\mathrm{p}-\mathrm{q}$
11. (I) Minimization history.

The details of the progress of the minimization of the discrepancy function.
(II) Minimum was achieved. This sentence indicates that the minimization process was without any disruptions.
12. (I) The value of the Chi-square test Statistic.

This is given by (Steiger, Shapiro and Browne, 1985)

$$
\vec{E}=n \vec{P}
$$

where $E(\alpha, a)$ is the minimum value of the discrepancy functions (Browne, 1982, 1984) of the form:

$$
C(\alpha, a)=[N-r] F(\alpha, \underset{-}{a})
$$

where $F\left(\alpha_{-}^{a}\right)=\left\{\frac{\sum_{g=1}^{G} N^{(g)} f\left(\mu^{(g)}, \sum^{(g)} ; \bar{x}, \hat{S}_{-}^{(g)}\right)}{N}\right\}$, and
$r$ is a nonnegative integer specified by the "\$chicorrect" command.
$f($.) denotes the discrepancy function which measures the discrepancy between the model and the sample moments,
$\mathrm{n}=\mathrm{N}-\mathrm{r}$,
$N=\sum_{g=1}^{G} N^{(g)}$, the total number of observations in all groups combined,
$\alpha(\gamma)$ is the vector of order p containing the population moments for all groups according to the model,
$a$ is the vector of order p containing the sample moments for all groups,
$\nexists$ is the value of $\gamma$ that minimizes $F(\alpha(\gamma) ; a)$,
$N^{(g)}$ is the number of observations in group g,
G is the number of groups,
$\mu^{(g)}(\gamma)$ is the mean vector for group g , according to the model,
$\sum^{(g)}(\gamma)$ is the covariance matrix for group g , according to the model,
$S^{(g)}$ is the sample covariance matrix for group g ,
$\bar{x}^{(g)}=\frac{1}{N_{g}} \sum_{r=1}^{N_{g}} x_{i r}^{(g)}, \quad x_{i r}^{(g)}$ is the r-th observation on the i-th variable in group g.
Different discrepancy functions are obtained by changing the way $f$ is defined. In the case of maximum likelihood estimation $(\$ \mathrm{ml}), \mathrm{C}_{\mathrm{ml}}$ and $\mathrm{F}_{\mathrm{ml}}$ are obtained by taking f to be
$f\left(\mu^{(g)}, \sum^{(g)} ; \bar{x}^{(g)} ; S^{(g)}\right)=\log \left|\sum^{(g)}\right|+\operatorname{tr}\left(S^{(g)} \sum^{(g)-1}\right)-\log \left|S^{(g)}\right|-p^{(g)}+\left(\bar{x}^{(g)}-\mu_{-}^{(g)}\right) \sum^{(g)-1}\left(\bar{x}^{(g)}-\underset{-}{\mu}\right)$
Row (II): $\quad$ Same as in (11) Row (II) above.
Row (III): The "p value" for testing the hypothesis that the model fits perfectly in the population.
(13) (a)

Column (I): The list of all the dependence paths in the model.
Column (II): Point estimates of the regression weights between the dependent and independent variables in the dependence paths.

Column (III): Standard errors of the estimators of the regression weights (parameters).
Column (IV): The Critical ratios (C.R) are the ratios of the estimates (Column (II)) and the corresponding standard errors (Column (III) ).

Column (V): Label
If any parameter of the model is not given a descriptive name, AMOS generates a name for the parameter. The AMOS' make-up name appear in the "Label" column. There are no such make-up names in this case.
(b)

Column (I): The list of the correlations among exogenous variables of the model
Column (II): Point estimate of the parameter.
(c)

Column (I): The list of all the covariance paths in the model.
Column (II): same as Column (II) in (a) above.
Column (III): same as Column (III) in (a) above.
Column (IV): same as Column (IV) in (a) above.

Column (V): same as Column (V) in (a) above.
(d)

Column (I): same as Column (I) in (c) above.
Column (II): same as Column (II) in (c) above.
(e)

Column (I): The list of all variance paths in the model
Column (II): same as Column (II) in (a) above.
Column (III): same as Column (III) in (a) above.
Column (IV): same as Column (IV) in (a) above.
Column (V): same as Column (V) in (a) above.
(f)

Column (I): The list of the endogenous variables of the model
Column (II): Point estimate of the squared multiple correlation between each endogenous variable and the variables (other than residual variables) that directly affect it.
(g)

The stability index for the unobserved variables BFAMB and REAMB. This is computed from:
(14) (a)

Column (I): Type of model.
Column (II): The number of distinct parameters (q) being estimated.
Column (III): The minimum discrepancy function value.
Column (IV): Degrees of freedom for the model.
Column (V): The probability level for testing the hypothesis that the model fits perfectly in the population.

Column (VI): The ratio of the minimum discrepancy function value and the corresponding degrees of freedom.
(b)

Column (I): Type of model.

Column (I): The square root of the average squared amount by which sample variances and covariances differ from their estimates obtained under the assumption that the model used in the analysis is correct. It is computed from:
$R M R=\sqrt{\sum_{g=1}^{G}\left\{\sum_{i=1}^{P_{g}} \sum_{j=1}^{j s i}\left(\mathcal{S}_{i j}^{(g)}-\sigma^{(g)}\right)\right\} . / \sum_{g=1}^{G} p^{*(g)}}$
where $\sigma^{(g)}(\gamma)=\operatorname{vec}\left(\sum^{(g)}(\gamma)\right)$
$p^{*(g)}$ is the number of sample moments in group g .

Column (III): The goodness of fit index (GFI) is given by ( Jöreskog and Sörbom, 1984; Tanaka and Huba, 1985)

$$
G F I=1-\frac{P}{F_{b}}
$$

where $P_{b}$ is obtained by evaluating F with $\sum^{(g)}=0, \mathrm{~g}=1,2, \ldots, \mathrm{G}$.
An exception has to be made for maximum likelihood estimation, since $f($.$) is$ not defined for $\sum^{(g)}=0$. For the purpose of computing GFI in the case of maximum likelihood estimation, $f\left(\sum^{(g)} ; S^{(g)}\right)$ is computed as
$f\left(\sum^{(g)} ; S^{(g)}\right)=\frac{1}{2} \operatorname{tr}\left[K^{(g)-1}\left(S^{(g)}-\sum^{(g)}\right)\right]^{2}$
with $K^{(g)}=\sum^{(g)}\left(\vec{p}_{M L}\right)$,
where $\vec{p}$ is the maximum likelihood estimate of $\gamma$.

Column (IV): The adjusted goodness of fit index (AGFI) is given by:
$A G F I=1-(1-G F I) \frac{d_{b}}{d}$
where $d_{b}=\sum_{g=1}^{G} p^{*(g)}$
Column (V): The PGFI, parsimony of fit index; is given by (Mulaik, et. al, 1989):

$$
\operatorname{PGFI}=\operatorname{GFI} \frac{d}{d_{b}}
$$

(c)

## Column (I): Type of model

Column (II): The normed fit index (NFI) or delta1, $\Delta_{1}$, is obtained from (Bentler and Bonett, 1980):
$\mathrm{NFI}=\Delta_{1}=1-\frac{\bar{\varrho}}{{\underset{C}{b}}^{P}}=\frac{\vec{P}}{F_{b}}$
where $\vec{e}_{b}=n \vec{F}_{b}$ is the minimum discrepancy function value for the baseline model.

Column (III): The relative fit index (RFI) or rho1, $\rho_{1}$, is obtained from (Bollen, 1989):
$\mathrm{RFI}=\rho_{1}=1-\frac{\bar{E} / d}{\bar{E}_{b} / d_{b}}=1-\frac{\vec{F} / d}{F_{b} / d_{b}}$.
Column (IV): The incremental fit index (IFI) or delta2, $\Delta_{2}$, is obtained from (Bollen, 1989):
$\mathrm{IFI}=\Delta_{2}=\frac{\bar{E}_{b}-\vec{e}}{E_{b}-d}$.
Column (V): The Tucker-Lewis coefficient of rho2, $\rho_{2}$, also known as Bentler and Bonett non-normed fit index (NNFI) is given by (Bentler and Bonett, 1980):
$\mathrm{TLI}=\rho_{2}=1-\frac{\max \left(e_{-d, 0)}\right.}{\max \left(e_{d}-d_{b}, 0\right)}=\frac{N C P}{N C P_{d}}$.
where NCP is the noncentrality parameter estimate for the model being evaluated and $\mathrm{NCP}_{\mathrm{d}}$ is the noncentrality parameter estimate for the baseline model.

## (d)

Column (I): Type of model
Column (II): The parsimony ratio (PRATIO) is given by (James, Mulaik and Brett, 1982, Mulaik, et. al, 1989):
PRATIO $=\frac{d}{d_{i}}$.
where $d_{i}$ is the degrees of freedom of the independence model.
Column (III): The PNIF is the result of applying James, et. al.'s 1982, parsimony to the NFI. It is obtained from:
$\operatorname{PNFI}=(\mathrm{NFI})($ PRATIO $)=\mathrm{NFI} \frac{d}{d_{b}}$.

Column (IV): The PCFI is the result of applying James, et al.'s (1982) parsimony adjustment to the CFI. It is obtained from:
$\mathrm{PCFI}=(\mathrm{CFI})(\mathrm{PRATIO})=\mathrm{CFI} \frac{d}{d_{b}}$.
(e)

Column (I): Type of model
Column (II): NCP $=\max \left(\mathcal{C}_{-d, 0)}\right.$ is an estimate of the noncentrality parameter, $\delta=C_{o}=n F_{o}$.
where $F_{o}$ is the value of the discrepancy function obtained by fitting a model to the population moments rather than to sample moments. $\mathrm{F}_{\mathrm{o}}$ is given by: $\mathrm{F}_{\mathrm{o}}=\min _{\gamma}\left[F\left(\alpha(\gamma), \alpha_{o}\right)\right.$.

Column (III): LO90 is the lower limit $\delta_{L}$ of a $90 \%$ confidence interval, on $\delta$ and is obtained by solving the equation:

$$
\Phi(\Xi / \delta, d)=0.95
$$

for $\delta$ where $\Phi(x / \delta, d)$ is the distribution function of the noncentral chisquared distribution with noncentrality parameter $\delta$ and degrees of freedom.

Column (IV): HI90 is the upper limit $\delta_{U}$ of a $90 \%$ confidence interval, on $\delta$ and is obtained by solving the equation:

$$
\Phi(\Theta / \delta, d)=0.05 \text { for } \delta
$$

(f)

Column (I): Type of model.
Column (II): this is the minimum value, $\vec{F}$, of the discrepancy function F .
Column (III): LO90 is the lower limit, $\boldsymbol{\delta}_{L}$, of a $90 \%$ confidence interval on $\mathrm{F}_{\mathrm{o}}$. It is given by:

$$
\mathrm{LO} 90=\sqrt{\frac{\delta_{L}}{n}}
$$

Column (IV): HI90 is the upper limit value, $\boldsymbol{\delta}_{U}$, of a $90 \%$ confidence interval on $\mathrm{F}_{\mathrm{o}}$. It is given by:

$$
\mathrm{HI} 90=\sqrt{\frac{\delta_{U}}{n}} .
$$

(g)

Column (I): Type of model.
Column (II): the root mean square error of approximation (RMSEA) is given by (Browne and Cudeck, 1993):
RMSEA $=\sqrt{\frac{F_{o}^{\prime}}{d}}$.
Column (III): LO90 is the lower limit, $\delta_{L}$, of a $90 \%$ confidence interval on the population value of RMSEA. It is given by:
$\mathrm{LO} 90=\sqrt{\frac{\delta_{L} / n}{d}}$.
Column (IV): HI90 is the upper limit, $\delta_{U}$, of a $90 \%$ confidence interval on the population value of RMSEA. It is given by:
HI90 $=\sqrt{\frac{\delta_{U} / n}{d}}$.
Column (V): PCLOSE $=1-\Phi\left(\mathcal{C} / 0.05^{2} n d, d\right)$
Is a "p value" for testing the null hypothesis that the population RMSEA is no greater that 0.05 .
i.e.: $\quad \mathrm{H}_{0}$ : RMSEA $\leq 0.05$.
(h)

Column (I): Type of model
Column (II): The Akaike information criterion (AIC) is given by:
$\operatorname{AIC}=E+2 q$.
Column (III): The Browne and Cudeck (1989) criterion (BCC) is given by:
$\mathrm{BCC}=E+2 q \frac{\sum_{g=1}^{G} b^{(g)} \frac{p^{(g)}\left(p^{(g)}+3\right)}{N^{(g)}-p^{(g)}-2}}{\sum_{g=1}^{G} p^{(g)}\left(p^{(g)}+3\right)}$
where $b^{(g)}=N^{(g)}-1$ if \$emulisrel6 command has been used, or

$$
b^{(g)}=n N^{(g)} / N \text { if it has not. }
$$

Column (IV): The Bayes information criterion (Schwarz 1978; Raftery, 1993) is given by the formula:

BIC $=\Theta+q \operatorname{Ln}\left(N^{(1)} p^{(1)}\right)$. Note that $\mathrm{g}=1$ in this case.
Column (IV): Bozdogan's (1987) CAIC (consistent AIC) is given by the formula
CAIC $=\Xi_{+} q\left(\operatorname{LnN}^{(1)}+1\right)$.
(i)

Column (I): Type of model.
Column (II): The expected cross-validation index (ECVI) is given by the formula:
$\mathrm{ECVI}=\frac{1}{n}(A I C)=F+\frac{2 q}{n}$.
Column (III): LO90 is the lower limit, $\delta_{L}$, of $90 \%$ confidence interval on the population ECVI. It is computed from:

LO90 $=\frac{\delta_{L}+d+2 q}{n}$.

Column (IV): HI90 is the upper limit, $\boldsymbol{\delta}_{U}$, of $90 \%$ confidence interval on the population ECVI. It is computed from:

$$
\mathrm{HI} 90=\frac{\delta_{U}+d+2 q}{n}
$$

Column (V): The modified expected cross-validation index (MECVI) is given by the formula:

MECVI $=\frac{1}{n}(B C C)=E+2 q \frac{\sum_{g=1}^{G} a^{(g)} \frac{p^{(g)}\left(p^{(g)}+3\right)}{N^{(g)}-p^{(g)}-2}}{\sum_{g=1}^{G} p^{(g)}\left(p^{(g)}+3\right)}$.
where $a^{(g)}=\left(N^{(g)}-1\right) /(N-G$ if the \$emulisrel6 command has been used, or $\quad a^{(g)}=N^{(g)} / N$ if it has not.
(j)

## Column (I): Type of model

Column (II): Hoelter's (1983) "critical N" is the largest sample size for which one would accept the hypothesis that a model is correct at 0.05 level of significance.

Column (III): Hoelter's (1983) "critical N" is the largest sample size for which one would accept the hypothesis that a model is correct at 0.01 level of significance.
(15) Row (I): The time for AMOS's minimization algorithm.

Row (II): The time used for anything not falling into another category, but consisting mostly of input parsing and output formatting.

Row (III): The time used to for bootstrap algorithm.
Row (IV): The sum of the times in Row (I) to Row (III).

## CHAPTER 3

## EQS

### 3.1 HISTORICAL BACKGROUND

Peter Bentler developed the first commercial version of the Structural Equation Modeling program EQS (which can be pronounced like the letter " X ") in 1985. The acronym EQS stands for EQuationS. EQS implements the Bentler and Weeks model (Bentler \& Weeks, 1979, 1980, 1982, 1985; Bentler, 1983a,b). The first commercial release of EQS was through BMDP. Bentler developed an updated version in 1989. The latest version of EQS (Bentler, 1995) is available for Windows. An Apple Macintosh version of EQS is also available.
The computer program EQS was developed to meet two major needs in statistical software. At the theoretical level, applied multivariate analysis based on methods that are more general than those stemming from multinormal theory have not been available to statisticians and researchers for routine use. At the applied level, powerful and general methods have also required extensive knowledge of matrix algebra and related topics that are often not routinely available among researchers. EQS is meant to make advanced multivariable analysis methods accessible to the applied statistician and practicing data analyst. EQS is intended for users who are familiar with the basic concepts of structural equation modeling.

### 3.2 THE EQS INPUT FILE

To run EQS, the user must prepare an EQS Input File. An EQS Input File is a text file that consists of several paragraphs. This file may be created by typing it manually in a text editor such as Notepad, Wordpad or by using the "Model Specifications" dialog box of EQS.

## GENERAL RULES FOR TYPING EQS INPUT FILES

- A slash, followed by a capitalized keyword, begin each section.
- V1, V2, etc are used for manifest variables whereas F1, F2, etc are used for latent variables.
- /END appears at the end of each input file.
- In the /EQUATIONS paragraph of the input file, there is one equation for each dependent variable in the model. A dependent variable is one that is a structured regression function of other variables and it is recognised in the path diagram by having one or more arrows aiming at it.
- For each parameter within an equation, an asterisk or star "*" after a numerical value specifies that the parameter is to be estimated, with the number to the left of the asterisks as a starting value. If no number is given next to the "*", the program will insert the starting value. Numerical values not followed by asterisks specify that the parameter is to be fixed to the numerical value.
- Every independent variable in the model must have a variance.
- The fixed constant V999, which is used in the structured means models, does not have a variance.
- When the raw data matrix is used as the input data matrix, it could be provided in another file.
- When a covariance or correlation matrix is used as the input data matrix, it should be part of the input file or it could be provided in another file.

An EQS Input File may be divided into three sections. These are:

1. Model and Data Information,
2. Model Specification and
3. Data

### 3.2.1 MODEL AND DATA INFORMATION

Model information is specified in three paragraphs, namely the TITLE, SPECIFICATIONS and LABELS paragraphs.

Details of each paragraph are discussed below.

## (a) TITLE Paragraph

This paragraph provides a description for the analysis to be performed. It starts with /TITLE. For the model, depicted in Figure 1.2, we may have a title paragraph as follows:

## /TITLE

Duncan, Haller and Portes (1971) Path Analysis Model for Data on Peer Influence on Ambition;

## (b) SPECIFICATIONS Paragraph

This paragraph starts with the keyword "/SPECIFICATIONS". It describes the problem to be analyzed, including the number of cases (observations), the number of variables and the type of input data matrix, the method(s) of estimation desired, input datafile's name, cases to be deleted, etc as explained below.

The syntax for the SPECIFICATIONS paragraph is given by:
VARIABLES = p ;
where p denotes the number of manifest variables in the model.
CASES $=\mathrm{n}$;
where n denotes the number of observations, cases or objects under study.
MATRIX= Any of the following options:
COV (Covariance matrix input)
COR (Correlation matrix input)
RAW (Raw data input)
If the sample covariance or correlation matrix is to be analyzed, it may be included in the input file after the Model information and the Model specification, or created separately as an EQS system file and then saved with extension ".ess". If the input covariance or correlation matrix is provided in a separate file, the name of the file must be specified as part of the "Specifications" paragraph. As a default, EQS uses a "free-field" input format, which requires that elements of the matrix be separated by at least one blank space. It is assumed that no extraneous information, such labels, missing data codes etc. exists. Typically, when a correlation matrix is input, standard deviations must also be provided. When a raw data matrix is to be analyzed, a separate text file, that contains the data matrix, should be prepared. The rows and columns refer to the cases and variables, respectively of the data. The raw data matrix can be created in EQS or imported from other files such as MICROSOFT EXCEL files and then saved as EQS system file with the extension ".ess". For an external data file, the file name may be specified as follows:

DA= filename
where "filename" is the name of the file containing the raw data matrix, covariance or correlation
matrix. MATRIX $=\mathrm{COV}$ is the default in this paragraph. This means that if the input data matrix is not a covariance matrix, it must be specified else the program will take it to be a covariance matrix in the analysis.

METHOD = method;
where method is one of:
Least squares, abbreviated LS,
Generalized least squares, abbreviated GLS,
Maximum likelihood, abbreviated ML,
Elliptical least squares, abbreviated ELS,
Elliptical generalized least squares, abbreviated EGLS,
Elliptical reweighted least squares, abbreviated ERLS,
Arbitrary distribution generalized least squares, abbreviated AGLS, (requires MATRIX = RAW), and

Robust statistics, xx (any method except AGLS), abbreviated xx, ROBUST.
ML is the default method.
For the model, depicted in Figure 1.2, we may have a /SPECIFICATIONS paragraph as follows: /SPECIFICATIONS

METHOD = ML; CASES=329; VARIABLES=10; MATRIX= COR;

## (c) LABELS paragraph

This paragraph allows the user to provide descriptive names for the variables in the model. Each variable is given a descriptive name of at most eight characters. For the model, depicted in Figure 1.2, we may have a /LABELS paragraph as follows:
/LABELS
V1= REINT; V2= REPAP; V3=RESOE; V4=REOAP; V5=REEAP; V6=BFINT; V7=BFPAP;
$\mathrm{V} 8=\mathrm{BFSOE} ; \mathrm{V} 9=\mathrm{BFOAP} ; \mathrm{V} 10=\mathrm{BFEAP} ; \mathrm{FI}=$ REAMB; F2=BFAMB;

### 3.2.2 MODEL SPECIFICATION WITH EQS.

Using several EQS paragraphs, many of which are not required for simple models, specifies the model. Brief descriptions of some of the sections are given below. Those sections, that are not always needed, are indicated as optional.

## /EQUATIONS

This section contains the structural equations involved in the model under consideration. The /EQUATIONS section also provides information for the automatic selection of variables from the input matrix. For the model, depicted in Figure 1.2, the endogenous manifest variable V4 (REOAP) receives single headed arrows from the latent variable F1 (REAMB) and a measuring error E4 respectively. These paths are displayed in Figure 3.1 below.


These regression path above is written in an equation form as

$$
\mathrm{V} 4=+* \mathrm{~F} 1+\mathrm{E} 4 ;
$$

where " $+*$ " indicates that the coefficient of F 1 is to be estimated with a starting value to be provided by EQS. The " + " in front of E4, without "*" indicates that the coefficient of E4 is fixed, in this case, to " 1 ".

## /VARIANCES

The variances of the independent variables are specified in this section.
For the model depicted in Figure 1.2, double headed arrows are employed from the manifest variable V2 (REPAP) to itself to specify a variance and to V3 (RESOE), and V1 (REINT), to specify covariances. These paths are shown in the diagram below.


Figure 3.2 Variance/Covariance Paths between V2, V3 and V1.

These variances are specified as the following structural equations:
/VARIANCES
$\mathrm{V} 1=1$;
$\mathrm{V} 2=1$;
$\mathrm{V} 3=1 ;$
where " $=1$ " indicates that the variance is fixed at 1 .

## /COVARIANCES (Optional)

If independent variables are correlated, the covariances between them are specified in this section. In addition to the usual covariances, such as those between the residuals of observed variables or between independent latent variables, the covariances between any pairs of independent variables may be estimated, subjected only to the requirement that the model be identified. The covariances, which exist between V1 and V2, V2 and V3 and between V1 and V3, may be specified as the following structural equations.

$$
\begin{aligned}
& \mathrm{V} 2, \mathrm{~V} 1=* ; \\
& \mathrm{V} 2, \mathrm{~V} 3=* \\
& \mathrm{~V} 1, \mathrm{~V} 3=*
\end{aligned}
$$

## /CONSTRAINTS (Optional)

Parameters, that are constrained to be equal, are indicated in this section.

## /INEQUALITIES (Optional)

An upper and/or lower bound for any free parameter to be estimated can be specified in this section. The basic convention uses capitalized FORTRAN -like greater than (GT), greater than or equal to (GE), less than (LT), and less than or equal to (LE) symbols. For example, the inequality (V1,V2) GT 0.1, LE1; specifies that the covariance between V1 and V2 is to be greater than 0.1 and less than or equal to one.

### 3.2.3 DATA

This keyword should be used if: 1) the data to be analyzed is in an external file, i.e., it is not the covariance/correlation matrix given in the /MATRIX section of the SPECIFICATIONS paragraph;
and 2) the user's computer system is interactive, for example, an IBM/PC, VAX, or equivalent system. The external data file is specified under the SPECIFICATION paragraph with the keyword "DA=" or "DATA=" followed by the filename, in single quotes, with the extension "DAT" for raw data and "ESS" for correlation or covariance matrix. The content of the file can be a raw data matrix, a covariance matrix or a correlation matrix. Neither missing data nor missing data codes are permitted.

For the analysis of the model depicted in Figure 1.2, the sample correlation matrix used is provided in lower triangle form in free format as shown below.

## /MATRIX

1.0000
.1841 .000
$.222 \quad .049 \quad 1.000$
.411 . 214.3241 .000
.404 . 274 . 405 . 6251.000
$.336 .078 \quad .230 \quad .300 \quad .2861 .000$
.102 .115 . 093 . 076 . 070 . 2091.000
.186 .019 . 271 . $293 \quad .241$. 295 . 0441.000
$.260 .084 \quad .279 .422 \quad .328 \quad .501 \quad .199 \quad .3611 .000$
.290 .112 .305 . 327 . 367 . 519 . 278 . 411 . 6401.000

## /STANDARD DEVIATIONS (Optional)

If the input matrix to be analyzed is a correlation matrix, the standard deviations should be provided. Providing the standard deviations cues the program to transform the correlation matrix into a covariance matrix prior to estimation and fit. An example is given below.
/STANDARD DEVIATIONS
$\begin{array}{llllllllll}1.043 & 2.440 & 1.138 & 3.476 & 6.206 & 0.953 & 2.441 & 1.593 & 0.741 & 4.337\end{array}$

### 3.3 ILLUSTRATIVE EXAMPLE. THE DUNCAN, HALLER AND PORTES’ APPLICATION.

### 3.3.1 CREATING THE EQS INPUT FILE

The steps by step method of creating an EQS Input File are outlined below.

- Double click on the EQS icon shown below.

- The above action will open the window below.

- Click on the "Build_EQS" menu to load the menu box below.

- Click on the "Title/Specifications" option of the "Build_EQS" menu to load the "Title for EQS Model's" dialog box shown below.

Title for EQS Model
The EQS model's title is
$\square$

Do you want to invoke EASY BUILD ?
©YES
CNO

OK

## Cancel

- Type the title "DUNCAN, HALLER AND PORTES' APPLICATION" into the "EQS models title is" string field to produce the dialog box shown below.

- Click on the "OK" push button to load the "EQS Model Specification" dialog box shown below.

- Type the number of manifest variables into the "Variables" string field.
- Type the number of cases into the "Cases" string field.
- Activate the "Correlation Matrix" radio button of the "Input Data Type is" radio buttons to produce the dialog box shown below.

- Click on the "OK" push button to load the "EQS for Windows" dialog box below.

- Click on the "OK" push button in the "EQS For Windows" dialog box above to load the "Build Equations" dialog box shown below.

- Type the number of latent variables into the "Number of Factors" string field to produce the dialog box shown below.

- Click on the "OK" push button to load the "Create New Equations" dialog box shown below.


In the model, depicted in Figure 1.2, a single headed arrow is drawn from F1 (REAMB) to V4 (REOAP) and also from F1 to V5 (REEAP) as shown below.


Figure 3.3: The dependence paths between F1, V4 and V5.

- The dependence path F1 to V4 is indicated in the windows above by clicking on the space corresponding to Column "F1" and Row "V4". An asterisk "*" appears in the space clicked. The dependence path "F1 to V5 " is also indicated in windows above by clicking on the space corresponding to Column "F1" and Row "V5".
- Continue with the steps above for all the other dependence paths in the model depicted in Figure 1.2 to produce the " Create New Equations" dialog box shown below.

- Click on the "DONE" push button to load the "Create Variances/Covariances" dialog box shown below.


All the variances in the model would be automatically indicated at this stage.
For the model, depicted in Figure 1.2, double headed arrows are employed from the manifest variable V2 (REPAP) to itself to specify a variance and to V3 (RESOE), and V1 (REINT), to specify covariances. These paths are shown in the diagram below.


Figure 3.4 Variance/Covariance Paths between V2, V3 and V1.

The covariances above are added to the equations by the following actions.

- Click on the cell in Row "V2" and Column "V1" of the "Create Variances/Covariances" window above until an asterisk "*" appears.
- Click on the cell Row "V3" and Colunm "V1".
- Repeat the above step for all the other covariance paths in the model to produce the " Create Variances/Covariances" dialog box shown below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | DONE |  |  | CANCEL |  |  |  |  |  |  |  |  |
|  |  | V1 | v2 | V3 | V6 | v7 | vs | E4 | E5 | E9 | E10 | D 1 |
|  | V1 | * |  |  |  |  |  |  |  |  |  |  |
|  | V2 | * | * |  |  |  |  |  |  |  |  |  |
|  | V3 | * | * | * |  |  |  |  |  |  |  |  |
|  | V6 | * | * | * | * |  |  |  |  |  |  |  |
|  | V7 | * | * | * | * | * |  |  |  |  |  |  |
|  | V8 | * | * | * | * | * | * |  |  |  |  |  |
|  | E4 |  |  |  |  |  |  | * |  |  |  |  |
|  | E5 |  |  |  |  |  |  |  | * |  |  |  |
|  | E9 |  |  |  |  |  |  |  |  | * |  |  |
|  | E10 |  |  |  |  |  |  |  |  |  | * |  |
|  | D1 |  |  |  |  |  |  |  |  |  |  | * - |
| 41.1 |  |  |  |  |  |  |  |  |  |  |  | $\stackrel{+}{+}$ |

- Click on the "Done" push button to open the window below.


The model file created has the default name, "WORK.EQS". Save the model file by following the steps below.

- Click on the "Save As" option from the EQS "File" menu to load the dialog box shown below.
- Select the right drive and the right path.
- Type the file name into the "File name" string field to produce the dialog box shown below.

- Click the "OK" push button to open the window shown below.

- Scroll the model file to the end as shown below.

- Type the keyword "/MATRIX" after the last row in the model file.
- Type in the entries of the correlation matrix.
- In the next row after the matrix, type in the keyword "/STANDARD DEVIATIONS" and enter the standard deviations of each of the manifest variables.
- Type in the keyword "/END" at the end of the model file to produce the window shown below.



### 3.3.2 INPUT FILE: EXAMPLE 3

The complete EQS input file for the Duncan, Haller and Portes' Application is provided below.
/TITLE
DUNCAN, HALLER AND PORTES' APPLICATION
/SPECIFICATIONS
VARIABLES=10;CASES=329;METHODS=ML;MATRIX=COR;
/LABELS
V1=REINT; V2=REPAP; V3=RESOE; V4=REOAP; V5=REEAP; V6=BFINT;
V7=BFPAP; V8=BFSOE; V9=BFEAP; V10=BFOAP; F1=REAMB; F2=BFAMB;
/EQUATIONS
$\mathrm{V} 4=+* \mathrm{~F} 1+\mathrm{E} 4 ;$
$\mathrm{V} 5=+\mathrm{F} 1+\mathrm{E} 5 ;$
$\mathrm{V} 9=+* \mathrm{~F} 2+\mathrm{E} 9 ;$
$\mathrm{V} 10=+\mathrm{F} 2+\mathrm{E} 10 ;$
$\mathrm{F} 1=+* \mathrm{~F} 2+* \mathrm{~V} 1+* \mathrm{~V} 2+* \mathrm{~V} 3+* \mathrm{~V} 8+\mathrm{D} 1 ;$
$\mathrm{F} 2=+* \mathrm{~F} 1+* \mathrm{~V} 3+* \mathrm{~V} 6+* \mathrm{~V} 7+* \mathrm{~V} 8+\mathrm{D} 2 ;$
/VARIANCES
$\mathrm{V} 1=1$;
$\mathrm{V} 2=1$;
$\mathrm{V} 3=1$;
$\mathrm{V} 6=1$;
V7 = 1;
$\mathrm{V} 8=1$;
$\mathrm{E} 4=$ *;
$\mathrm{E} 5=$ *;
$\mathrm{E} 9=$ *;
$\mathrm{E} 10=*$;
D1 = *;
D2 = *;
/COVARIANCES
V2, V1 = *;
$\mathrm{V} 2, \mathrm{~V} 3=*$;

$$
\begin{aligned}
& \text { V2, V6 = *; } \\
& \text { V2, V7 = *; } \\
& \text { V2, V8 = *; } \\
& \text { V1, V3 = *; } \\
& \mathrm{V} 1, \mathrm{~V} 6=\text { *; } \\
& \text { V1, V7 = *; } \\
& \text { V1, V8 = *; } \\
& \text { V3, V6 = *; } \\
& \text { V3, V7 = *; } \\
& \text { V3, V8 = *; } \\
& \text { V6, V7 = *; } \\
& \text { V8, V6 = *; } \\
& \text { V8, V7 = *; } \\
& \text { /MATRIX } \\
& 1.000 \\
& 0.1841 .000 \\
& 0.2220 .0491 .000 \\
& 0.4110 .2140 .3241 .000 \\
& 0.4040 .2740 .4050 .6251 .000 \\
& 0.3360 .0780 .2300 .3000 .2861 .000 \\
& 0.1020 .1150 .0930 .0760 .0700 .2091 .000 \\
& 0.1860 .0190 .2710 .2930 .2410 .295-0.0441 .000 \\
& 0.2600 .0840 .2790 .4220 .3280 .5000 .1990 .3611 .000 \\
& 0.2900 .1120 .3050 .3270 .3670 .5190 .2780 .4110 .6401 .000 \\
& \text { /STANDARD DEVIATIONS } \\
& 1.0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001 .000 \\
& \text { /END }
\end{aligned}
$$

### 3.3.3 RUNNING EQS

To run EQS:

- Click on the "Build EQS" menu to load the following menu box.

- Click on the "Run EQS/386" option to load the "EQS for Windows" dialog box below.

- Click on the "OK" push button to start the iteration process.

When the iteration is completed, the following DOS window appears.


- Click on the close button to close the DOS window to open the output file with the same filename as the model file and with extension "out", as shown below.



### 3.3.4 THE EQS OUTPUT FILE

(1)

EQS, A STRUCTURAL EQUATION PROGRAM MULTIVARIATE SOFTWARE, INC. COPYRIGHT BY P.M. BENTLER VERSION 5.1 (C) $1985-1995$.
(2)

```
/TITLE
DUNCAN, HALLER AND PORTES' APPLICATION
/SPECIFICATIONS
    VARIABLES=10;CASES=329;METHODS=ML;MATRIX=COR;
/LABELS
    V1=REINT;V2=REPAP;V3=RESOE;V4=REOAP;V5=REEAP;V6=BFINT;
    V7=BFPAP;V8=BFSOE;V9=BFEAP;V10=BFOAP;F1=REAMB;F2=BFAMB;
    /EQUATIONS
V4 = + *F1 + E4;
V5 = + F1 + E5;
V9 = + *F2 + E9;
V10 = + F2 + E10;
F1 = + *F2 + *V1 + *V2 + *V3 + *V8 + D1;
F2 = + *F1 + *V3 + *V6 + *V7 + *V8 + D2;
```

```
15 /VARIANCES
16 V1 = 1;
17 V2 = 1;
18 V3 = 1;
19 V6 = 1;
20 V7 = 1;
21 V8 = 1;
22 E4 = *;
23 E5 = *;
24 E9 = *;
25 E10 = *;
26 D1 = *;
27 D2 = *;
28 /COVARIANCES
29 V2 , V1 = *;
30 V2 , V3 = *;
31 V2 , V6 = *;
32 V2 , V7 = *;
33 V2 , V8 = *;
34 V1 , V3 = *;
35 V1 , V6 = *;
36 V1 , V7 = *;
37 V1 , V8 = *;
38 V3 , V6 = *;
39 V3 , V7 = *;
40 V3 , V8 = *;
41 V6 , V7 = *;
42 V8 , V6 = *;
43 V8 , V7 = *;
44 /MATRIX
4 5 ~ 1 . 0 0 0
46 0.184 1.000
47 0.222 0.049 1.000
48 0.411 0.214 0.324 1.000
49 0.404 0.274 0.405 0.625 1.000
50 0.336 0.078 0.230 0.300 0.286 1.000
51 0.102 0.115 0.093 0.076 0.070 0.209 1.000
52 0.186 0.019 0.271 0.293 0.241 0.295 -0.044 1.000
```

(3)

| TITLE: | $\quad$ DUNCAN, HALLER | AND PORTES' | APPLICATION | $17 / 11 / 00$ | PAGE : 2 |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 53 | 0.260 | 0.084 | 0.279 | 0.422 | 0.328 | 0.500 | 0.199 | 0.361 | 1.000 |  |  |
| 54 | 0.290 | 0.112 | 0.305 | 0.327 | 0.367 | 0.519 | 0.278 | 0.411 | 0.640 | 1.000 |  |
| 55 | /STANDARD DEVIATIONS |  |  |  |  |  |  |  |  |  |  |
| 56 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |  |
| 57 | /END |  |  |  |  |  |  |  |  |  |  |

(4) 57 RECORDS OF INPUT MODEL FILE WERE READ

TITLE: DUNCAN, HALLER AND PORTES' APPLICATION 17/11/00 PAGE : 3

| REINT | REPAP | RESOE | REOAP | REEAP |
| :---: | :---: | :---: | :---: | :---: |
| V 1 | V 2 | V 3 | V 4 | V 5 |
| 1.000 |  |  |  |  |
| 0.184 | 1.000 |  |  |  |
| 0.222 | 0.049 | 1.000 |  |  |
| 0.411 | 0.214 | 0.324 | 1.000 |  |
| 0.404 | 0.274 | 0.405 | 0.625 | 1.000 |
| 0.336 | 0.078 | 0.230 | 0.300 | 0.286 |
| 0.102 | 0.115 | 0.093 | 0.076 | 0.070 |
| 0.186 | 0.019 | 0.271 | 0.293 | 0.241 |
| 0.260 | 0.084 | 0.279 | 0.422 | 0.328 |
| 0.290 | 0.112 | 0.305 | 0.327 | 0.367 |
| BFINT | BFPAP | BFSOE | BFEAP | BFOAP |
| V 6 | V 7 | V 8 | V 9 | V 10 |
| 1.000 |  |  |  |  |
| 0.209 | 1.000 |  |  |  |
| 0.295 | -0.044 | 1.000 |  |  |
| 0.500 | 0.199 | 0.361 | 1.000 |  |
| 0.519 | 0.278 | 0.411 | 0.640 | 1.000 |

(6)

```
NUMBER OF DEPENDENT VARIABLES = 6
    DEPENDENT V'S : 4 5 9 10
    DEPENDENT F'S : 1 2
    NUMBER OF INDEPENDENT VARIABLES = 12
        INDEPENDENT V'S : 
        INDEPENDENT E'S : 4 5 9 10
        INDEPENDENT D'S : 1 2
```

3RD STAGE OF COMPUTATION REQUIRED 5297 WORDS OF MEMORY.
PROGRAM ALLOCATE 100000 WORDS
(7)

DETERMINANT OF INPUT MATRIX IS $0.70018 \mathrm{E}-01$
TITLE: DUNCAN, HALLER AND PORTES' APPLICATION 17/11/00 PAGE : 4

## (8)

MAXIMUM LIKELIHOOD SOLUTION (NORMAL DISTRIBUTION THEORY)

## (9)

PARAMETER ESTIMATES APPEAR IN ORDER,
NO SPECIAL PROBLEMS WERE ENCOUNTERED DURING OPTIMIZATION.

|  |  |  | REINT | REPAP | RESOE | REOAP | REEAP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | V 1 | V 2 | V 3 | V 4 | V 5 |
| REINT | V | 1 | 0.000 |  |  |  |  |
| REPAP | V | 2 | 0.000 | 0.000 |  |  |  |
| RESOE | V | 3 | 0.000 | 0.000 | 0.000 |  |  |
| REOAP | V | 4 | 0.018 | -0.026 | -0.033 | 0.001 |  |
| REEAP | V | 5 | -0.013 | 0.020 | 0.026 | 0.001 | 0.001 |
| BFINT | V | 6 | 0.000 | 0.000 | 0.000 | 0.042 | 0.012 |
| BFPAP | V | 7 | 0.000 | 0.000 | 0.000 | -0.027 | -0.040 |
| BFSOE | V | 8 | 0.000 | 0.000 | 0.000 | 0.038 | -0.030 |
| BFEAP | V | 9 | 0.005 | -0.011 | -0.003 | 0.091 | -0.023 |
| BFOAP | V | 10 | 0.017 | 0.010 | 0.002 | -0.028 | -0.009 |
|  |  |  | BFINT | BFPAP | BFSOE | BFEAP | BFOAP |
|  |  |  | V 6 | V 7 | V 8 | V 9 | V 10 |
| BFINT | V | 6 | 0.000 |  |  |  |  |
| BFPAP | V | 7 | 0.000 | 0.000 |  |  |  |
| BFSOE | V | 8 | 0.000 | 0.000 | 0.000 |  |  |
| BFEAP | V | 9 | 0.011 | -0.038 | -0.013 | 0.001 |  |
| BFOAP | V | 10 | -0.006 | 0.024 | 0.010 | 0.001 | 0.001 |

(11)
(12) AVERAGE OFF-DIAGONAL ABSOLUTE COVARIANCE RESIDUALS = 0.0140

AVERAGE ABSOLUTE COVARIANCE RESIDUALS
$=\quad 0.0115$
(13)

(14) AVERAGE ABSOLUTE STANDARDIZED RESIDUALS = 0.0115
(15) AVERAGE OFF-DIAGONAL ABSOLUTE STANDARDIZED RESIDUALS $=0.0140$
(16)

| $\mathrm{V} 9, \mathrm{~V} 4$ | $\mathrm{~V} 6, \mathrm{~V} 4$ | $\mathrm{~V} 7, \mathrm{~V} 5$ | $\mathrm{~V} 8, \mathrm{~V} 4$ | $\mathrm{~V} 9, \mathrm{V7}$ |
| :---: | :---: | :---: | :---: | :---: |
| 0.091 | 0.042 | -0.040 | 0.038 | -0.038 |
|  |  |  |  |  |
| V4,V3 | $\mathrm{V} 8, \mathrm{~V} 5$ | $\mathrm{~V} 10, \mathrm{~V} 4$ | $\mathrm{~V} 7, \mathrm{~V} 4$ | $\mathrm{~V} 5, \mathrm{~V} 3$ |
| -0.033 | -0.030 | -0.028 | -0.027 | 0.026 |
|  |  |  |  |  |
| V4,V2 | $\mathrm{V} 10, \mathrm{V7}$ | $\mathrm{~V} 9, \mathrm{~V} 5$ | $\mathrm{~V} 5, \mathrm{~V} 2$ | $\mathrm{~V} 4, \mathrm{~V} 1$ |
| -0.026 | 0.024 | -0.023 | 0.020 | 0.018 |
|  |  |  |  |  |
| V10,V1 | $\mathrm{V} 5, \mathrm{~V} 1$ | $\mathrm{~V} 9, \mathrm{~V} 8$ | $\mathrm{~V} 6, \mathrm{~V} 5$ | $\mathrm{~V} 9, \mathrm{~V} 2$ |
| 0.017 | -0.013 | -0.013 | 0.012 | -0.011 |

(17)

| ! |  |  | ! |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 40- |  |  | - |  |  |  |  |  |  |
| ! |  |  | ! |  |  |  |  |  |  |
| ! |  |  | ! |  |  |  |  |  |  |
| ! |  |  | ! |  |  |  |  |  |  |
| ! |  |  | ! |  |  | N |  | FREQ | PERCENT |
| 30- | * |  | - |  |  |  |  |  |  |
| ! |  | * | ! | 1 | -0. 5 | - | -- | 0 | 0.00\% |
| ! | * | * | ! | 2 | -0.4 | - | -0.5 | 0 | 0.00\% |
| ! | * | * | ! | 3 | -0.3 | - | -0.4 | 0 | 0.00\% |
| ! | * | * | ! | 4 | -0.2 | - | -0.3 | 0 | 0.00\% |
| 20- | * | * |  | - 5 | -0.1 | - | -0.2 | 0 | 0.00\% |
| ! | * | * | ! | 6 | 0.0 | - | -0.1 | 26 | 47.27\% |
| ! | * | * | ! | 7 | 0.1 | - | 0.0 | 29 | 52.73\% |
| ! | * | * | ! | 8 | 0.2 | - | 0.1 | 0 | $0.00 \%$ |
| ! | * | * | ! | 9 | 0.3 | - | 0.2 | 0 | $0.00 \%$ |
| 10- | * | * |  | -A | 0.4 | - | 0.3 | 0 | $0.00 \%$ |
| ! | * | * | ! | B | 0.5 | - | 0.4 | 0 | $0.00 \%$ |
| ! | * | * | ! | C | ++ | - | 0.5 | 0 | 0.00\% |
| ! | * | * | ! |  |  |  |  | ---- | ----- |
| ! | * | * | ! |  |  |  |  | 55 | 100.00\% |

TITLE: DUNCAN, HALLER AND PORTES' APPLICATION $17 / 11 / 00$ PAGE : 6
MAXIMUM LIKELIHOOD SOLUTION (NORMAL DISTRIBUTION THEORY)

## (18) GOODNESS OF FIT SUMMARY

(I) InDEPENDENCE MODEL CHI-SQUARE =
872.155 ON
45 DEGREES OF FREEDOM
(II) InDEPENDENCE AIC $=882.15493$
(III) INDEPENDENCE CAIC = 930.48333
(IV) MODEL AIC $=104.84050$
$(\mathbf{V})$ MODEL CAIC $=291.44446$
(VI) CHI-SQUARE $=\quad 26.840$ BASED ON $\quad 16$ DEGREES OF FREEDOM
(VII) PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.002
(VIII) THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS 26.084.

| (IX) BENTLER-BONETT NORMED FIT INDEX | $=$ | 0.969 |
| :--- | :--- | :--- | :--- |
| (X) BENTLER-BONETT NONNORMED FIT INDEX | $=$ | -0.406 |
| (XI) COMPARATIVE FIT INDEX (CFI) | $=$ | 0.969 |

(19)

|  | PARAMETER |  |  |
| :---: | :---: | :---: | ---: |
| ITERATION | ABS CHANGE | ALPHA | FUNCTION |
| 1 | 0.595770 | 1.00000 | 10.54929 |
| 2 | 0.437456 | 1.00000 | 8.01110 |
| 3 | 0.200444 | 1.00000 | 7.85747 |
| 4 | 0.182135 | 1.00000 | 5.98122 |
| 5 | 0.158818 | 1.00000 | 4.52051 |
| 6 | 0.190420 | 1.00000 | 3.01704 |
| 7 | 0.104382 | 1.00000 | 2.04361 |
| 8 | 0.083959 | 1.00000 | 1.05939 |
| 9 | 0.055219 | 1.00000 | 0.21761 |
| 10 | 0.020089 | 1.00000 | 0.08861 |
| 11 | 0.005698 | 1.00000 | 0.08194 |
| 12 | 0.001084 | 1.00000 | 0.08184 |
| 13 | 0.000273 | 1.00000 | 0.08183 |

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(20)

```
REOAP =V4 = .943*F1 + 1.000 E4
                            .080
                            11.815
REEAP =V5 = 1.000 F1 + 1.000 E5
BFEAP =V9 = .932*F2 + 1.000 E9
            .070
                13.226
BFOAP =V10 = 1.000 F2 + 1.000 E10
```

(21)

| REAMB | =F1 | = | $\begin{aligned} & .173 * F 2 \\ & .085 \\ & 2.040 \end{aligned}$ | + | $\begin{aligned} & .270 * V 1 \\ & .044 \\ & 6.101 \end{aligned}$ |  | $\begin{gathered} .174 * V 2 \\ .041 \\ 4.264 \end{gathered}$ |  | $\begin{gathered} .236 \star \mathrm{~V} 3 \\ .045 \\ 5.178 \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | $\begin{aligned} & .084 * V 8 \\ & .050 \\ & 1.673 \end{aligned}$ | + | 1.000 D 1 |  |  |  |  |
| BFAMB | =F2 | = | $\begin{aligned} & .188 * F 1 \\ & .080 \\ & 2.341 \end{aligned}$ | + | $\begin{aligned} & .072 * \mathrm{~V} 3 \\ & .046 \\ & 1.545 \end{aligned}$ | + | $\begin{aligned} & .354 * V 6 \\ & .043 \\ & 8.238 \end{aligned}$ | + | $\begin{gathered} .163 * V 7 \\ .039 \\ 4.215 \end{gathered}$ |
|  |  |  | $\begin{gathered} .234 * V 8 \\ .043 \\ 5.471 \end{gathered}$ | + | 1.000 D 2 |  |  |  |  |

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```
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```

(23)

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(24)


|  |  | I | I |
| :---: | :---: | :---: | :---: |
| V8 | -BFSOE | .186*I | I |
| V1 | -REINT | . 052 I | I |
|  |  | 3.571 I | I |
|  |  | I | I |
| V3 | -RESOE | . 049 *I | I |
| V2 | -REPAP | . 055 I | I |
|  |  | . 892 I | I |
|  |  | I | I |
| V6 | -BFINT | . 078 *I | I |
| V2 | -REPAP | . 055 I | I |
|  |  | 1.430 I | I |
|  |  | I | I |
| V7 | -BFPAP | . 115 *I | I |
| V2 | -REPAP | . 054 I | I |
|  |  | 2.125 I | I |
|  |  | I | I |
| V8 | -BFSOE | .019*I | I |
| V2 | -REPAP | . 055 I | I |
|  |  | . 345 I | I |
|  |  | I | I |
| V6 | -BFINT | . 230 *I | I |
| V3 | -RESOE | . 051 I | I |
|  |  | 4.532 I | I |
|  |  | I | I |
| V7 | -BFPAP | .093*I | I |
| V3 | -RESOE | . 054 I | I |
|  |  | 1.710 I | I |
|  |  | I | I |
| V8 | -BFSOE | . 271 *I | I |
| V3 | -RESOE | . 049 I | I |
|  |  | 5.498 I | I |
|  |  | 1 | I |

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## (25)

| V7 | -BFPAP | . 209 *I | I |
| :---: | :---: | :---: | :---: |
| V6 | -BFINT | . 052 I | I |
|  |  | 4.049 I | I |
|  |  | I | I |
| V8 | -BFSOE | . 295 *I | I |
| V6 | -BFINT | . 048 I | I |
|  |  | 6.115 I | I |
|  |  | I | I |
| V8 | -BFSOE | $-.044 * I$ | I |
| V7 | -BFPAP | . 055 I | I |
|  |  | -. 804 I | I |
|  |  | I | I |

```
(26)
REOAP =V4 = .767*F1 +.642 E4
REEAP =V5 = .814 F1 +.581 E5
BFEAP =V9 = .772*F2 +..636 E9
BFOAP =V10 = .828 F2 + .561 E10
REAMB =F1 = .176*F2 + .332*V1 + .213*V2 + .290*V3 + % . % % % % V8
BFAMB =F2 = . 184*F1 +.087*V3 +.427*V6 +.197*V7 +.283*V8
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```


## (27)



|  |  | $I$ | $I$ |
| :--- | :--- | ---: | ---: |
| V7 | -BFPAP | $.209 * I$ | $I$ |
| V6 | -BFINT | $I$ | $I$ |
|  |  | $I$ | $I$ |
| V8 | -BFSOE | $.295 * I$ | $I$ |
| V6 | BFINT | $I$ | $I$ |
|  |  | $I$ | $I$ |
| V8 | BFSOE | $-.044 * I$ | $I$ |

(28)


## ENTRIES IN THE EQS OUTPUT FILE

(1) This paragraph gives the name of the Program, the author's name and the publishers of EQS.
(2) Program control information.

This paragraph gives the number of records or lines of the actual input file. This input feedback helps locate any problems in the input, and also provide a summary of the proposed analysis. The title of the input file will be part of this paragraph and it is repeated as the first line of every page.
(3) Continuation of the Program control information.
(4) This paragraph gives the details of the number of rows in the complete model file used in the analysis.
(5) The input correlation matrix to be analyzed, the number of variables and the number of cases appear in this paragraph. The matrix reproduced here enables the user to check that the arrangement of the variables and the variable codes were correctly entered in the input file.
(6) Bentler-Weeks Structural Representation.

The program input is decoded to generate a matrix specification consistent with the BentlerWeeks designation of dependent and independent variables. The number of dependent variables is printed, and index numbers are given for all measured and latent variables in the sequence $\mathrm{V}, \mathrm{F}, \mathrm{E}, \mathrm{D}$ with all V variables listed first, F variables listed next, and so on. Then the number of independent variables is printed along with the index numbers for the variables, again in the sequence V, F, E, D. This information enables the user, if necessary, to determine whether the model was specified as intended.
(7) This paragraph gives the determinant of the input correlation matrix.
(8) This is the line of information on the estimation method and the distributional theory used in the analysis. This printed information will head each page of output associated with the given method. When this information changes, a new solution method is being reported.
(9) This message appears if the estimates for all parameters seem to be technically acceptable. This message should always be located prior to evaluating the meaning of any results.
(10) Residual covariance matrix $\left(\mathbf{S}-\hat{\sum}\right)$.

This is the difference between the sample covariance matrix $\mathbf{S}$ (or the covariance matrix calculated from the input correlation matrix) and the reproduced covariance matrix $\hat{\sum^{\prime}}$. The closer the entries are to zero, the better the model fits the data.
(11) The average absolute covariance residuals.

This value is the average of the absolute standardized residuals including the diagonal elements.
(12) The average off-diagonal absolute covariance residuals.

This value is the average of the absolute standardized residuals excluding the diagonal elements.
(13) Standardized residual matrix.

This the matrix produced by a standardization on the Residual Covariance Matrix so that the elements are in a more similar range. The residual matrix $(\mathbf{S}-\hat{\boldsymbol{Z}}$ ) is pre- and postmultiplied by the diagonal matrix of inverse elements of standard deviations of the manifest variables, so that the resulting residual matrix can be interpreted in the metric of correlations among the input variables. The standardized residual matrix contains elements given by

$$
r_{i j}-\vec{\theta}_{i j} / s_{i} s_{j}
$$

where $r_{i j}$ is the observed correlation between the two manifest variables $\mathrm{V}_{\mathrm{i}}$ and $\mathrm{V}_{\mathrm{j}}, \vec{\theta}_{i j}$ is the corresponding reproduced model covariance, and $s_{i}$ and $s_{j}$ are standard deviations of the manifest variables $V_{i}$ and $V_{j}$ respectively.
(14) The average absolute standardized residuals.

Same as in (9) above.
(15) The average off-diagonal absolute standardized residuals.

Same as in (10) above.
(16) Largest standardized residual.

In this paragraph, the elements from the Standardized Residual Matrix are ordered from large to small in absolute value, and the largest twenty of these are printed out along with a designation of which pairs of variables are involved.
(17) Distribution of standardized residuals.

A frequency distribution of the standardized residuals is given in this paragraph. The legend for the figure describes how many residual elements are described by a single asterisk in the figure, and information on the specific frequencies and percentages that fall within a given range used in the figure. Note that the diagram is labeled $1,2, \ldots, 9$ A, B, C. Each of these numbers or letters refers to a given range of numbers that describes the size of the residuals.
(18) Goodness of Fit Indices.
(I) The Independence model chi-square is given by Independence model $\chi^{2}=\mathrm{N} F_{o}$.
where $F_{o}$ denotes the minimal discrepancy function value for the independence model and N denotes the number of cases.
(II) The Independent Akaike's Information Criterion (AIC) is given by

Independence AIC $=$ Independence model $\chi^{2}-2 d_{i}$
where $d_{i}$ denotes the degrees of freedom of the independence model.
(III) The Independence Cross-validated Akaike's Information Criterion (CAIC) is given by (Bozdogan, 1987)

Independence CAIC $=$ Independence model $\chi^{2}-(\operatorname{In} N+1) \mathrm{d}_{\mathrm{i}}$
(IV) The model Akaike's Information Criterion (AIC) is given by

Model AIC $=$ Model $\chi^{2}-2 \mathrm{~d}_{\mathrm{k}}$
where $d_{k}$ denotes the degrees of freedom of the model of interest.
(V) The model Cross-validated Akaike Information Criterion (CAIC) is given by

Model CAIC $=$ model $\chi^{2}-(\operatorname{In} N+1) d_{k}$.
(VI) The chi-square (model $\chi^{2}$ test statistic) is calculated as $n \times \hat{F}$.
where $\hat{F}$ is the minimal sample discrepancy function value.
(VII) This is the probability of obtaining a $\chi^{2}$ value as greater or equal to the value actually obtained, given that the model is correct.
(VIII) This is the value obtained from the normal theory rewieghted least squares chi-square for maximum likelihood solution.
(IX) The Bentler-Bonett normed fit index (NFI) value is computed from

$$
\mathrm{NFI}=1-\frac{\bar{छ}_{k}}{\overline{Q_{i}}}
$$

where $\mathcal{Z}_{k}$ and $\mathcal{Z}_{i}$ are the minimal values of the fitting functions obtained for the model of interest and the corresponding independence model, respectively. The general fitting function Q is given by:

$$
\mathrm{Q}=(s-\sigma(\theta))^{\prime} W(s-\sigma(\theta))
$$

where $s$ is the vector of $\frac{1}{2} p(p+1)$ elements obtained by stringing out the lower triangular elements of the unbiased sample covariance matrix $\mathrm{S}, \sigma$ is the corresponding vector obtained from $\sum$, and $\theta$ is the vector of free parameters of the structural equation model.
(X) The Bentler-Bonett non-normed fit index (NNFI) value is computed from

$$
\mathrm{NNFI}=\frac{\left(f_{i}-f_{k}\right)}{\left(\not f_{i}-1\right)}
$$

where $\vec{f}_{i}=N Q_{i} / d_{i}$ and $\nexists_{k}=N Q_{k} / d_{k}$ are $\chi^{2}$ variates divided by the associated degrees of freedom for the null $\left(d_{i}\right)$ and substantive models $\left(d_{k}\right)$, respectively.
(XI) The Comparative Fit Index (CFI) is computed from

$$
\mathrm{CFI}=1-\frac{\bar{\eta}_{k}}{\eta_{i}}
$$

where $\vec{च}_{k}=\max \left[\left(N \bar{Q}_{k}-d_{k}\right), 0\right]$ based on the model of interest and

$$
\exists_{i}=\max \left[\left(N \Xi_{i}-d_{i}\right),\left(N \Xi_{k}-d_{k}\right), 0\right]
$$

(19) Iterative summary.

This paragraph contains information obtained from each iteration.
Column 1: Iteration number
Column 2: Change in parameter estimate.
Column 3: Alpha.
Alpha is the value of the stepsize parameter used in the iteration.
Column 4: Function.
The value of the sample discrepancy function.
(20) Measurement equations with standard errors and test statistics.

In this paragraph, the measurement equations that relate manifest dependent variables (Vs) to other variables are printed. The equations are printed with the updated parameter estimates rather than the starting values using a three-line format as follows:

Line 1: the equation with estimated parameter values.
Line 2: the standard error of the estimator(s).
Line 3: the test statistic(s) for the significance of the parameter(s).
(21) Construct equations with standard errors and test statistics.

The construct equations that have dependent latent variables (Fs) are printed in this paragraph. Each measurement equation with optimal estimates for free parameters is printed in the same format as outlined in (20) above.
(22) Variances of independent variables.

There are four columns in this paragraph.
Column 1:
Manifest variables (Vs).
Column 2:
Latent variables (Fs).
Column 3:
Error terms (Es).
Column 4:
Disturbances (Ds).
Column 3 and Column 4 are printed separately in paragraph (23) below.
(23) Variances of independent variables continued.

This paragraph is the E and D part of paragraph (22) above.
(24) Covariances among independent variables.

The same format and column headings are used in this paragraph as in paragraphs (22) and (23) above. The labels for the pair of variables involved in a covariance are printed below each other.
(25) Covariances among independent variables.

This paragraph is the continuation of paragraph (24) above.
(26) The maximum likelihood solution (normal distribution theory). Standardized solution.

In this paragraph, each measurement and construct equation is printed out giving the standardized solution. This is a complete standardized path analysis type of solution, except that manifest variables are not standardized: all V, F, E, and D model variables are rescaled to have unit variances. Standardization is done for all variables in the linear structural equation system, including errors and disturbances. Consequently, all coefficients in the equations have similar interpretation, and the magnitude of these standardized coefficients may be easier to interpret than the magnitudes of the coefficients obtained from the covariance or raw data matrix.
(27) Correlations among independent variables.

These correlations accompany the standardized solution when it is computed. These must be scanned to see whether they are in the necessary $\pm 1$ range. If not, the solution has a problem that may imply theoretical or empirical under identification.
(28) End of Method.

The phrase "End of Method" delineates the end of output from a given estimation problem with a given method. It has three rows described below:
(I) The time the execution (iteration) started.
(II) The time the execution (iteration) ended.
(III) The elapsed time. This is the difference between (ii) and (i).

## CHAPTER 4 <br> LISREL

### 4.1 HISTORICAL BACKGROUND

The acronym LISREL stands for Linear Structural RELationships. Karl Jöreskog and Dag Sörbom developed a DOS application that implements the LISREL methodology in 1974. The 1974 version was improved upon in 1978 and again in 1986. LISREL 5 and LISREL 6 were released in 1981 and 1984 respectively. LISREL 7 was released in 1989 and LISREL 8 in 1996. The latest version is LISREL 8.30, which was released in 1999. The Scientific Software International Inc (SSI) publishes LISREL. One may obtain more information about LISREL from the SSI website www.ssicentral.com.

The LISREL model specifies linear relationships between observed and/or unobserved variables. In its general form the LISREL model is defined by the following system of linear structural relations:

$$
\begin{aligned}
& \underline{-}=\Lambda_{x} \underline{-}+\underset{-}{\delta} \\
& \underset{-}{Y}=\Lambda_{y}^{y} \underline{\eta}+\underset{-}{\varepsilon} \\
& \eta=B \underset{\underline{\eta}}{ }+\Gamma \underset{\underline{\xi}}{\underline{\xi}} \boldsymbol{\zeta}
\end{aligned}
$$

where $X$ represents the vector of all exogenous manifest variables and the measurements of exogenous latent variable of the model,
$Y$ represents the vector of all measurements of endogenous latent variables and the endogenous manifest variables of the model, $\eta$ represents the vector of all the dependent latent variables of the model,
$\xi$ represents the vector of all the independent latent variables of the model,
$\zeta$ represents the random vector of residuals (errors in equations, random disturbance terms),
$B, \Gamma, \Lambda_{x}$, and $\Lambda_{y}$ are parameter matrices.

The covariance structure of the observed variables which is also known as the Covariance Structure of the LISREL model is given by

$$
\sum=\operatorname{Cov}\left(\begin{array}{lc}
\Lambda_{y}(I-B)^{-1}\left(\Gamma \Phi \Gamma^{\prime}+\Psi\right)(I-B)^{-1} \Lambda_{y}^{\prime}+\Theta_{\varepsilon} & \Lambda_{y}(I-B)^{-1} \Gamma \Phi \Lambda_{x} \\
\Lambda_{x} \Phi \Gamma^{\prime}(I-B)^{-1} \Lambda_{y}^{\prime} & \Lambda_{x} \Phi \Gamma^{\prime}(I-B)^{-1} \Lambda_{y}^{\prime}+\Theta_{\delta}
\end{array}\right)
$$

where
$\Phi \quad$ denotes the covariance matrix of $\xi$,
$\Psi \quad$ denotes the covariance matrix of $\zeta$,
$\Theta_{\varepsilon} \quad$ denotes the covariance matrix of $\varepsilon$ and
$\Theta_{\delta} \quad$ denotes the covariance matrix of $\delta$.
The LISREL model is, as seen above, a formal mathematical model, which has to be, given substantive content in each application. The meaning of the terms involved in the model varies from one application to another. The formal LISREL model defines a large class of models within which one can work and this class contains several useful subclasses as special cases.

The program LISREL 8.30 implements the LISREL model. LISREL8.30 consists of two programs: PRELIS and LISREL. One can run PRELIS or LISREL separately or PRELIS and LISREL in sequence. PRELIS handles everything that has to do with raw data; LISREL handles the fitting and testing of models to summary statistics produced by PRELIS, i.e. PRELIS is a preprocessor for LISREL. But it can also be conveniently used to provide a first descriptive look at raw data even when LISREL analysis is intended or when other programs will do further analysis.

The LISREL8.30 command language requires a user to be familiar with matrices so as to be able to formulate a model in matrix form using Greek matrix notations. Beginning users of LISREL8.30 and users who often make mistakes when they specify the LISREL model can use the SIMPLIS command language as this is much easier to learn and reduces the possibilities for mistakes to a minimum. The SIMPLIS command language is in plain English. The user is only required to name the variables of the model and then formulate the model to be estimated.

The LISREL 8.30 for windows program allows the user to create and run the LISREL syntax interactively. One way to do this is to draw the appropriate path diagram on the screen and then to build the corresponding SIMPLIS or LISREL code directly from the path diagram. The model can be modified interactively at run time by adding or deleting paths in the diagram.

### 4.2 THE LISREL INPUT SYSTEM

There are three ways of fitting a structural equation model to data with LISREL8.30. These are:

1) To specify the structural equation model in a LISREL input file by using the LISREL command language to create LS8 or LPJ files. These input files are text files that specify the structural equation model in terms of the eight parameter matrices of the LISREL model.
2) To specify the structural equation model by using the SIMPLIS command language to create SPL or SPJ files. These files are text files that can be created using any text editor such as notepad.
3) To specify the structural equation model by creating a graphics file which contains the path diagram for the model and then build the corresponding LISREL syntax file directly from the path diagram. The graphics file created is saved with the extension "*.PTH".

The data to be analyzed, is provided in a LISREL data file with the extension "*.DAT" or a data system file with the extension "*.DSF". A LISREL data file is a text file that contains the raw data matrix, the sample covariance matrix or sample correlation matrix. Data can also be imported from other applications, such as SPSS, SYSTAT, BMDP, EXCEL, etc.

## GENERAL RULES FOR TYPING LISREL INPUT FILES

- Uppercase elements are commands, keywords or options. They must be entered as they appear, or they may be lengthened (LABELS instead of LA, for example). Thus, except for the ALL option on the VA and ST commands and the PATH DIAGRAM command, everything has two significant characters.
- Only the first two characters are significant in command names, options, keywords and character keyword values. Any additional character up to the first blank, comma, semicolon, or equals sign will be ignored. Thus DA, DATA, DAta, and data are all equivalent.
- An exclamation mark (!) or the slash-asterisk combination (/*) may be used to indicate that everything that follows on the line is to be regarded as comments. Blank (empty) lines are accepted without the ! or /*.
- The order of the options and keywords is immaterial.
- Equal signs are required after option names and keywords.
- Commas or blanks are used to separate subcommand names, keywords, and options.
- Blanks on either side of equal sign are allowed.
- A command ends with a return character.
- More than one command may appear on a physical line as long as semicolons separate them.
- A line may not exceed 127 columns except under some operating systems that restricts input lines to 80 columns.
- A command line which exceeds 127 characters may be continued on the next physical line by replacing the original option or keyword with C (for continue).
- Detail lines giving additional information may follow a command.
- It is recommended to place the data to be analyzed in an external file.
- Any number of problems may be stacked together and analyzed in one run.
- A parameter matrix element should be written as a parameter matrix name (LY, LX, BE, GA, PH, PS, TE, TD, or TH), followed by row and column positions (or linear indexes) of the specific element. Row and column positions may be separated by a comma and enclosed in parentheses, for example $\operatorname{LY}(3,2), \mathrm{LX}(4,1)$, or separated from the matrix name and each other by spaces, for example LY 32 LX 41.
- The order of the form and mode values for the parameter matrices on the MO subcommand is optional, but if both are given, a comma in between is required.
- Order of commands. The order of the LISREL commands is arbitrary except for the following conditions:
* $\quad$ After optional title lines, a DA (data) command must always come first.
* $\quad$ The OU (output) command must always be last.
* The LK, LE, FR, FI, EQ, CO, IR, PA, VA, ST, MA, PL, and NF commands must always come after the MO (model) command.
* The MO command is optional only if no LISREL model is analyzed. If the MO command is missing, only the matrix to be analyzed will be printed out. Otherwise, the MO command must appear in the command file.
* Although the order of other commands is relatively free, a later command will overrule earlier command, in so far as the same elements are referenced.


### 4.2.1 THE LISREL INPUT FILE SYNTAX

The basic structure of the LISREL 8.30 input file is outlined below. The commands, options and keywords that are not always required are indicated as "optional". The three phases, data specification, model specification and the output results are outlined separately.

## Data Specification

## TITLE STATEMENT

(Optional)

## Purpose

To provide a description of the analysis to be performed.
Syntax
TITLE $=$ title
where "title" denotes a character string of at most 137 characters.

## Example

For the model depicted in Figure 1.2 the "TITLE STATEMENT" may be given as follows:
TITLE $=$ The Duncan, Haller and Portes' Application

## DA command

Purpose
To specify the data to be analyzed. This should be the first command after the optional title statement. The available options and keywords under DA are given below.

## NI keyword

## Purpose

To specify the Number of Input variables in the data file.
Syntax
$\mathrm{NI}=\mathrm{p}$
where p denotes the number of input variables in the data file to be analyzed.

## Example

For the model depicted in Figure 1.2, there are 10 observed variables. This is specified as: $\mathrm{NI}=10$

## NO keyword

## Purpose

To specify the Number of cases or Observations in the data file. This is optional if raw data are read in from an external file. Otherwise, it is required.

Syntax
$\mathrm{NO}=\mathrm{n}$
where n is number of cases in the data file.

## Example

For the model depicted in Figure 1.2, there were 329 cases. This is therefore specified as:
$\mathrm{NO}=329$

NG keyword (Optional)
Purpose
To specify the Number of Groups in multi-group or multi-sample analysis.
Syntax
NG=k
where k is the number of groups in the data to be analyzed.
Default
$\mathrm{NG}=1$

## Example

For the model depicted in Figure 1.2, there is only one group. This is therefore specified as:
NG=1

## MA keyword

Purpose
To specify the Matrix to be Analyzed, not the matrix to be input.
Syntax
MA= matrix
where "matrix" denote any of the following possible specifications:
MA=CM (covariance matrix)

```
\(\mathrm{MA}=\mathrm{MM}\) (moment matrix)
MA=AM (augmented moment matrix)
MA=KM (correlation matrix of Pearson correlations)
\(\mathrm{MA}=\mathrm{PM}\) (polychoric correlation matrix)
MA=OM (canonical correlation matrix of Optimal scores)
MA=TM (Kendall's Tau-c correlation matrix)
MA=RM (Spearman rank correlation matrix)
Default
\(\mathrm{MA}=\mathrm{CM}\)
```


## Example

For the model depicted in Figure 1.2, the matrix to be analyzed is correlation matrix of Pearson correlations. This is specified as
$\mathrm{MA}=\mathrm{KM}$

## LA command (Optional).

## Purpose

The descriptive name of each observed variable for the model is listed after the LA (or LABEL) command. If no LA command appears, default labels (VAR 1, VAR 2, etc.) are used. The order of the labels follows the order of the input variables. When both $x$ - and $y$ variables are present, $y$-variables should come first. The maximum length for each label is eight characters.

Syntax
LA
VAR 1 VAR 2.... VAR p
where "VAR 1 VAR $2 \ldots$ VAR p" denotes the descriptive names of the input variables.
Example
For the model depicted in Figure 1.2, the 10 observed variables listed after the LA command may be as shown below:
LA
REINT REPAP RESOE REOAP REEAP BFINT BFPAP BFSOE BFOAP BFEAP

## KM command

Purpose
To read summary statistics for the LISREL analysis: covariances, correlations, or moments about zero. Using KM means that a Pearson correlation matrix will be read.

Other possibilities:
CM (covariance matrix)
MM (matrix of moments)
OM (matrix of optimal scores)
PM (polychoric correlation matrix)
RM (Spearman rank correlation matrix)
TM (Kendall's Tau-c correlation matrix)

## SE command

Purpose
To SElect in any order any number of variables from the NI input variables. The selected variables should be listed either by number or by label in the order that they are wanted in the model and the y-variables should be listed first. The list ends with a forward slash (/).

Syntax
SE
List of numbers or variable names

## Example

For the model depicted in Figure 1.2 , the $y$-variables are in the $4^{\text {th }}, 5^{\text {th }}, 9^{\text {th }}$ and the $10^{\text {th }}$ positions in the correlation matrix to be analyzed. The x -variables are in the $1^{\text {st }}, 2^{\text {nd }}, 3 \mathrm{rd}, 6^{\text {th }}$, $7^{\text {th }}$, and $8^{\text {th }}$ positions.

This order is specified as:
SE
$\begin{array}{llllllllll}4 & 5 & 9 & 10 & 1 & 2 & 3 & 6 & 7 & 8 /\end{array}$
Default
The list of names follows the SE command.

## Model Specification

## MO command

## Purpose

To specify the LISREL variables and the LISREL model to be fitted to the data.
The various options and keywords under the MO command are given below.

## NY keyword (Optional)

Purpose
To specify the Number of $\mathbf{Y}$-variables (indicators of endogenous latent (eta) variables and/or other endogenous manifest variables) of the model.

Syntax
$\mathrm{NY}=\mathrm{n}_{\mathrm{y}}$
where $\mathrm{n}_{\mathrm{y}}$ denotes the number of indicators of endogenous latent variables and other endogenous manifest variables.

## Example

For the model depicted in Figure1, there are four y-variables. This is specified as follows:
NY=4
Default
$\mathrm{NY}=0$

NX keyword (Optional)

## Purpose

To specify the Number of $\mathbf{X}$-variables (indicators of exogenous latent (ksi) variables and/or other exogenous manifest variables) of the model.

Syntax
$\mathrm{NX}=\mathrm{n}_{\mathrm{x}}$
where $\mathrm{n}_{\mathrm{x}}$ denotes the number of indicators of exogenous latent variables and exogenous manifest variables.

## Example

For the model depicted in Figure1, there are six x -variables. This is specified as follows:
NX=6
Default
$\mathrm{NX}=0$

## NE keyword (Optional)

## Purpose

To specify the Number of Eta-variables (endogenous latent variables) of the model.
Syntax
$\mathrm{NE}=\mathrm{n}_{\mathrm{e}}$
where $n_{e}$ denotes the number of endogenous latent variables of the model.

## Example

For the model depicted in Figure1, there are two eta-variables. This is specified as follows:
$\mathrm{NE}=2$
Default
$\mathrm{NE}=0$

NK keyword (Optional)
Purpose
To specify the Number of Ksi-variables (exogenous latent variables) of the model.
Syntax
$\mathrm{NK}=\mathrm{n}_{\mathrm{k}}$
where $n_{k}$ denotes the number of exogenous latent variables of the model.
Example
For the model depicted in Figure1, there are no ksi-variables. This is specified as follows:
NK=0
Default
NK=0

FI command (Optional)
Purpose
To FIx the parameter matrix elements in the list.

## LY keyword (optional)

## Purpose

To specify the format of the Lambda-Y matrix of the LISREL model. The elements of this matrix consist of the regression weights of the regression relationships between the Y and the Eta variables.

Syntax
$\mathrm{LY}=$ form, mode
where "form" is one of:

- DI (diagonal)
- FU (full)
- ID (identity)

A IZ (identity, zero)

- $\quad \mathrm{ZI}$ (zero, identity)
and "modes" is one of:
a $\quad \mathrm{FI}$ (fixed)
- $\quad \mathrm{FR}$ (free)
- PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)
a IN (invariant)
The last four modes are only used in multi-group analysis.


## Example

For the model depicted in Figure 1.2, the Lambda-Y matrix has the form FU and mode FI.
These are specified as:
LY=FU, FI
Default
LY=FU, FI

LX keyword (optional)
Purpose
To specify the format of the Lambda-X matrix of the LISREL model. The elements of this matrix consist of the regression weights of the regression relationships between the X and the Ksi-variables.

Syntax
$\mathrm{LX}=$ form, mode
where "form" is one of:

- DI (diagonal)
$\rightarrow \quad \mathrm{FU}$ (full)
a ID (identity)
- IZ (identity, zero)
- $\quad \mathrm{ZI}$ (zero, identity)
and "modes" is one of:
- $\quad$ FI (fixed)
- FR (free)
- $\quad$ PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)

A IN (invariant)
The last four modes are only used in multi-group analysis.

## Example

For the model depicted in Figure 1.2, there are no Ksi-variables therefore the LX does not appear at all.

## Default

LX=FU,FI

## BE keyword (Optional)

## Purpose

To specify the format of the BEta matrix of the LISREL model. The elements of this matrix consist of the regression weights of the regression relationships between the Eta variables.

Syntax
$\mathrm{BE}=$ form, mode
where "form" is one of:

- FU (full)
- $\quad$ SD (subdiagonal)
- ZE (zero)
and "mode" is one of:
- $\quad$ FI (fixed)
- $\quad \mathrm{FR}$ (free)
- $\quad$ PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)
a $\quad$ IN (invariant)
The last four modes are only used in multi-group analysis.


## Example

For the model depicted in Figure 1.2, the form of the BE is $F U$ and the mode FI. These are specified as:
BE=FU, FI
Default
BE=ZE, FI

## GA keyword (Optional)

## Purpose

To specify the format of the GAmma matrix of the LISREL model. The elements of this matrix consist of the regression weights of the regression relationships between the Ksi variables and the Eta variables.

Syntax
$\mathrm{BE}=$ form, mode
where "form" is one of:

- DI (diagonal)
- ID (identity)
- $\quad \mathrm{FU}$ (full)
- IZ (identity, zero)
and "mode" is one of:
- $\quad \mathrm{FI}$ (fixed)
- $\quad$ FR (free)
- $\quad$ PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)
a $\quad$ IN (invariant)
The last four modes are only used in multi-group analysis.


## Example

For the model depicted in Figure 1.2, the form of the GA is $F U$ and the mode FI. These are specified as:

GA=FU, FI

## Default

GA=FU, FR

PH keyword (Optional)

## Purpose

To specify the format of the PHi matrix of the LISREL model. The elements of this matrix consist of the covariances and the variances of the KSI-variables.

Syntax
$\mathrm{PH}=$ form, mode
where "form" is one of:

- $\quad$ DI (diagonal)
- ID (identity)
- $\quad$ SY (symmetric)
- $\quad$ ST (standardized symmetric)

The specification $\mathrm{PH}=\mathrm{ST}$ means that the diagonal elements are fixed at one and the offdiagonal elements are free. This specification cannot be overridden by fixing and/or freeing elements of PH on FI, FR, or PA commands. The specification $\mathrm{PH}=\mathrm{ST}$, FI or $\mathrm{PH}=\mathrm{ST}, \mathrm{FR}$ is not permitted and "mode" is one of:

- $\quad$ FI (fixed)
- $\quad \mathrm{FR}$ (free)
- $\quad$ PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)
- $\quad \mathrm{IN}$ (invariant)

The last four modes are only used in multi-group analysis.

## Example

For the model depicted in Figure 1.2, the form of the PH is $S Y$ and the mode $F R$. These are specified as:

PH=SY, FR

Default
PH=SY, FR

## PS keyword (Optional)

Purpose
To specify the format of the PSi matrix of the LISREL model. The elements of this matrix consist of the covariances and the variances of the residuals $(\zeta)$

Syntax
$\mathrm{PS}=$ form, mode
where "form" is one of:

- DI (diagonal)
- $\quad$ SY (symmetric)
- ZE (zero matrix)
and "mode" is one of:
- $\quad$ FI (fixed)
- $\quad$ FR (free)
- PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)

A IN (invariant)
The last four modes are only used in multi-group analysis.

## Example

For the model depicted in Figure 1.2, the form of the PS is $D I$ and the mode $F R$. These are specified as:

PS=DI, FR
Default
PS=DI, FR

## TE keyword (Optional)

## Purpose

To specify the format of the Theta-Epsilon matrix of the LISREL model. The elements of this matrix consist of the covariances and the variances of the error terms $(\varepsilon)$ associated with endogenous manifest variables.

Syntax
TE=form, mode
where "form" is one of:
a $\quad \mathrm{DI}$ (diagonal)

- $\quad$ SY (symmetric)
- ZE (zero matrix)
and "mode" is one of:
- $\quad \mathrm{FI}$ (fixed)
- FR (free)
- $\quad$ PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)
a $\quad$ IN (invariant)
The last four modes are only used in multi-group analysis.


## Example

For the model depicted in Figure 1.2, the form of the TE is $D I$ and the mode $F R$. These are specified as:

TE=DI, FR
Default
TE=DI, FR

TD keyword (Optional)

## Purpose

To specify the format of the Theta-Delta matrix of the LISREL model. The elements of this matrix consist of the covariances and the variances of the error terms $(\underset{-}{\delta})$ associated with the indicators of the exogenous latent variables.

Syntax
$\mathrm{TD}=$ form, mode
where "form" is one of:

- DI (diagonal)
- $\quad \mathrm{SY}$ (symmetric)
- ZE (zero matrix)
and "mode" is one of:
- $\quad \mathrm{FI}$ (fixed)
- $\quad \mathrm{FR}$ (free)
- PS (same pattern and starting values)
- $\quad$ SP (same pattern)
- $\quad$ SS (same starting values)
a IN (invariant)
The last four modes are only used in multi-group analysis.

LK command (Optional).
Purpose
To provide descriptive names for the Ksi variables. If no LK command appears, the default labels for the latent KSI variables (KSI 1, KSI 2, etc.) are used. The maximum length for each label is eight characters.

Syntax
LK
KSI 1 KSI $2 \ldots$ KSI k
where "KSI 1 KSI $2 \ldots$...KSI k" denotes the descriptive names for the Ksi variables.
Example
For the model depicted in Figure 1.2, there are no KSI variables and so the LK command does not appear.

## Purpose

To provide descriptive names for the Eta variables. If no LE command appears, the default labels for the latent ETA variables (ETA 1, ETA 2, etc.) are used. The maximum length for each label is eight characters.
Syntax
LE
ETA 1 ETA $2 \ldots$ ETA q
where "ETA 1 ETA $2 \ldots$ Eta q" denotes the descriptive names for the ETA variables.
Example
For the model depicted in Figure 1.2, the names of the ETA-variables in the model are REAMB and BFAMB. These are specified as:
LE
REAMB BFAMB

FR command (Optional).
Purpose
To free certain parameter matrix elements which are specified in the form: $\mathrm{LY}(\mathrm{i}, \mathrm{j}) \mathrm{BE}(\mathrm{i}, \mathrm{j})$ or LY i j , BE ij, where i and j are used to indicate the ith row and the jth column of the matrix respectively. Syntax
FR LY(i,j) BE(r,a)
where $(\mathrm{i}, \mathrm{j})$ and ( $\mathrm{r}, \mathrm{a}$ ) indicate the positions of the elements in the LY and BE matrices, respectively, to be freed.

## Example

For the model depicted in Figure1, the element in the $3^{\text {rd }}$ row and $1^{\text {st }}$ column of the LY matrix was freed, the element in the $2^{\text {nd }}$ row and $1^{\text {st }}$ column of the BE matrix was freed and the element in the $1^{\text {st }}$ row and $3^{\text {rd }}$ column of the GA matrix was freed. These free parameters are specified as follows:
$\operatorname{FR} \operatorname{LY}(3,1) \operatorname{BE}(2,1) \operatorname{GA}(1,3)$

## PD command

(Optional).

## Purpose

To generate a Path Diagram of the specified model.
The PD command should be given after the DA command and before the OU command.

Path Diagram may be used instead of PD.
Syntax
PD

## Output Results

OU command (Required Command).
Purpose
To specify the results to be printed by LISREL 8.30.
The options and keywords under this command are discussed below.

## IT keyword (Optional).

## Purpose

To specify the maximum number of ITerations allowed for the current problem.
Syntax
$\mathrm{IT}=\mathrm{n}_{\mathrm{t}}$
where $\mathrm{n}_{\mathrm{t}}$ denotes the maximum number of iterations allowed for the current problem.

## Example

For the model depicted in Figure1, the user may allow the maximum number of iterations of 250. This may be specified as:
$\mathrm{IT}=250$
Default
$\mathrm{IT}=$ five times the number of free parameters.

## ND keyword

Purpose
To specify the number of decimal places allowed for the current problem.
Syntax
ND=k
where k is an integer.

## Example

For the model depicted in Figure 1.2, the number of places allowed is 3 . This is specified as:
$\mathrm{ND}=3$
Default
$\mathrm{ND}=2$

## ME keyword

Purpose
To specify the Method of Estimation.
Syntax
ME= method
where "method" may be one of the following methods:
IV (Instrumental variables)
TS (Two-stage least squares)
UL (Unweighted least squares)
GL (Generalized least squares)
ML (Maximum likelihood)
WL (Generally weighted least squares)
DW (Diagonally weighted least squares)

## Default

ME=ML

## Options of printed Output (1)

Purpose
To select the printed output of LISREL.
Syntax
OU option 1 option $2 \ldots$ option k
where "option 1 to k " denotes some or all of the following options.
SS (print Standardized Solution)
SC (print Complete Standardized solution)
VA (print VAriances and covariances)
PC (Print Correlations of parameter estimates)
PT (Print Technical information)
FS (print Factor Scores regression)

EF (print total and indirect EFfects, their standard errors, and t-values)
RS (print Residuals, Standardized residuals, Q-plot, and fitted covariance (or correlation, or moment) matrix sigma)

ALL (Print everything)

For the model depicted in Figure1, the OU command may be specified as shown below.
OU ME=ML PC RS FS SS SC EF $I T=250 \mathrm{ND}=3$

## Options of printed Output (2)

## Purpose

To save various matrices in specified files at termination.
Syntax
OU matrix $_{1}=$ filename $_{1}$ matrix $_{2}=$ filename $_{2} \ldots$
where " matrix $_{i}$ " may be any of the following matrices:
LY, LX, BE, GA, PH, PS, TE, TD, TH, AL, KA, TX, TY, or
MA (The Matrix Analyzed after selection and/or reordering of variables).
SI (The fitted (moment, covariance, or correlation) matrix, $\hat{\sum}$ (SI for Sigma).
RM (The Regression Matrix of latent variables on observed variables).

EC (The Estimated asymptotic Covariance matrix of the LISREL parameter estimates).

GF (All the Goodness-of-Fit measures).
PV (Free Parameters Vector)
SV (Standard errors Vector).
TV (T-values Vector)
and "filename" are the names of the files containing the matrices and vectors specified above which will be the same as the input file name but with different extensions.

Using the above definitions and description, a LISREL Input File for the model depicted in Figure 1.2, may be obtained as shown below.

TI !DUNCAN, HALLER AND PORTES' APPLICATION
DA NI=10 NO=329 NG=1 MA=KM
LA
REINT REPAP RESOE REOAP REEAP BFINT BFPAP BFSOE BFOAP BFEAP KM FI=C:LLISREL83\PEPRAH\PEPDHP.COR
SE
45109123678 /
MO NX=6 NY=4 NE=2 LY=FU,FI BE=FU,FI GA=FU,FI PH=SY,FR PS=DI,FR TE=DI,FR TD=DI,FR
LE
REAMB BFAMB
FR LY( 3,2$) \mathrm{LY}(2,1) \mathrm{BE}(1,2) \mathrm{BE}(2,1) \mathrm{GA}(1,1) \mathrm{GA}(1,2) \mathrm{GA}(1,3) \mathrm{GA}(1,4) \mathrm{GA}(2,3)$
FR GA( 2,4 ) GA( 2,5 ) GA(2,6)
VA 1.00 LY(1,1) LY(4,2)
EQ BE $(1,2) \mathrm{BE}(2,1)$
PD
OU ME=ML PC RS FS SS SC IT=250 ND=3 LY=PEPDHP.lys BE=PEPDHP.bes GA=PEPDHP.gas

### 4.3 TYPING A SIMPLIS FILE USING SIMPLIS COMMAND LANGUAGE

The LISREL input file, given in Section 4.2.3 can also be specified by using the SIMPLIS command language. The SIMPLIS command language uses plain English input commands, so that no matrix notations have to be used. It requires the names of the observed and latent (if any) variables and a specification of the model to be estimated.

## GENERAL RULES FOR TYPING INPUT FILE USING SIMPLIS COMMAND LANGUAGE.

- A SIMPLIS file must contain ASCII characters only.
- The exclamation mark (!) or the slash-asterisks combination (/*) may be used to indicate that everything that follows on this line is to be regarded as comments.
- A SIMPLIS command line ends either with a RETURN and/or LINE FEED character or a semicolon (;). By using a semicolon to end a command line, several of these can
be put on the same physical line. Thus, for example, the physical line
Correlation Matrix from File PEPDHP.COR; Sample Size $=329$
consists of the two SIMPLIS command lines:
Correlation Matrix from File PEPDHP.COR
Sample Size $=329$
- A SIMPLIS file consists of a number of header lines, each followed by the type of information that the header indicates.
- Any number of problems may be stacked together and analyzed in one run.
- The first line for each problem may be a title line containing any information used as a heading for the problem. Title lines are optional but strongly recommended. Important note: Although title lines are optional in single-sample problems, at least one title line is necessary for each group except the first in multi-sample problems, and the first title line for each group must begin with the word

Group.

- After the title line, if any, a header line must follow with the either the words Observed Variables or the word Labels.
- The labels determine both the number of variables and the order of the variables. Each label may consist of any number of characters, but only the first eight characters will be retained and printed by the program.
- After the line with either the words Observed Variables or the word Labels, a space (space character) or a colon and a space and then a list of names (labels) of the observed variables in the data. The names can begin on the header line itself or on the next line or they can be read from a file. The same rule holds when listing the latent variables.
- The labels should be entered in free format. Spaces, commas, and return characters (carriage returns or line feeds) should be used as delimiters. Therefore, spaces and commas should not be used within a label unless the label is enclosed in single quotes. The same holds for - (dash or minus sign), which has a special meaning.
- Labels are case sensitive; upper case or lower case can be used without restriction but one must use the same name to refer to the same variable each time.
- It is recommended that each variable be given a unique name. However, if you do not want to name all the variables, the following options are available.

If there are 10 variables, say, the line
VAR1 - VAR10
will automatically name the variables VAR1, VAR2,. . ., VAR10. Even more simply, one can use the line

1-10
to label the variables $1,2, \ldots, 10$.
The general rule is that if two labels end with integers $m$ and $n$, with $m$ less than $n$, one can use a - (dash or minus sign) to name all variables that end with consecutive integers from m through n . Whatever appears before the integer m will also appear before all the other integers.

### 4.3.1 THE SYNTAX OF THE SIMPLIS FILE

A SIMPLIS file consists of a number of header lines, each followed by the type of information that the header indicates. All header lines and all information on them are presented in the following sections. This material is presented in the order it normally arises in the preparation of the SIMPLIS file.

## Title (Optional)

Purpose
To specify the title line containing any information used as a heading for the problem. The title line may be the first line for each problem.

Syntax
TITLE= "Title"
where "Title" denotes the title as specified by the user.

## Example

For the model depicted in Figure 1.2, the title may be given as:
The Duncan Haller and Portes' Application

## Observed Variables or Labels keyword:

## Purpose

To specify the Observed Variables or Labels of the model. In the SIMPLIS command language, the words Labels and Observed Variables are synonymous.

Syntax
Observed Variables
VAR 1 VAR $2 \ldots$
where "VAR 1 VAR 2..." denote the descriptive name of the observed variables of the model.
or $\quad$ Observed Variables from File $=$ filename
or $\quad$ Labels from File $=$ filename
where "filename" denotes the name of the external file containing "VAR 1 VAR $2 \ldots$.."
Example
For the model depicted in Figure 1.2, this section of the input file may be specified as:
Observed Variables
REINT REPAP RESOE REOAP REEAP BFINT BFPAP BFSOE BFOAP BFEAP

## Data

Purpose
To specify the data be fitted to the model.
Syntax
Data
where "data" is given in the SIMPLIS file as " Matrix From File Filename", "Matrix" denotes any of the following matrices:

Raw data matrix
Covariance matrix
Covariance matrix and means
Correlation matrix
Correlation matrix and standard deviations
Correlation matrix, standard deviations, and means
Asymptotic Covariance Matrix, and
"Filename" denotes the name of the external file in which the data to be to be fitted to the model is found.
Example
For the model depicted in Figure 1.2, the data to be analyzed is a correlation matrix and it is found in the file "PEPDHP.COR". This is specified as:
Correlation Matrix from File PEPDHP.COR

## Sample Size command

## Purpose

To specify the sample size (the number of cases) on which the covariance or correlation matrix is based.

Syntax

## Sample Size=n

or Sample Size $n$
or Sample Size: n
where " $n$ " is an integer value for the number of cases.
Example
For the model depicted in Figure 1.2, the sample size was 329. This may be specified as:
Sample Size 329
The sample size is needed to compute standard errors, t-values of parameter estimates, goodness-offit measures, and modification indices. If the sample size is not specified in the input file, the program will stop.

## Latent Variables or Unobserved Variables command

Purpose
To specify the descriptive names of the Latent Variables or Unobserved Variables of the model.
Syntax

## Latent Variables

VAR 1 VAR $2 \ldots$
where "VAR 1 VAR $2 \ldots$... here, denotes the descriptive names of the latent variables of the model.

## Example

For the model depicted in Figure 1.2, the latent variables section may be specified as:

## Latent Variables

Reamb Bfamb

## Relationships command (Optional)

## Purpose

To specify the relationships found in the model. This keyword is optional, i.e., relationships can be entered without this keyword.

Syntax
For each relationship, enter a list of variables of the form:
left-hand variable $=$ right-hand variables
where left-hand variable is a name of a dependent variable and right-hand variables is a list of all variables on which the left-hand variable depends. The variable names are separated by spaces or + signs. In a path diagram, a left-hand variable is a variable (observed or latent) such that one or more one-way (unidirected) arrows are pointing to it, and the right-hand variables are the variables where these arrows are coming from. As a mnemonic, we may also consider the relationship as

## TO variable $=\boldsymbol{F R O M}$ variables

## Example

The figure below is part of the model depicted in Figure 1.2.


Figure 4.1: Dependence paths between REAMB and REOAP and REEAP

These relationships are specified as follows:
REOAP REEAP = REAMB

## Paths

Purpose
To specify relationships in a model in terms of paths instead of relationships.
Syntax
FROM variables - > TO variables
where in the model there is a path from each variable in the "FROM variables" to all variables in the "TO variables".

## Example

The paths depicted in Figure 4.1 above may be specified in the path form as:
REAMB -> REOAP REEAP

## Equal Paths

## Purpose

To specify equal path coefficients. This means that the two coefficients will be treated as a single free parameter rather than as two independent parameters.

Syntax
Set the Path from VAR A to VAR B Equal to the Path from VAR C to VAR D or

The following shorter versions of this can also be used.
Set Path from VAR A to VAR B = Path from VAR C to VAR D
Set Path VAR A -> VAR B = Path VAR C -> VAR D
Set VAR A -> VAR B = VAR C $->$ VAR D
or
using "Let" lines instead of "Set" lines, this can also be expressed as:
Let the Path from VAR A to VAR B be Equal to the Path from VAR C to VAR D
Let Path from VAR A to VAR B = Path from VAR C to VAR D
Let Path VAR A -> VAR B = Path VAR C -> VAR D
Let VAR A -> VAR B = VAR C -> VAR D

## Example

For the model depicted in Figure 1.2, the coefficients of the path from Reamb to REOAP and from Bfamb to BFOAP are fixed to 1 . These are specified in SIMPLIS command language as:

Reamb->REOAP $=$ Bfamb $->$ BFOAP

## OUTPUT FILE

One can choose to obtain the estimated LISREL solution either in SIMPLIS output or in LISREL output. In SIMPLIS output, the estimated model is presented in equation form, while in LISREL output the model is presented in matrix form. Otherwise, the two output formats contain the same information. SIMPLIS output will be obtained by default if SIMPIS syntax file is used.

The keywords and options described below are used to request for the information required in the output file.

## ME keyword

 (Optional)
## Purpose

To specify the Method of Estimation to be used in the analysis.

Syntax
ME= method
where "method" denotes one of the following seven options:
IV (Instrumental Variables)
TSLS (Two-Stage Least Squares)
ULS (Unweighted Least Squares)
GLS (Generalized Least Squares)
ML (Maximum Likelihood)
WLS (Generally Weighted Least Squares)
DWLS (Diagonally Weighted Least Squares)
or put the corresponding option on the Options line as:

Options: ... UL ...
The dots (...) indicate that there may be other options or keywords on the Options line.

## Example

For the model depicted in Figure 1.2, the method of estimation is ML. This is specified as:
$\mathrm{ME}=\mathrm{ML}$
Default
$\mathrm{ME}=\mathrm{ML}$

## ND keyword (Optional)

Purpose
To specify the Number of Decimal places required in the output file.
Syntax
$\mathrm{ND}=\mathrm{n}$
where n is a positive integer.

## Example

For the model depicted in Figure 1.2, the number of decimal places was 3. This is specified as:
$\mathrm{ND}=3$
Default
$\mathrm{ND}=2$

## IT keyword

 (Optional)
## Purpose

To specify the maximum Number of Iterations allowed by the user. For models that are reasonable for the data to be analyzed, the iterations will converge before this maximum is reached.

Syntax
IT $=\mathrm{k}$
where " $k$ " denotes the maximum number of iterations allowed.
or
Options: ... IT=100 ...
where the dots (...) indicate that there may be other options or keywords on the Options line.

## Example

For the model depicted in Figure 1.2, the maximum number of iterations allowed is 250 . This is specified as:
$\mathrm{IT}=250$
Default
$\mathrm{IT}=20$

## Options keyword

Purpose
To specify the various options available to be printed in the output file. Each option can either be spelled out directly on a separate line or be put as a two-character keyword on an "Options line".

Syntax

## Options: options

where "options" denotes the keywords and options that are requested for to be printed in the output file.

## Example

For the model depicted in Figure 1.2, the "Options line" may be specified as:
Options: ME=ML ND=3 IT=250 $\ldots$
where the dots (...) indicate that there may be other options or keywords on the Options line.

The other options available under the "Options command or line" are:

This option requests a standardized solution, i.e., a solution in which the latent variables are standardized but not the observed. If the EF option is given also, the standardized effects for the SS solution will be given as well.

## SC (Print Completely Standardized Solution) (Optional)

This option requests a completely standardized solution, i.e., the solution in which both latent and observed variables are standardized. If the EF option is also specified, the standardized effects for the SC solution will be given as well.

EF (Print Total and indirect EFfects, their standard errors, and t-values). (Optional. Include the total and indirect effects in the output.

VA (Print VAriances and covariances) (Optional)
To print variances and covariances of the model.

MR (Equivalent to RS and VA)

FS (Print Factor Scores regression) (Optional)
Include the factor-scores regression in the output.

PC (Print Correlations of Parameter estimates) (Optional).
Both the covariance matrix and the correlation matrix of the parameter estimates are printed in the output file.

## PT (Print Technical information)

The above options and keywords could be put together to form the "Options line" below.

Output: SS SC EF SE VA MR FS PC PT ND=3 IT=250 ME=ML

## PD

(Optional)

## Purpose

To produce the Path Diagram, corresponding to the model that was fitted to the data, from the SIMPLIS syntax created.

Syntax
PD

End of Problem (Optional)

## Purpose

To indicate the end of the problem. This is optional but recommended, especially when several problems are stacked together in the same input file. In multi-sample problems one puts End of Problem after the last group, not after each group.

Syntax
End of Problem

### 4.3.1 SIMPLIS FILE FOR THE MODEL DEPICTED IN FIGURE 1.2

A complete SIMPLIS FILE FOR THE MODEL DEPICTED IN Figure 1.2 may be as shown below.

The Duncan Haller and Portes' Application
Observed Variables
REINT REPAP RESOE REOAP REEAP BFINT BFPAP BFSOE BFOAP BFEAP

Correlation Matrix From File PEPDHP.COR
Standard Deviations From File PEPDHP.STD
Sample Size $=329$

Latent Variables
REAMB BFAMB
Relationships
REOAP $=1 *$ REAMB
REEAP = REAMB
$\mathrm{BFEAP}=\mathrm{BFAMB}$
BFOAP $=1 *$ BFAMB
REAMB $=$ BFAMB REPAP REINT RESOE BFSOE
BFAMB = REAMB RESOE BFSOE BFINT BFPAP
Options: SS SC SE VA MR FS PC EF PT RS WP ME=ML ND=3 IT=250

## Path Diagram

End of Problem

### 4.4 ILLUSTRATIVE EXAMPLE

The model depicted in Figure 1.2 will now be used to illustrate the interactive use of LISREL8. 30 to create the LISREL input file and the path diagram of the model.

### 4.4.1 CREATING LISREL SYNTAX INTERACTIVELY FOR THE DUNCAN, HALLER AND PORTES' MODEL DEPICTED IN FIGURE 1.2

LISREL8.30 for Windows allows the user to create LISREL syntax interactively by making use of a set of menus and dialogs. The steps to be followed to create the input file listed in section 4.3.2 follow.

- Create an external data file in any text editor, such as Notepad, to obtain the data file "pepdhp.cor" shown below.

- Double click the LISREL8.30 icon
to open the window shown below.

- Click on the "File" menu to load the menu box below.

| 它 LISREL Windows Application |  |
| :---: | :---: |
| File View Help |  |
| New | Ctil + |
| Open... <br> Import Data in Free Format <br> Import External Data in Other Formats | Ctrlo |
| Print Setup... |  |
| 1 PEPRAHYSEEPDHP.LPJ 2 PEPRAAH $\ P E P D H P$.PTH 3 PEPRAH 1 PEPDHP.OUT 4A:IDHP.OUT |  |
| Exit |  |

- Click on the "New" option of the "File" menu to load the "New" dialog box shown below.

| New | 区 |
| :---: | :---: |
| New | OK |
| Syntax Only |  |
| PRELIS Data | Cancel |
| LISREL Project |  |

- Select the "LISREL Project" option to produce the dialog box shown below.

- Click on the "OK" push button to load the "File Save As" dialog box shown below.

- Type the file name "pepdhp.lpj" in the "File name" string field of the "File Save As" dialog box to produce the dialog box shown below.

- Click on the "OK" push button to open the window shown below.

- Click on the "Setup" menu to load the menu box below.

| Setup Model Qutput | Options |
| :---: | :---: |
| Iitle and Comments ... <br> Groups... <br> Variables. <br> Data... |  |
| Initialize | F2 |
| Build LISREL Syntax | F4 |
| Build SIMPLIS Syntax |  |

- Click on the "Title and Comments" option of the "Setup" menu to load the "Title and Comments" dialog box below.

- Type the title in the "Title" string field and comments, if any, in the "Comments" string field to produce the dialog box below.

- Click on the "Next" push button to load the "Group Names" dialog box below.

- Click on the "Next" push button to load the "Labels" dialog box below.

- Click on the "VAR1" in the "Observed Variables" string field.
- Press the "Insert" key on the keyboard to insert empty rows or the "Delete" key to delete selected rows.
The above actions produce the "Labels" dialog box shown below.

- Click on the "VAR1" in the "Observed Variables" string field and type "REINT", the descriptive name of the first manifest variable in the data matrix.
- Press the "Down" arrow on the keyboard to insert one row at a time once a label has been typed in the previous row.

The above actions produce the "Labels" dialog box shown below.


- Click on the "Name" push button under the "Latent Variables" in the "Labels" dialog box.
- Press the "Insert" key on the keyboard to insert empty rows or the "Delete" key to delete selected rows.
- Type the descriptive latent variable names in the same way as was done for the manifest variables.

The above actions produce the "Labels" dialog box shown below.


- Click on the "Next" push button to load the "Data" dialog box below.

- From the "Statistics from" menu field options, select "Correlations".
- From the "Matrix to be analyzed menu field options, select "Correlations"
- From the "File type" menu field options, select "LISREL System Data"
- In the "File name" string field, type in the path to the external file containing the data to be analyzed or click on the "Browse" push button to select the file from the correct directory.
- Type the number of observations in the "Number of observations" string field.

The above actions produce the dialog box below.


- Click on the "Next" push button to load the dialog box below.

- Click on the number next to REOAP (a Y- variable).

This action will cause row 4 to be highlighted in blue colour as shown in the "Define Observed Variables" dialog shown below.


- Click on the "Select as Y" push button to select REOAP as shown below.


When a variable, is selected as a Y-variable the variable is highlighted green in the original list of manifest variables.

- Repeat the above actions for the other three Y-variables to produce the dialog box below.

- $\quad$ Click on the number next to REINT (an X-variable).

This action will cause row 1 to be highlighted in blue as before.

- Click on the "Select as X" push button to select REINT as shown below.

- Repeat the above actions for the other five X-variables.

The above actions will produce the "Define Observed Variables" dialog box below.


- Click on the "Next" push button to load the "Define Latent Variables" dialog box below.

- Click on the number next to the latent variable "REAMB".
- Click on the "Select Eta" push button to select REAMB as an Eta-variable.

The above actions produce the "Define Latent Variables" dialog box below.


- Repeat the above steps for the latent variable BFAMB.

The above actions produce the "Define Latent Variables" dialog box below.


- Click on the "Next" push button to load the "Model Parameters" dialog box below.

- Select the "Lambda-Y Full Matrix Fixed" option in the "Model Summary" menu field of the "Model Parameters" dialog box.

The above action will produce the "Model Parameters" dialog box below.


- Click on the "Specify" push button to load the " Elements and Values for Lambda-Y" dialog box below.


In the model depicted in Figure 1.2, the regression weight of the relationship between REAMB and REOAP is fixed at 1 . This is specified as follows:

- Click on the row 1, and column 1 entry of the matrix highlighted in yellow.
- Type " 1 " in the entry.
- Click on the "Fix" push button.
- Repeat the three steps above for the element in row 4 and column 2.
- Click on the "OK" push button to load the "Elements and Values for Lambda-Y" dialog box below.


In the model depicted in Figure 1.2, the regression weight of the relationship between REAMB and REEAP is a free parameter to be estimated. This is specified as follows:

- Click on the row 2 and column 1 entry.
- Click on the "Free" push button.

These actions highlights the row 2 and column 1 entry in green colour, indicating that it is now a free parameter to be estimated in the analysis.

- Repeat the above steps for the row 3 and column 2 entry.
- Click on the "OK" push button to load the " Elements and Values for Lambda-Y" dialog box below.

- Click on the "OK" push button to reload the "Model Parameters" dialog box.
- Select the "Beta Full Matrix, Fixed" option from the "Model Type" menu field of the "Model Parameters" dialog box as shown below.

- Click on the "Specify" push button to load the "Elements and Values for Beta" dialog box below.


For the model depicted in Figure1.2, the regression weight for the relationship between BFAMB and REAMB is to be estimated. This free parameter is specified as follows:

- Click on the row 2 and column 1 entry.
- Click on the "Free" push button.

The above actions produce the "Elements and Values for Beta" dialog box below.


- Repeat the two steps above for the entry in row 1 and column 2.
- Click on the "OK" push button to load the "Elements and Values for Beta" dialog box below.

- Click on the "OK" push button to reload the "Model Parameters" dialog box.

The other parameter matrices can be specified in the a similar way as described for the Lambda-Y and the Beta matrices.

- Click on the "Next" push button after the last parameter matrix for the model has been specified to load the "Constraints" dialog box below.


In the Beta matrix, the elements $\mathrm{BE}(1,2)$ and $\mathrm{BE}(2,1)$ are constrained to be equal. This is specified as follows:

- Click on the "EQ" push button of the "Constraints" dialog box to produce the "Constraints" dialog box below.

- Select "Beta" in the "Parameter" list box to produce the dialog box below.

- Double click on the $\operatorname{BE}(1,2)$ and $\operatorname{BE}(2,1)$ in the "Free" list box, one at a time to produce the dialog box below.

- Click on the "Next" push button to load the "Selections" dialog box below.

- Check the required options of the "Selected Printout" check box.
- Change the "Number of Decimals in the Print Output to " 3 " to produce the dialog box below.

| Selections | 区 |
| :---: | :---: |
| Selected Printout |  |
| $\square$ Correlation Matrix of Parameter Estimators |  |
| Residuals,Standardized Residuals, Q-plot and Fitted Covariance | OK |
|  |  |
| $\square$ Total Effects and Indirect Effects | Cancel |
| Г Factor-scores Regression |  |
| $\checkmark$ Standardized Solution | Next |
| - Completely Standardized Solution |  |
| $\square$ Technical Output | Help |
| $\square$ Miscellaneous Results [see Sec 1.11] |  |
| $\square$ Excluding Modification Indices |  |
| $\square$ Print All |  |
| Number of Decimals [0-8) in the Printed Output 3 - |  |
|  |  |

- Click on the "Next" push button to load "Save matrices" dialog box below.

| Save matrices |  |  |  | 区 |
| :---: | :---: | :---: | :---: | :---: |
| Save ... | File Name: | Save ... | File Name: |  |
| $\Gamma$ Lambda-Y | DHP.lys | $\Gamma$ Matrix Analyzed | DHP.mas |  |
| ГLambda-X | DHP.lxs | ГAsym.Cov of Param.Est. | DHP.ecs |  |
| $\Gamma$ Beta | DHP.bes | $\square$ Regr.Matrix of Latent | DHP.rms |  |
| ГGamma | DHP.gas | Г Fitted Matrix | DHP.sis |  |
| $\square \mathbf{P h i}$ | DHP.phs | $\Gamma$ Goodness of Fit | DHP.gfs |  |
| $\square \mathbf{P s i}$ | DHP.pss | ГEst. Free Param. | DHP.pfs |  |
| $\square$ Theta-Epsilon | DHP.tes | ■Std. Errors | DHP.svs |  |
| $\Gamma$ Theta-Delta | DHP.tds | $\Gamma t$-Values | DHP.tys |  |
| $\square$ Theta-Delta-Epsilon | DHP.ths | $\square$ Write TeX Output | DHP.tex |  |
| ГTau-Y | DHP.tas | $\Gamma$ Write RTF Output | DHP.rtf |  |
| ГTau-X | DHP.tas |  |  |  |
| -Alpha | DHP.als | OK | Cancel |  |
| ГKappa | DHP.kas | Check All | Help |  |

- Check the desired check boxes to produce the dialog box below.

| Save matrices |  |  |  | 区 |
| :---: | :---: | :---: | :---: | :---: |
| Save ... | File Name: | Save ... | File Name: |  |
| ГLambda-Y | DHP.lys | $\lceil$ Matrix Analyzed | DHP.mas |  |
| ГLambda-X | DHP.lxs | ГAsym.Cov of Param.Est. | DHP.ecs |  |
| $\checkmark$ Beta | DHP.bes | ГRegr.Matrix of Latent | DHP.rms |  |
| V Gamma | DHP.gas | $\square$ Fitted Matrix | DHP.sis |  |
| V Phi | DHP.phs | $\lceil$ Goodness of Fit | DHP.gfs |  |
| $\lceil\mathbf{P s i}$ | DHP.pss | V Est. Free Param. | DHP.pfs |  |
| $\Gamma$ Theta-Epsilon | DHP.tes | $\bar{\square}$ Std. Errors | DHP.svs |  |
| $\Gamma$ Theta-Delta | DHP.tds | $\Gamma \mathrm{t}$-Values | DHP.tys |  |
| $\square$ Theta-Delta-Epsilon | DHP.ths | $\Gamma$ Write Te× Output | DHP.tex |  |
| ГTau-Y | DHP.tas | $\Gamma$ Write RTF Output | DHP.rtf |  |
| ГTau-X | DHP.tas |  |  |  |
| $\Gamma$ Alpha | DHP.als | OK | Cancel |  |
| ГKappa | DHP.kas | Check All | Help |  |

- Click on the "OK" push button to open the "LISREL Windows Application" window below.



### 4.4.2 CREATING SIMPLIS SYNTAX FILES INTERACTIVELY

LISREL 8.30 for Windows allows the user to create SIMPLIS syntax interactively by making use of a text window and keypad dialog box.
The following steps should be followed to open this window and keypad dialog box.

- Double click on the LISREL 8.30 icon
- Click on the "File" menu to load the file menu box.
- Click on the "New" option from the menu box to open a "New" dialog box.
- Select the "SIMPLIS Project" option from the "New" dialog box.
- Click on the "OK" push button to load the "File Save As" dialog box.
- Give the "SIMPLIS Project" a filename and save the file.
- Click on the "OK" push button to open the text window and dialog box shown below.


Clicking (left mouse button) on the appropriate symbol operates the keypad. Note that the <== symbol represents the backspace key while the symbol <--| denotes the enter key.
To enter the descriptive names of the variables of the model you have to do the following (See Section 4.4.1).

- Click on the "Setup" menu to load a "Setup" menu box.
- Click on the "Title and Comments" option of the "Setup" menu to load a "Title and Comments" dialog box.
- Type the title and comments in the "Title" string and "Comments" string fields respectively.
- Continue with similar steps as described in Section 4.4.1 to enter the descriptive names of the variables of the model to produce the window shown below.

- Click on the "Setup" menu again to reload the "Setup" menu box below.

- Click on the "Build SIMPLIS Syntax" option of the "Setup" menu to open the text window below.


The skeleton model in the text window would enable you to put the paths, covariances and variances at the correct section of the input file.

To specify a relationship, for example, between two variables "REAMB" and "REOAP", you may do the following:

- Click on "REOAP".
- Hold and drag it to the section of the input file in the text window headed "Relationships" and drop it.
- Put the cursor after the variable.
- Click on the " $=$ " push button.
- Click on "REAMB".
- Hold and drag it to the right hand side of the " $=$ " sign and drop it.
- Follow similar steps to those described above to specify the other relationships and the covariances or variances of the model.


### 4.4.3 CREATING LISREL/SIMPLIS SYNTAX USING PATH DIAGRAMS

A path diagram is a graphical representation of the relationships among variables in the LISREL model. If drawn and labeled correctly and in sufficient details, the diagram can specify exactly the fixed, constrained or free status of all parameters in the model.

## GENERAL RULES FOR DRAWING PATH DIAGRAMS

- $\quad$ The observed $x$ - and $y$ - variables are enclosed in boxes.
- The latent variables $\xi$ and $\eta$ are enclosed in circles or ellipses.
- The error variables $\varepsilon, \delta$, and $\zeta$ appear in the diagram but are not enclosed.
- A one-way arrow between two variables indicates a postulated direct influence of one variable on another. A two-way arrow between two variables indicates that these variables are correlated without any assumed direct relationship. One-way arrows are drawn straight, while two-way arrows are generally curved.
- There are a fundamental distinction between independent variables ( $\xi$-variables) and dependent variables ( $\eta$-variables). Variation and covariation in the dependent variables is
to be accounted for or explained by the independent variables. In a path diagram this corresponds to the statements,

1 no one-way arrow can point to a $\xi$-variable;
2 all one-way arrows pointing to an $\eta$-variable come from $\xi$ - and $\eta$-variables.

- All direct influences of one variable on another must be included in the path diagram. The non-existence of an arrow between two variables means that the two variables are assumed not to be directly related.


### 4.4.4 DRAWING A PATH DIAGRAM INTERACTIVELY IN LISREL 8.30 FOR WINDOWS FOR THE DUNCAN, HALLER AND PORTES' APPLICATION

LISREL 8.30 includes features, which allows a user to interactively draw a path diagram for a model to be analyzed. The step by step ways of doing this for the Duncan, Haller and Portes’ example is described in details below.

- Double click on the LISREL8.30 icon
to open the window with part shown below.

- Click on the "File" menu to load the menu box below.

- Click on the "New" option of the "File" menu to load the "New" dialog box shown below.

- Select the "Path Diagram" option to produce the dialog box shown below.

- Click on the "OK" push button to load the "File Save AS" dialog box shown below.

- Type the file name "pepdhp.pth" in the "File name" string field of the "File Save As" dialog box to produce the dialog box shown below.

- Click on the "OK" push button to open the windows shown below.

- Click on the "Setup" menu to load the menu box below.
Windows Application - PEP.
setup Draw View ! mage 0
IIte and Comments....
Groups...
Varibles.
Data...
BuildLSREL Syntax F4
BuildLSREL Syntax F4
BuildSIMPLIS Syntax F8
- Click on the "Title and Comments" option of the "Setup" menu to load the "Title and Comments" dialog box below.

- Type the title, "DUNCAN HALLER AND PORTES' APPLICATION", in the "Title" string field.
- Type comments, if any, in the "Comments" string filed to produce the "Title and Comments" dialog box below.

- Click on the "Next" push button to load the "Group Names" dialog box below.


Note: Proceed to the next screen if the analysis is for one group only. For multi-sample data, insert group name rows by using the Down Arrow key.

- Click on the "Next" push button to load the "Labels" dialog box below.

- Click on the "VAR 1" string in the "Observed Variables" string field.
- Press the "Insert" key on the keyboard to insert empty rows or the "Delete" key to delete selected rows.

The above actions produce the "Labels" dialog box shown below.


- Click on the "VAR 1" string in the "Observed Variables" string field again.
- Type, "REINT", the descriptive name of the first manifest variable in the data matrix in place of "VAR 1" to produce the dialog box below.

- Press the "Down" arrow on the keyboard to insert one row at a time once a label has been typed in the previous row.
The above actions produce the "Labels" dialog box shown below.

- Click on the "Name" push button under the "Latent Variables" string field in the "Labels" dialog box.
- Press the "Insert" key on the keyboard to insert empty rows or the "Delete" key to delete selected rows.
- Type the descriptive latent variable names in the same way as for the manifest variables.

The above actions produce the "Labels" dialog box shown below.

| Labels |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Observed Variables |  | Latent Variables |  |  |
|  | Name | Name |  |  |
| 1 | BEINT | 1 REAMB |  | < Previous |
| 2 | REPAP | 2 BFAMB |  |  |
| 3 | RESOE |  |  | Next > |
| 4 | REOAP |  |  |  |
| 5 | REEAP |  |  |  |
| 6 | BFINT |  |  | OK |
| 8 | BFSOE |  |  | Cancel |
|  | BFOAP |  |  |  |
|  | d/Read Variables | Add Latent V | ables |  |
| Move | Down Move Up | Move Down | Move Up |  |
| Press the Down Arrow to insert one row at a time once a label has been typed in the previous row <br> Press the Insert key to insert empty rows or the Delete key to delete selected rows |  |  |  |  |

- Click on the "Next" push button to load the "Data" dialog box below.

- In the "Statistics form" menu filed select "Correlations".
- In the "File Type" menu field select "LISREL System Data".
- In the "Filename" string field, type the filename or click on the Browse button to locate the required data file.
- Type the number of observations, " 329 ", in the "Number of observations" string field.
- In the "Matrix to be analysed " menu field select "Correlations".

The above actions produce the "Data" dialog box below.


- Click on the "OK" push button to open the "LISREL Windows Application" window.
- Click on the radio buttons next to the indicators of endogenous latent variables and other endogenous manifest variables (y-variables) and also the radio buttons next to the etavariables.

The above actions produce the window below.


- Right-click on "REOAP", hold it and drag it to the screen to produce the "LISREL Windows Application" window below.

- Repeat the above process for the other three $y$-variables to produce the window below.

- Repeat the dragging process for the eta-variables to produce the window below.

- Repeat the dragging process for the indicators of exogenous latent variables and exogenous manifest variables ( x -variables) to produce the window shown below.

- Click on the unidirectional arrow push button

- Click on "REAMB" ellipse and extend the arrow to "REOAP" square to produce the window shown below.

- Continue with the process of drawing the arrows until you have drawn all the required arrows as shown in the window below.


To run the project, you have to follow the same steps as described under Section 4.4.2.

If you did not specify the options and keywords under the OU (Output) command, they can be specified after the drawing of the path diagram. The way to do these are described below.

- Click on the "Output" menu to load the menu box below.

- Click on the "LISREL Output" option of the "Output" menu to load the dialog box below.

- Click on the "Estimations" option to load the "Estimations" dialog box shown below.

- Select the method of estimation by checking the radio button for the appropriate method.
- Click on the "OK" push button to reopen the graphics window below.

- Click on the "Output" menu to load the menu box below.

- Click on the "LISREL Output" option of the "Output" menu to load the dialog box below.


## CD.PTH



- Click on the "Selections" option to load the "Selections" dialog box shown below.

| Selections | 区 |
| :---: | :---: |
| Selected Printout <br> $\lceil$ Correlation Matrix of Parameter Estimators <br> $\lceil$ Residuals,Standardized Residuals, <br> Q-plot and Fitted Covariance <br> - Total Effects and Indirect Effects <br> - Factor-scores Regression <br> $\lceil$ Standardized Solution <br> $\lceil$ Completely Standardized Solution <br> $\Gamma$ Technical Butput <br> ■ Miscellaneous Results [see Sec 1-11] <br> - Excluding Modification Indices <br> Г Print All | OK <br> Cancel <br> Next <br> Help |
| Number of Decimals [0-8] in the Printed Dutput Invoke Path Diagram Г wide Print | $2 \quad=$ |

- Select the required options of the "Selected Printout" by checking the check box for the appropriate option.
- Click on the "OK" push button to reopen the graphics window below.


If the SIMPLIS output is required follow the following steps.

- Click on the "Output" menu to load the menu box below.

- Click on the "SIMPLIS Output" option of the "Output" menu to load the dialog box below.

- Select the required options and keywords and fill in the appropriate numbers in the string field.
- Click on the "OK" push button to accept the changes and to reopen the window with the path diagram as described above.

The steps below would enable you to build either the LISREL syntax or the SIMPLIS syntax from the path diagram drawn prior to running of the analysis.

To obtain the LISREL syntax do the following:

- Click on the "Setup" option to load the menu box below.


## Windows Application - PEPC <br> Setup Draw View Image @ <br> Iitle and Comments.. <br> Groups... <br> Variables.. <br> Data.. <br> Euild LISREL Syntax F4 <br> Build SIMPLIS Syntax F8

- Select the "Build LISREL Syntax" option of the "Setup" menu to open the window below.


To obtain the SIMPLIS syntax do the following:

- Click on the "Setup" option to load the menu box below.

```
Windows Application - PEPL
Setup Draw Yiew Image @
    Iitle and Comments.
    Groups..
    Variables.
    Data...
    Build LISREL Syntax F4
    Build SIMPLIS Syntax F8
```

- Select the "Build SIMPLS Syntax" option of the "Setup" menu to open the window below.



### 4.4.5 RUNNING LISREL 8.30

With the LISREL or SIMPLIS syntax file prepared as illustrated earlier, LISREL 8.30 can be run by clicking on the run push button shown below.


If there are no syntax errors in the input file the program will run and the message

will appear on the screen until the program terminates.
The Output will be saved in a file "filename.out", where "filename" denotes the name of the input file.

### 4.4.6 THE LISREL OUTPUT FILE

(1) (I) DATE: 11/22/2000
(II) TIME: 14:35
(2) (I) L I S REL 8.30

BY
(II) Karl G. Jöreskog \& Dag Sörbom
(3) This program is published exclusively by

Scientific Software International, Inc.
7383 N . Lincoln Avenue, Suite 100
Chicago, IL 60712-1704, U.S.A.
Phone: (800)247-6113, (847)675-0720, Fax: (847)675-2140
Copyright by Scientific Software International, Inc., 1981-99
Use of this program is subject to the terms specified in the
Universal Copyright Convention.
Website: www.ssicentral.com
(4) The following lines were read from file C:\LISREL83\KWAAPRAH\PEPDHP.LPJ:
(5) TI The Duncan Haller and Portes' Application

DA $N I=10$ NO=329 NG=1 MA=KM
LA
ReInt repap Resoe reoap reeap bfint bfpap bfsoe bfoap bfeap KM FI=C:\LISREL83\KWAAPRAH $\backslash$ PEPDHP.COR SY
SE
$45910123678 /$
MO NX=6 NY=4 NE=2 LY=FU,FI BE=FU,FI GA=FU,FI PH=SY,FR PS=DI,FR TE=DI,FR
LE
REAMB BFAMB
FR LY( 3,2 ) LY(1,1) $\operatorname{BE}(1,2) \quad \mathrm{BE}(2,1) \quad \mathrm{GA}(1,1) \quad \mathrm{GA}(1,2) \quad \mathrm{GA}(1,3) \quad \mathrm{GA}(1,6) \mathrm{GA}(2,3)$
FR GA $(2,4)$ GA $(2,5)$ GA $(2,6)$
VA 1.000 LY $(2,1)$ LY (4,2)
PD
OU ME=ML SL=0 PC RS FS SS SC SE VA MR PT ND=3 IT=250
(6) TI The Duncan Haller and Portes' Application
(7) (I) Number of Input Variables 10
(II) Number of Y - Variables 4 (III) Number of X - Variables 6
(IV) Number of ETA - Variables 2
(V) Number of KSI - Variables 6
(VI) Number of Observations 329

TI The Duncan Haller and Portes' Application
( 8 )

|  | REOAP | REEAP | BFOAP | BFEAP | REINT | REPAP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | 1.000 |  |  |  |  |  |
| REEAP | 0.625 | 1.000 |  |  |  |  |
| BFOAP | 0.422 | 0.328 | 1.000 |  |  |  |
| BFEAP | 0.327 | 0.367 | 0.640 | 1.000 |  |  |
| REINT | 0.411 | 0.404 | 0.260 | 0.290 | 1.000 |  |
| REPAP | 0.214 | 0.274 | 0.084 | 0.112 | 0.184 | 1.000 |
| RESOE | 0.324 | 0.405 | 0.279 | 0.305 | 0.222 | 0.049 |
| BFINT | 0.300 | 0.286 | 0.501 | 0.519 | 0.336 | 0.078 |
| BFPAP | 0.076 | 0.070 | 0.199 | 0.278 | 0.102 | 0.115 |
| BFSOE | 0.293 | 0.241 | 0.361 | 0.411 | 0.186 | 0.019 |


|  | RESOE | BFINT | BFPAP | BFSOE |
| :--- | ---: | :--- | :--- | :--- |
|  | ----- | ----- | ----- | ----- |
| RESOE | 1.000 |  |  |  |
| BFINT | 0.230 | 1.000 |  |  |
| BFPAP | 0.093 | 0.209 | 1.000 |  |
| BFSOE | 0.271 | 0.295 | 0.044 | 1.000 |

TI The Duncan Haller and Portes' Application
(9) (I) LAMBDA-Y

|  | REAMB | BFAMB |
| :--- | :---: | :---: |
| REOAP | ------- | ------ |
| REEAP | 1 | 0 |
| BFOAP | 0 | 0 |
| BFEAP | 0 | 2 |
|  | 0 | 0 |

(II) BETA

|  | REAMB | BFAMB |
| :---: | :---: | :---: |
|  | ------ | ----- |
| REAMB | 0 | 3 |
| BFAMB | 4 | 0 |


(IV) PHI

|  | REINT | REPAP | RESOE | BFINT | BFPAP | BFSOE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REINT | 13 |  |  |  |  |  |
| REPAP | 14 | 15 |  |  |  |  |
| RESOE | 16 | 17 | 18 |  |  |  |
| BFINT | 19 | 20 | 21 | 22 |  |  |
| BFPAP | 23 | 24 | 25 | 26 | 27 |  |
| BFSOE | 28 | 29 | 30 | 31 | 32 | 33 |

(V) PSI

Note: This matrix is diagonal. REAMB BFAMB

$34 \quad 35$
(VI) THETA-EPS

| REOAP | REEAP | BFOAP | BFEAP |
| :---: | :---: | :---: | :---: |
| 36 | 37 | 38 | 39 |

TI The Duncan Haller and Portes' Application
(10) Number of Iterations $=6$
(11) (I) LAMBDA-Y

|  | REAMB | BFAMB |
| :---: | :---: | :---: |
| REOAP | 0.943 |  |
|  | (0.080) |  |
|  | 11.817 |  |
| REEAP | 1.000 | - - |
| BFOAP | - - | 0.938 |
|  |  | (0.071) |
|  |  | 13.146 |
| BFEAP |  | 1.000 |

(II) BETA

|  | REAMB | BFAMB |
| :--- | :--- | :--- |
|  | ------- | ------- |
| REAMB | - | 0.172 |
|  |  | $(0.086)$ |
| BFAMB | 0.191 | 1.995 |
|  | $(0.081)$ | - |
|  | 2.365 |  |

(III) GAMMA

|  | REINT | REPAP | RESOE | BFINT | BFPAP | BFSOE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REAMB | $\begin{aligned} & 0.270 \\ & (0.044) \end{aligned}$ | $\begin{aligned} & 0.174 \\ & (0.041) \end{aligned}$ | $\begin{aligned} & 0.236 \\ & (0.046) \end{aligned}$ |  | - - | $\begin{aligned} & 0.084 \\ & (0.050) \end{aligned}$ |
|  | 6.104 | 4.274 | 5.182 |  |  | 1.678 |
| BFAMB |  |  | 0.075 | 0.362 | 0.139 | 0.215 |
|  |  |  | (0.047) | (0.043) | (0.038) | (0.043) |
|  |  |  | 1.604 | 8.400 | 3.619 | 5.067 |

## (12)

|  | REAMB | BFAMB | REINT | REPAP | RESOE | BFINT | BFPAP | BFSOE |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | ------ | ----- | ----- | ----- | ----- | ---- |  |  |
| REAMB | 0.661 |  |  |  |  |  |  |  |
| BFAMB | 0.376 | 0.681 |  |  |  |  |  |  |
| REINT | 0.417 | 0.272 | 1.000 |  |  |  |  |  |
| REPAP | 0.254 | 0.101 | 0.184 | 1.000 |  |  |  |  |
| RESOE | 0.379 | 0.302 | 0.222 | 0.049 | 1.000 |  |  |  |
| BFINT | 0.273 | 0.524 | 0.336 | 0.078 | 0.230 | 1.000 |  |  |
| BFPAP | 0.117 | 0.253 | 0.102 | 0.115 | 0.093 | 0.209 | 1.000 |  |
| BFSOE | 0.270 | 0.400 | 0.186 | 0.019 | 0.271 | 0.295 | 0.044 | 1.000 |

(13) PHI

|  | REINT | REPAP | RESOE | BFINT | BFPAP | BFSOE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REINT | $\begin{aligned} & 1.000 \\ & (0.078) \\ & 12.806 \end{aligned}$ |  |  |  |  |  |
| REPAP | $\begin{gathered} 0.184 \\ (0.056) \\ 3.276 \end{gathered}$ | $\begin{aligned} & 1.000 \\ & (0.078) \\ & 12.806 \end{aligned}$ |  |  |  |  |
| RESOE | $\begin{gathered} 0.222 \\ (0.057) \\ 3.925 \end{gathered}$ | $\begin{gathered} 0.049 \\ (0.055) \\ 0.886 \end{gathered}$ | $\begin{gathered} 1.000 \\ (0.078) \\ 12.806 \end{gathered}$ |  |  |  |
| BFINT | $\begin{gathered} 0.336 \\ (0.058) \\ 5.761 \end{gathered}$ | $\begin{gathered} 0.078 \\ (0.055) \\ 1.408 \end{gathered}$ | $\begin{gathered} 0.230 \\ (0.057) \\ 4.059 \end{gathered}$ | $\begin{aligned} & 1.000 \\ & (0.078) \\ & 12.806 \end{aligned}$ |  |  |
| BFPAP | $\begin{gathered} 0.102 \\ (0.056) \\ 1.840 \end{gathered}$ | $\begin{gathered} 0.115 \\ (0.056) \\ 2.069 \end{gathered}$ | $\begin{gathered} 0.093 \\ (0.055) \\ 1.677 \end{gathered}$ | $\begin{gathered} 0.209 \\ (0.056) \\ 3.705 \end{gathered}$ | $\begin{aligned} & 1.000 \\ & (0.078) \\ & 12.806 \end{aligned}$ |  |
| BFSOE | $\begin{gathered} 0.186 \\ (0.056) \\ 3.314 \end{gathered}$ | $\begin{gathered} 0.019 \\ (0.055) \\ 0.344 \end{gathered}$ | $\begin{gathered} 0.271 \\ (0.057) \\ 4.737 \end{gathered}$ | $\begin{gathered} 0.295 \\ (0.058) \\ 5.124 \end{gathered}$ | $\begin{gathered} 0.044 \\ (0.055) \\ 0.796 \end{gathered}$ | $\begin{gathered} 1.000 \\ (0.078) \\ 12.806 \end{gathered}$ |

(14) PS

$$
\begin{aligned}
& \text { Note: This matrix is diagonal. } \\
& \text { REAMB BFAMB } \\
& \text {------ ------- } \\
& 0.317 \quad 0.266 \\
& \text { (0.053) (0.045) } \\
& 6.009 \quad 5.868
\end{aligned}
$$

| (15) | REAMB | BFAMB |
| :---: | :---: | ---: |
|  | ----- | ----- |
|  | 0.475 | 0.563 |

(16) THETA-EPS

| REOAP | REEAP | BFOAP | BFEAP |
| :---: | :---: | :---: | :---: |
| ------- | ------ | ----- | ----- |
| 0.412 | 0.338 | 0.400 | 0.318 |
| $(0.051)$ | $(0.052)$ | $(0.046)$ | $(0.046)$ |
| 8.059 | 6.518 | 8.629 | 6.892 |


| (17) REOAP | REEAP | BFOAP | BFEAP |  |
| :---: | :---: | :---: | :---: | ---: |
| ------ | ----- | ----- | ----- |  |
|  | 0.588 | 0.662 | 0.599 | 0.681 |

(18) Goodness of Fit Statistics.
(I)
(a) Degrees of Freedom $=16$
(b) Minimum Fit Function Chi-Square $=26.833(\mathrm{P}=0.0434)$
(c) Normal Theory Weighted Least Squares Chi-Square $=26.197$ ( $\mathrm{P}=0.0513$ )
(d) Estimated Non-centrality Parameter (NCP) = 10.197
(e) 90 Percent Confidence Interval for $\mathrm{NCP}=(0.0$; 28.315)
(II)
(a) Minimum Fit Function Value $=0.0818$
(b) Population Discrepancy Function Value (FO) $=0.0311$
(c) 90 Percent Confidence Interval for $\mathrm{FO}=(0.0$; 0.0863 )
(d) Root Mean Square Error of Approximation (RMSEA) $=0.0441$
(e) 90 Percent Confidence Interval for RMSEA $=(0.0$; 0.0735)
(f) P-Value for Test of Close Fit (RMSEA $<0.05$ ) $=0.591$
(III)
(a) Expected Cross-Validation Index (ECVI) $=0.318$
(b) 90 Percent Confidence Interval for ECVI $=(0.287$; 0.373 )
(c) ECVI for Saturated Model $=0.335$
(d) ECVI for Independence Model $=2.691$
(IV)
(a) Chi-Square for Independence Model with 45 Degrees of Freedom $=862.637$
(b) Independence AIC $=882.637$
(c) Model AIC $=104.197$
(d) Saturated AIC $=110.000$

```
    (e) Independence CAIC = 930.597
    (f) Model CAIC = 291.243
(g) Saturated CAIC = 373.783
```


## (V)

```
(a) Normed Fit Index \((N F I)=0.969\)
(b) Non-Normed Fit Index (NNFI) \(=0.963\)
(c) Parsimony Normed Fit Index \((\) PNFI) \(=0.344\)
(d) Comparative Fit Index (CFI) \(=0.987\)
(e) Incremental Fit Index (IFI) \(=0.987\)
(f) Relative Fit Index \((\) RFI) \(=0.913\)
(VI) Critical \(\mathrm{N}(\mathrm{CN})=392.159\)
(VII)
(a) Root Mean Square Residual (RMR) \(=0.0207\)
(b) Standardized \(\mathrm{RMR}=0.0207\)
(c) Goodness of Fit Index (GFI) \(=0.984\)
(d) Adjusted Goodness of Fit Index (AGFI) \(=0.946\)
(e) Parsimony Goodness of Fit Index (PGFI) \(=0.351\)
```

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(19)

|  | REOAP | REEAP | BFOAP | BFEAP | REINT | REPAP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | 0.999 |  |  |  |  |  |
| REEAP | 0.624 | 0.999 |  |  |  |  |
| BFOAP | 0.332 | 0.352 | 0.999 |  |  |  |
| BFEAP | 0.354 | 0.376 | 0.639 | 0.999 |  |  |
| REINT | 0.393 | 0.417 | 0.255 | 0.272 | 1.000 |  |
| REPAP | 0.240 | 0.254 | 0.094 | 0.101 | 0.184 | 1.000 |
| RESOE | 0.357 | 0.379 | 0.283 | 0.302 | 0.222 | 0.049 |
| BFINT | 0.258 | 0.273 | 0.491 | 0.524 | 0.336 | 0.078 |
| BFPAP | 0.110 | 0.117 | 0.238 | 0.253 | 0.102 | 0.115 |
| BFSOE | 0.255 | 0.270 | 0.375 | 0.400 | 0.186 | 0.019 |


|  | RESOE | BFINT | BFPAP | BFSOE |
| :--- | :--- | :--- | :--- | :--- |
|  | ------ | ----- | ----- | ----- |
| RESOE | 1.000 |  |  |  |
| BFINT | 0.230 | 1.000 |  |  |
| BFPAP | 0.093 | 0.209 | 1.000 |  |
| BFSOE | 0.271 | 0.295 | 0.044 | 1.000 |


|  | REOAP | REEAP | BFOAP | BFEAP | REINT | REPAP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | 0.001 |  |  |  |  |  |
| REEAP | 0.001 | 0.001 |  |  |  |  |
| BFOAP | 0.090 | -0.024 | 0.001 |  |  |  |
| BFEAP | -0.027 | -0.009 | 0.001 | 0.001 |  |  |
| REINT | 0.017 | -0.013 | 0.005 | 0.018 | - - |  |
| REPAP | -0.026 | 0.020 | -0.010 | 0.011 | - - | - - |
| RESOE | -0.033 | 0.026 | -0.004 | 0.003 | - - | 0.000 |
| BFINT | 0.042 | 0.013 | 0.010 | -0.005 | - - | - - |
| BFPAP | -0.034 | -0.047 | -0.039 | 0.025 | 0.000 | 0.000 |
| BFSOE | 0.038 | -0.029 | -0.014 | 0.011 |  | 0.000 |
|  | RESOE | BFINT | BFPAP | BFSOE |  |  |
| RESOE | - - |  |  |  |  |  |
| BFINT |  | - - |  |  |  |  |
| BFPAP | 0.000 |  | - |  |  |  |
| BFSOE |  |  | 0.000 | - - |  |  |

## (II)

(a) Smallest Fitted Residual $=-0.047$
(b) Median Fitted Residual $=0.000$
(c) Largest Fitted Residual $=0.090$
(d) $-4 \mid 7$

- 2|9439764
- 0|430954000000000000000000000

0|11111135011378
$2 \mid 0568$
4|2

| 6 |  |
| :--- | :--- |
| $8 \mid 0$ |  |


| (21) (I) | REOAP | REEAP | BFOAP | BFEAP | REINT | REPAP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | 0.464 |  |  |  |  |  |
| REEAP | 0.464 | 0.464 |  |  |  |  |
| BFOAP | 3.196 | -0.951 | 0.464 |  |  |  |
| BFEAP | -1.092 | -0.397 | 0.464 | 0.464 |  |  |
| REINT | 0.916 | -0.882 | 0.132 | 0.561 | - - |  |
| REPAP | -1.054 | 1.057 | -0.256 | 0.298 | - - | - - |
| RESOE | -1.630 | 1.630 | -0.176 | 0.176 | - - | - - |
| BFINT | 1.351 | 0.443 | 0.639 | -0.409 | - - | - - |
| BFPAP | -0.799 | -1.141 | -1.567 | 1.333 |  | - - |
| BFSOE | 1.595 | -1.595 | -0.690 | 0.690 |  | - - |
|  | RESOE | BFINT | BFPAP | BFSOE |  |  |
| RESOE | - - |  |  |  |  |  |
| BFINT | - - | - |  |  |  |  |
| BFPAP |  |  |  |  |  |  |
| BFSOE | - - | - - | - - |  |  |  |

(II) (a) Smallest Standardized Residual $=-1.630$
(b) Median Standardized Residual $=0.000$
(c) Largest Standardized Residual $=3.196$
(d) $\quad-1 \mid 666$

- 1|1110
- 0|987
- 0|4432000000000000000000000
$0 \mid 1234$
0|5555556679
1|134
$1 \mid 66$

| 2 |  |
| :--- | :--- |
| 2 |  |
| 3 | 2 |

(e) Residual for BFOAP and REOAP 3.196
(22)
3.5. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .


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| (23) ETA |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | REOAP | REEAP | BFOAP | BFEAP RE |
| REAMB | 0.278 | 0.359 | 0.039 | 0.0520. |
| BFAMB | 0.038 | 0.049 | 0.260 | $0.349-0$. |
| ETA |  |  |  |  |
|  | RESOE | BFINT | BFPAP | BFSOE |
| REAMB | 0.086 | -0.009 | -0.003 | 0.026 |
| BFAMB | 0.029 | 0.147 | 0.056 | 0.087 |

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## (24)

(I) LAMBDA-Y

|  | REAMB | BFAMB |
| :--- | :---: | :---: |
|  | ------ | ----- |
| REOAP | 0.767 | -- |
| REEAP | 0.813 | -- |
| BFOAP | -- | 0.774 |
| BFEAP | -- | 0.825 |

## (II) BETA

|  | REAMB | BFAMB |
| :--- | :---: | :---: |
|  | ------ | ----- |
| REAMB | -- | 0.174 |
| BFAMB | 0.189 | -- |


| (III) GAMMA |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | REINT | REPAP | RESOE | BFINT | BFPAP | BFSOE |
|  | ------ | ----- | ----- | ----- | ----- | ------ |
| REAMB | 0.333 | 0.214 | 0.290 | -- | -- | 0.103 |
| BFAMB | -- | -- | 0.091 | 0.438 | 0.168 | 0.261 |

(IV)

|  | REAMB | BFAMB | REINT | REPAP | RESOE | BFINT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REAMB | 1.000 |  |  |  |  |  |
| BFAMB | 0.560 | 1.000 |  |  |  |  |
| REINT | 0.513 | 0.330 | 1.000 |  |  |  |
| REPAP | 0.312 | 0.122 | 0.184 | 1.000 |  |  |
| RESOE | 0.466 | 0.366 | 0.222 | 0.049 | 1.000 |  |
| BFINT | 0.336 | 0.635 | 0.336 | 0.078 | 0.230 | 1.000 |
| BFPAP | 0.144 | 0.307 | 0.102 | 0.115 | 0.093 | 0.209 |
| BFSOE | 0.333 | 0.485 | 0.186 | 0.019 | 0.271 | 0.295 |


|  | BFPAP | BFSOE |
| :--- | ---: | ---: |
|  | ----- | ---- |
| BFPAP | 1.000 |  |
| BFSOE | 0.044 | 1.000 |


(V)

```
PSI
    Note: This matrix is diagonal.
                REAMB BFAMB
                ------- ------
                0.479 0.391
```

(VI) THETA-EPS

| REOAP | REEAP | BFOAP | BFEAP |
| :--- | :--- | :--- | :--- |
| ------ | ------ | ------ | ------ |
| 0.412 | 0.338 | 0.401 | 0.319 |

(VII)

|  | REINT | REPAP | RESOE | BFINT | BFPAP | BFSOE |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | ------ | ------ | ----- | ------ | ------ | ---154 |
| REAMB | 0.344 | 0.221 | 0.316 | 0.079 | 0.030 | 0.154 |
| BFAMB | 0.065 | 0.042 | 0.150 | 0.453 | 0.174 | 0.290 |

(26) The Problem used 27712 Bytes ( $=0.0 \%$ of Available Workspace)
(27) Time used: 0.879 Seconds

## ENTRIES OF THE LISREL OUTPUT FILE

(1) (I) Date on which the analysis was performed.
(II) Time at which the analysis was performed.
(2) (I) Name and the version of the program.
(II) The authors of the program.
(3) The details of the company which handles the sales and distribution of LISREL 8.30.
(4) The complete path and filename of the file containing the data to be analyzed.
(5) Reproduction of the LISREL input file used for the analysis.
(6) Repeat of the Title Statement (This appears first on each new page).
(7) Row (I) The number of input variables.

Row (II) The number of endogenous manifest variables.
Row (III) The number of exogenous manifest variables.
Row (IV) The number of endogenous latent variables.

Row (V) The number of exogenous latent variables.
Row (VI) The number of observations or cases.
(8) (I) Correlation matrix to be analyzed.
(9) Parameter Specifications.
(I) Specifications of the order in which the elements of the Lambda-Y matrix are specified.
(II) Specifications of the order in which the elements of the Beta matrix are specified.
(III) Specifications of the order in which the elements of the Gamma matrix are specified.
(IV) Specifications of the order in which the elements of the Phi matrix are specified.
(V) Specifications of the order in which the elements of the Psi matrix are specified.
(VI) Specifications of the order in which the elements of the Theta-Eps matrix are specified.
(10) Number of iterations the program went through before reaching a local minimum.
(11) LISREL Estimates (Maximum Likelihood).
(I) The estimated values, standard error estimates and t-test statistic values for the unknown elements of the Lambda-Y matrix.
(II) The estimated values, standard error estimates and t-test statistic values for the unknown elements of the Beta matrix.
(III) The estimated values, standard error estimates and t-test statistic values for the unknown elements of the Gamma matrix.
(12) The estimated values of the Covariance Matrix between the ETA and KSI-variables.
(13) The estimated values, standard error estimates and t-test statistic values for the unknown elements of the PHI matrix.
(14) The estimated values, standard error estimates and t-test statistic values for the unknown elements of the PSI matrix.
(15) The Squared Multiple Correlations for the Structural Equations.
(16) The estimated values, standard error estimates and t-test statistic values for the unknown elements of the THETA-EPS matrix.
(17) The Squared Multiple Correlations for the Y-Variables. The squared multiple correlation for the i-th Y-variable is given by:

$$
1-\frac{\vec{\theta}_{i i}}{\theta_{i i}}
$$

where $\vec{\theta}_{i i}$ is the estimated error variance and $\vec{\sigma}_{i i}$ is the estimated total variance of the i-th Y-variable.
(18) Goodness of Fit Statistics.
(I) (a) Degrees of Freedom, $d$, is given by:
$d=\frac{1}{2} k(k+1)-t$
where $k$ being the number of observed variables analyzed and $t$ the number of free parameters.
(b) Minimum Fit Function Chi-square value, is obtained from

$$
c=n F\left[\mathbf{S}, \sum\binom{\hat{\theta}}{-}\right]
$$

which is approximately distributed as $\chi^{2}$ with d degrees of freedom, where $\mathrm{n}=\mathrm{N}-1, \mathrm{~F}$ is the fit function, $\mathbf{S}$ is the sample covariance matrix, $\sum(\underset{-}{\theta})$ the population covariance matrix and $\theta$ is the vector of the $t$ parameters in the statistical model.
(c) Normal Theory Weighted Least Squares Chi-Square test statistic value, given by

$$
\chi_{W L S}^{2}=(N-1) F_{W L S}
$$

where $F_{W L S}$ is the minimum value for $F_{W L S}$ with

$$
\begin{aligned}
F_{W L S} & =(S-\sigma)^{\prime} W^{-1}(S-\sigma) \\
& =\sum_{g=1}^{k} \sum_{h=1}^{g} \sum_{i=1}^{k} \sum_{j=1}^{i} W^{g h^{\prime} i j}\left(S_{g h}-\sigma_{g h}\right)\left(S_{i j}-\sigma_{i j}\right)
\end{aligned}
$$

where $\underset{-}{S^{\prime}}=\left(s_{11}, s_{21}, s_{22}, s_{31}, \ldots, s_{k k}\right)$ is a vector of the elements in the lower half including the diagonal, of the covariance matrix $\mathbf{S}$,
$\sigma_{-}^{\prime}=\left(\sigma_{11}, \sigma_{21}, \sigma_{22}, \sigma_{31}, \ldots, \sigma_{k k}\right)$
is the vector of corresponding elements of $\sum(\underset{-}{\theta})$ reproduced from the model parameter vector $\theta$ and
$W^{g h, i j}$ is a typical element of the positive definite matrix $W^{-1} . \mathrm{W}$ is a consistent estimate of the asymptotic covariance matrix of the sample variances and covariances.
(d) Estimated Non-centrality Parameter (NCP), is given by (Browne and Cudeck, 1993):

$$
\mathrm{NCP}=\bar{A}=\max (c-d, 0)
$$

(e) $90 \%$ confidence interval for the NCP is obtained by solving for $\bar{\lambda}_{L}$ and $\bar{\lambda}_{U}$ from the equations below:

$$
G\left(c \backslash \lambda_{L}, d\right)=0.95 \quad \text { and } \quad G\left(c \backslash \lambda_{U}, d\right)=0.05
$$

where $G(x \backslash \lambda, d)$ is the distribution function of the non-central chi-square distribution with non-centrality parameter $\lambda$ and $d$ degrees of freedom.
(II)
(a) The Minimal Discrepancy Function Value This is the minimal value of the discrepancy function $\mathrm{F}\left(\mathbf{S}, \sum_{\underline{-}}(\boldsymbol{\theta})\right.$ ),
where $\mathbf{S}$ is the sample covariance matrix, $\theta$ contains the unknown parameters of the
 covariance matrix $\sum$.
(b) The Estimated Population Discrepancy Function Value, $F_{O}$, is given by (McDonald, 1989; Browne and Cudeck, 1993):

$$
F_{o}=\operatorname{Max}\{P-(d / n), 0\}
$$

where $F$ is the minimum value of the fit function.
(c) The $90 \%$ confidence interval for $F_{o}$ is calculated as:

$$
\left(\frac{\bar{\lambda}_{L}}{n} ; \frac{\bar{\lambda}_{U}}{n}\right) .
$$

(d) The Root Mean Square Error of Approximation (RMSEA) value. It is obtained by (Browne \& Cudeck, 1993):

$$
\varepsilon=\sqrt{\frac{\bar{F}_{O}}{d}}
$$

(e) The $90 \%$ confidence interval for the RMSEA value is calculated as:

$$
\left(\sqrt{\frac{\bar{\lambda}_{K L}}{n d}} ; \sqrt{\frac{\boldsymbol{\lambda}_{U}}{n d}}\right)
$$

(f) The p-value for a lower tail test for close fit is calculated as (Browne \& Cudeck, 1993):

$$
p=1-G(c \backslash 0.0025 n d, d)
$$

(III)
(a) The Expected Cross Validation Index (ECVI) is given as (Browne \& Cudeck, 1989):

$$
\mathrm{ECVI}=\frac{c}{n}+2\left(\frac{t}{n}\right)
$$

(b) The $90 \%$ confidence interval for the ECVI is computed a:

$$
\left(\frac{\mathcal{Z}_{L}+s+t}{n} ; \frac{\bar{Z}_{U}+s+t}{n}\right)
$$

(c) The ECVI value for Saturated Model. This is when the ECVI value is calculated with no structure imposed on $\sum$.
(d) The ECVI value for the Independence Model.
(IV)
(a) The Independence model chi-square is given by

Independence model $\chi^{2}=\mathrm{N} F_{I}$.
where $F_{I}$ denotes the minimal discrepancy function value for the independence model and N denotes the number of cases.
(b) The Independent Akaike's Information Criterion (AIC) is given by

Independence AIC $=$ Independence model $\chi^{2}-2 d_{I}$
where $d_{I}$ denotes the degrees of freedom of the independence model.
(c) The model Akaike's Information Criterion (AIC) is given by (Akaike, 1974, 1987):

Model AIC $=\mathrm{c}-2 \mathrm{t}$
(d) The Saturated AIC is given by

Saturated AIC $=k(k+1)$
(e) The Independence Cross-validated Akaike's Information Criterion (CAIC) is given by (Bozdogan,1987):

Independence CAIC $=$ Independence model $\chi^{2}-(\operatorname{In} N+1) \mathrm{d}_{\mathrm{i}}$
(f) The model Cross-validated Akaike Information Criterion (CAIC) is given by (Bozdogan, 1987):

$$
\text { Model CAIC }=\mathrm{c}+(1+\operatorname{In} N) t
$$

(g) The Saturated CAIC is given by

$$
\text { Saturated CAIC }=(\operatorname{lnN}+1)[k(k+1)]
$$

(V)
(a) The Bentler-Bonett Normed Fit Index is computed from (Bentler and Bonett, 1980):

$$
\mathrm{NFI}=1-\frac{\vec{F}}{\stackrel{F}{F_{I}}}
$$

(b) The Non-Normed Fit Index (NNFI) is computed as (Bentler \& Bonett, 1980):

$$
\mathrm{NNFI}=\frac{\overrightarrow{f_{I}}-\vec{f}}{\overrightarrow{f_{I}}-1}
$$

where $\nexists=\frac{n \vec{F}}{d}$, and $\nexists_{I}=\frac{n \vec{F}}{d_{I}}$
(c) The Parsimony Fit Index (PNFI) is computed as (James, Mulaik, and Brett, 1982):

$$
\mathrm{PNFI}=\left(\frac{d}{d_{i}}\right)\left(1-\frac{\vec{F}}{F_{i}}\right)
$$

where $d$ the degrees of freedom for the estimated model.
(d) The Comparative Fit Index (CFI) is computed as (Bentler, 1990):

$$
\mathrm{CFI}=1-\frac{\bar{\theta}}{\bar{\theta}_{I}}
$$

where $\vec{\exists}=\max (n \vec{F}-d, 0)$ and $\vec{Z}_{I}=\max \left(n F_{I}-d_{I}, n \vec{F}-d, 0\right)$
(e) The Incremental Fit Index (IFI) is computed as (Bollen, 1986, 1989a,b):

$$
\mathrm{IFI}=\frac{n \vec{P}_{I}-n P}{n \vec{F}_{I}-d}
$$

(f) The Relative Fit Index (RFI) is computed as (Bollen, 1986, 1989a,b):

$$
\mathrm{RFI}=\frac{\bar{f}_{I}^{\prime}-\vec{f}}{f_{I}}
$$

(VI) The Critical $\mathrm{N}(\mathrm{CN})$ value is computed as (Hoelter, 1983):

$$
\mathrm{CN}=\frac{\chi_{1-\alpha}^{2}}{\vec{F}}+1
$$

where $\chi_{1-\alpha}^{2}$ is the $100(1-\alpha)$ th percentile of the chi-square distribution with d degrees of freedom.
(VII)
(a) The Root Mean Square Residual(RMR) is computed from (Bentler, 1995)

$$
\mathrm{RMR}=\sqrt{\frac{2}{k(k+1)} \sum_{i=1}^{p} \sum_{j=1}^{i}\left(\left[\mathbf{S}_{i j}-\mathbf{g}_{i j}(\hat{\theta})\right]_{-}^{2}\right)}
$$

(b) The Standardized Root Mean Squared Residual(SRMR) is computed as (Bentler, 1995)

$$
\mathrm{SRMR}=\sqrt{\frac{2}{k(k+1)} \sum_{i=1}^{p} \sum_{j=1}^{i}\left(\left[s_{i j}-g_{i j}(\hat{\theta}) / \sqrt{s_{i i} s_{j j}}\right]^{2}\right)}
$$

(c) The Goodness of Fit Index (GFI) is computed as (Jöreskog and Sörbom, 1989):

$$
\mathrm{GFI}=1-\frac{F\left[\mathbf{S}, \sum(\vec{\theta})\right]}{F\left[\mathbf{S}, \sum(\mathbf{0})\right]}
$$

(d) The Adjusted Goodness of Fit Index (AGFI) is given by (Jöreskog and Sörbom, 1989): $\quad \mathrm{AGFI}=1-\frac{k(k+1)}{2 d}(1-\mathrm{GFI})$
(e) The Parsimony Normed Fit Index (PGFI) is computed as (Mulaik, et al; 1989):

$$
\mathrm{PGFI}=\frac{2 d}{k}(k+1) \mathrm{GFI}
$$

(19) The fitted Covariance Matrix. This is the covariance matrix calculated from the model by using the final parameters estimated as the parameter values of the model.
(20)
(I) The fitted residuals. This is the matrix of the difference between the sample covariance matrix (the sample moment matrix) and the fitted covariance matrix.
(II) The summary statistics for the fitted residuals.
(a) Smallest Fitted Residual.
(b) Median Fitted Residual.
(c) Largest Fitted Residual.
(d) The steam-and-leaf plot of the fitted residuals.
(I) Standardized Residuals. These are fitted residuals divided by the largest sample standard error of the residuals.
(II) Summary statistics for standardized residuals.
(a) Smallest standardized residual.
(b) Medium standardized residual.
(c) Largest standardized residual.
(d) The stem-and-leaf plot of the standardized residuals.
(e) The largest positive standardized residuals.
(22) Q-plot of standardized residuals.
(23) Factor Scores Regressions.

These are estimates of the measurement strengths of the manifest variables as measurements of the two latent variables.
(24) Standardized solution. The parameters are estimated with the condition that the latent variables are scaled to have standard deviations equal to unity.
(I) The standardized estimates of the elements of the Lambda-Y matrix.
(II) The standardized estimates of the elements of the Beta matrix.
(III) The standardized estimates of the elements of the Gamma matrix.
(IV) Correlation matrix of exogenous manifest variables.
(V) The estimates of the elements of the Psi.
(VI) Regression matrix Eta on X (standardized).
(25) Complete standardized solutions. The parameters are estimated with the condition that the observed as well as the latent variables are standardized.
(I) The completely standardized estimates of the elements of the Lambda-Y matrix.
(II) The completely standardized estimates of the elements of the Beta matrix.
(III) The completely standardized estimates of the elements of the Gamma matrix.
(IV) Correlation matrix of Eta and Ksi variables.
(V) The completely standardized estimates of the elements of the Psi matrix.
(VI) The completely standardized estimates of the elements of the theta Eps matrix.
(VII) Regression matrix of eta on X (standardized)
(26) The disk space taken by the entire problem.
(27) Time, in seconds, used by the program to perform the analysis.

# CHAPTER 5 <br> $\mathbf{M x}$ 

### 5.1 HISTORICAL BACKGROUND

The acronym Mx stands for MatriX algebra interpreter. Michael C. Neal developed the first version of Mx in 1991. The development of Mx was greatly influenced by LISREL (Jöreskog \& Sörbom 1981-1999). The first version was improved upon in 1994. Mx is a combination of a matrix algebra interpreter and a numerical optimizer. It enables exploration of matrix algebra through a variety of operations and functions. There are many built-in functions to enable Structural Equation Modeling and other types of statistical modeling of data. It offers the fitting functions found in commercial software such as LISREL, LISCOMP, EQS, SEPATH, AMOS and CALIS, including facilities for maximum likelihood estimation of parameters from missing data structure, under normal theory. Complex 'nonstandard' models are easy to specify. For further general applicability, it allows the users to define their own fit functions, and optimization may be performed subject to linear and nonlinear equality or boundary constraints.

There have been other improvements upon the 1994 version. The latest version was released in 1999. The 1999 version has many additional new features. One of the new features is the path diagram drawing software, RAMPATH. This new feature allows the user to generate the Mx script by simply drawing the path diagram of the model to be fitted to the data. This has made Mx userfriendlier, especially, to those who find it difficult to write the Mx script in the matrix language.

Mx is available free of charge from the internet at http://griffin.vcu.edu/mx/. With a suitable browser, you can obtain the program, documentation and examples, send comments, see the latest version available for your platform, and so on.

### 5.2 THE Mx INPUT SCRIPT FILE

There are two ways of fitting a structural model to data with Mx. These are:

1) To prepare an Mx Input Script File by using the appropriate Mx commands. The Mx Input Script File is a text file and can be prepared with any text editor of one's choice and should have the extension ".mx".
2) To use the path diagram drawing software, RAMPATH to draw the path diagram of the model to be fitted to the data. The path diagram can be saved as a graphics file with extension ".mxd". An Mx Input Script file may then be generated from the graphics file.

## GENERAL RULES FOR PREPARING Mx INPUT SCRIPT FILES.

- At the beginning of an Mx script, you have to specify how many groups there are with a \#Ngroup statement.
- Input files should be prepared with the text editor of your choice. If you use a word processor (such as Word Perfect or MS Word) the input file should be saved in DOS text (ASCII) format.
- The Title line is required.
- The Matrices line is required and starts the declaration of matrices that will be used in the covariance statement.
- The keyword Specify is used to put free parameters into matrices. All the usable elements of the matrix are listed (i.e. only the lower triangle for symmetric matrices, or only the diagonal elements for diagonal matrices)
- A zero indicates that the element of the matrix is fixed, and a positive integer indicates that it is free. Different positive integers represent different free parameters, i.e. if we wish to have parameter 1 and 2 set equal, we would replace the 2 with a 1 .
- The fixed values of 1 for the variances of the latent variables are given with a Value statement.
- Start 0.5 all sets all the free parameters to 0.5 as an initial guess of the parameter estimates.
- You may put comments anywhere in your input file by using the character "!" to preceed the comment.
- Lines in Mx script may be up to 1200 characters long on most systems. The Mx command processor ignores anything after column 1200.
- Mx ignores blank lines.
- The processor is also entirely insensitive to case, except for filenames under UNIX.
- Unless explicitly stated otherwise, the first two letters of a keyword used in Mx script are sufficient to identify it. Keywords are separated by one or more blank spaces. Once the program has identify a keyword you can extend it to anything you like as long as it does not have a blank character in it, so Data and Data_for_all have the same effect.
- Quite often, a keyword has the format $K E Y=n$ where $n$ is a numeric value to be input. This is called a parameter. Mx ignores all (including blanks) non-numeric characters found between recognition of a parameter and reading a number, so that " $N I=100$ " and "Ninput_vars are equal to $100^{\prime \prime}$ have the same effect.

The exception to this rule is when it encounters a \#define'd variable, which it will accept instead of a number.

- The syntax described for commands follows these conventions:
* alternatives are represented by /
* optional parameters or keywords are enclosed by \{and \}
* items to be substituted according to the specific application are enclosed by <and>


### 5.2.1 PREPARING AN Mx INPUT SCRIPT FILE

An Mx input script file consists of three sections, namely: Specify the Data, Specify the Model and Specify Options.

Details of each part are discussed below. The paragraphs, which may be omitted without causing any problems, are indicated as (Optional).

## (a) SPECIFY THE DATA

The following information are provided under this section.
(i) \#NGroup Sentence

## Purpose

To specify the Number of $\mathbf{G r o u p}(\mathbf{s})$ there are in the Mx input script file. In a multigroup job, the number for that group must be indicated first before any information is provided for the group.

Syntax
\#Ngroup $k$
where $k$ is an integer.

## Example

For the model depicted in Figure 1.2, there is only one group in the script file. This is specified as follows:
\#Ngroup 1

## (ii) Title Sentence (Optional)

## Purpose

To provide a description for the analysis to be performed.
Syntax
TITLE: "Title"
where "Title" denotes the title as specified by the user.

## Example

For the model depicted in Figure 1.2, we may have a title paragraph as follows:
Title The Duncan Haller and Portes' Application

## (iii) Data Sentence

## Purpose

To provide the following information: Number of observations, Number of input variables and the number of group(s) (if the number of groups is not specified already).

Syntax
Data NObservations=n NInput_variables $=p$ Ngroup $=k$
where $\mathrm{n}, \mathrm{p}$ and $k$ are integers indicating the number of observations, observed variables and groups respectively.

## Example

For the model depicted in Figure 1.2, we may have a data paragraph as follows:
Data NObservation =329 NInput_variables=10 Ngroup=1

## (iv) Matrix Sentence

Purpose
To provide the data matrix to be analyzed.

## Syntax

## Matrix Type

[Matrix]
where "Matrix Type may be any of the following:
CMatrix Covariance Matrix
KMatrix Polyserial Correlation Matrix
PMatrix Polychoric correlation Matrix
RE REctangular matrix of balance raw data using "." (dots) as missing values.

VL Rectangular matrix of unbalanced raw data with Variable Length.
and [Matrix] is the array of the elements of the matrix to be analyzed if the matrix to be anlayzed is submitted as part of the input file.

Or
Matrix File=filename
where "filename" is the filename of an external file containing the data matrix.

## Example

The data used in the model depicted in Figure 1.2 is a correlation matrix. This is included in the input script file as:
KMatrix
1.000
0.6251 .000
0.3270 .3671 .000
$0.4220 .327 \quad 0.640 \quad 1.000$
0.2140 .2740 .1120 .0841 .000
$\begin{array}{llllllll}0.411 & 0.404 & 0.290 & 0.260 & 0.184 & 1.000\end{array}$
$\begin{array}{lllllll}0.324 & 0.405 & 0.305 & 0.279 & 0.049 & 0.222 & 1.000\end{array}$
$\begin{array}{lllllllll}0.293 & 0.241 & 0.411 & 0.361 & 0.019 & 0.186 & 0.271 & 1.000\end{array}$
$\begin{array}{llllllllllll}0.300 & 0.286 & 0.519 & 0.501 & 0.078 & 0.336 & 0.230 & 0.295 & 1.000\end{array}$


## (b) SPECIFY THE MODEL

The following information is provided under this section.

## (i) Begin Matrices Paragraph

## Purpose

To specify the name and order of the matrices to be used.

## Syntax

## Begin Matrices;

```
<Matrix name 1> <Type 1> <r 1> <c 1>
```

<Matrix name 2> <Type 2> <r 2> <c 2>
<Matrix name 3> <Type 3> <r 3> <c 3>
<Matrix name 4> <Type 4> <r 4> <c 4>
End Matrices;
where " $<$ Matrix name $\mathrm{i}>$ " is any of the following:
S matrix for the Symmetric paths, or double-headed arrows.
A matrix for Asymmetric paths, or single-headed arrows.
F matrix for Filtering the observed variables out of the whole set.
I Identity matrix.
"<Type i>" is either Symmetric (Symm) or Full. If the matrix type is "Symmetric"
only the lower triangle entries are provided. If the matrix type is "Full" all the entries are to provided.
" $\langle\mathrm{r} \mathrm{i}\rangle$ " denotes the number of rows in the matrix and
"<c $\mathrm{i}>$ " denotes the number of columns in the matrix.

## Example

For the model depicted in Figure 1.2, the RAM model specification requires four matrices which are specified as follows:

Begin Matrices;
S Symm 1818
A Full $18 \quad 18$
F Full 1018
I Iden 1818
End Matrices;

## (ii) Matrix S Paragraph <br> Purpose

To provide the entries of the Symmetric paths of the model.

Syntax

## Matrix S

$<c, r>$
where $c$ indicates the position of the observed variable in the column from which the arrow starts and $r$ indicates the position of the observed variable in the row at which the arrow ends.

## Example

For the model depicted in Figure 1.2, the two manifest variables "REINT" and "RESOE" are connected by a double-headed arrow as shown Figure 5.1 below.


Figure 5.1 Covariance path between REINT and RESOE.

In the list of variables "REINT" and "RESOE" are in the $6^{\text {th }}$ and $7^{\text {th }}$ positions respectively. The entry in Figure 5.1 above is specified by entering a starting value, 0.75 , say in the cell at row 7, column 6. The same approach is used for the other double-headed arrows of the model.

The complete matrix S may be as shown below.

```
Matrix S
    0
0
00
0000
00001
00000.751
00000.750.751
00000.750.750.75 1
00000.750.750.750.75 1
00000.750.750.750.750.75 1
00000000000
000000000000
0000000000000.75
00000000000000.75
000000000000000.75
0000000000000000.75
00000000000000000.75
000000000000000000.75
```


## (iii) Specify S Paragraph

## Purpose

To Specify the parameter numbers of matrix $\mathbf{S}$, i.e. the order in which the starting values and the fixed parameters were entered in the matrix $S$.

## Syntax

Matrix S
<numlist>
where <numlist> is a free format list of numbers.

## Example

If the entry for Figure 5.1 was the $14^{\text {th }}$ value to be entered, the number 14 is entered as the parameter number in row 7 , column 6 . The same approach is used for the other doubleheaded arrows of the model.

The complete "Specify S" matrix may be as shown below.

## Specify S

0
00
000
0000
00007
0000813
000091418
000010151922
00001116202325
0000121721242627
00000000000
000000000000
0000000000001
00000000000002
000000000000003
0000000000000004
00000000000000005
000000000000000006

## Label Row S Paragraph

## Purpose

To provide a list of the descriptive names for all the variables of the model, in the order in which they appear in the Rows of matrix $\mathbf{S}$.

Syntax
Label Row S
Var 1, Var 2....
where "Var 1, Var 2, ..." are the descriptive names of all the variables of the model in the rows of matrix S .

## Example

For the model depicted in Figure 1.2, the variables in the rows of the matrix S are: REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 and Z2.

These are specified as follows:
Label Row S
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP
REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## Label Col S Paragraph

## Purpose

To provide a list of the descriptive names of all the variables of the model, in the order in which they appear in the Columns of matrix $\mathbf{S}$.

Syntax
Label Col S
Var 1, Var 2....
where "Var 1, Var 2, ..." are the descriptive names of all the variables of the model in the columns of matrix S.

## Example

for the model depicted in Figure 1.2, the variables in the columns of the matrix S are: REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 and Z2.

These are specified as follows:

Label Col S<br>REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## (iv) Matrix A Paragraph

## Purpose

To Specify the entries of the Asymmetric paths or single-headed arrows of the model.

## Syntax

Matrix A
$<c, r>$
where $c$ indicates the position of the observed variable in the column from which the arrow starts and $r$ indicates the position of the observed variable in the row at which the arrow ends.

## Example

For the model depicted in Figure 1.2, a single-headed arrow starts from the latent variable REAMB and ends on the manifest variable REOAP as shown in Figure 5.2 below.


Figure 5.2 Dependence path between REAMB and REOAP.

In the list of all the labels of the observed variables, REAMB and REOAP are in the $1^{\text {st }}$ and $11^{\text {th }}$ positions respectively. The entry in Figure 5.2 above is specified by entering a starting value, 0.75 , say in the cell at row 1 , column 11 . The same approach is used for the other single-headed arrows of the model.

The complete matrix A may be as shown below.

## Matrix A

$$
\begin{aligned}
& 00000000000.750100000 \\
& 000000000010010000 \\
& 000000000001001000 \\
& 000000000000.75000100 \\
& 000000000000000000 \\
& 000000000000000000 \\
& 000000000000000000 \\
& 000000000000000000 \\
& 000000000000000000 \\
& 000000000000000000 \\
& 00000.750 .750 .750 .750000 .75000010 \\
& 0000000.750 .750 .750 .750 .750000001 \\
& 000000000000000000 \\
& 000000000000000000 \\
& 000000000000000000
\end{aligned}
$$

## (v) Specify A Paragraph

## Purpose

To Specify the parameter numbers of the matrix $\mathbf{A}$, i.e. the order in which the starting values and the fixed parameters were entered in the matrix $A$.

## Syntax

Matrix A

## <numlist>

where <numlist> is a free format list of numbers.

## Example

If the entry for Figure 5.2 was the $28^{\text {th }}$ value to be entered, the number 28 is entered as the parameter number in row17, column 11. The same approach is used for the other singleheaded arrows of the model.

The complete "Specify A" matrix may be as shown below.

## Specify A

0000000000280000000
000000000000000000
000000000000000000
0000000000029000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
00003233343500031000000
00000036373839300000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000

## Label Row A Paragraph

Purpose
To provide a list of the descriptive names of all the variables of the model, in the order in which they appear in the Rows of matrix $\mathbf{A}$.

## Syntax

Label Row A
Var 1, Var 2....
where "Var 1, Var 2, ..." are the descriptive names of all the variables of the model in the rows of matrix A .

## Example

For the model depicted in Figure 1.2, the variables in the rows of the matrix A are: REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 and Z2.

These are specified as follows:
Label Row A
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## Label Col A Paragraph

## Purpose

To provide a list of the descriptive names of all the variables of the model, in in the order in which they appear the Columns of matrix $\mathbf{A}$.

Syntax
Label Col A
Var 1, Var 2....
where "Var 1, Var 2, ..." are the descriptive names of all the variables of the model in the columns of matrix A.

## Example

For the model depicted in Figure 1.2, the variables in the columns of the matrix S are: REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 and Z2.

These are specified as follows:
Label Col S
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## (vi) Matrix F Paragraph

## Purpose

To provide a matrix which Filters the observed variables out of the whole set of variables of the model.

## Syntax

Matrix F

## <numlist>

where " numlist $>$ " is a free format list of the numbers " 1 " and " 0 ".

## Example

For the list of the variables in the model depicted in Figure 1.2, REOAP is the first manifest variable. The number " 1 " is entered in the cell with position row 1 and column 1 . The number " 1 " is also entered in the cell with position row 2 and column 2 to indicate the second manifest variable REEAP. A similar procedure is carried out for the eight other manifest variables of the model.

The complete matrix F may be as shown below.

## Matrix F

$$
\begin{array}{llllllllllllllllll}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{array}
$$

## Label Row F Paragraph

## Purpose

To provide a list of the descriptive names of all the observed variables of the model, in the order in which they appear in the Rows of matrix $\mathbf{F}$.

Syntax
Label Row F
Var 1, Var 2....
where "Var 1, Var 2, ..." are the descriptive names of all the observed variables of the model in the rows of matrix $F$.

## Example

For the model depicted in Figure 1.2, the observed variables are: REOAP REEAP BFOAP
BFEAP REPAP REINT RESOE BFSOE BFINT and BFPAP.
These are specified as follows:
Label Row F
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP.

## Label Col F Paragraph

Purpose
To provide a list of the descriptive names of all the variables of the model, in the order in which they appear in the Columns of matrix $\mathbf{F}$.

Syntax
Label Col F
Var 1, Var 2....
where "Var 1, Var 2, ..." are the descriptive names of all the variables of the model in the columns of matrix F .

## Example

For the model depicted in Figure 1.2, the variables in the columns of the matrix F are:
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP
REAMB BFAMB E1 E2 E3 E4 Z1 and Z2
These are specified as follows:
Label Col F
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## (c) SPECIFY OPTIONS

## (i) Covariance Keyword

Purpose
To specify the formula for the covariance structure.

## Syntax

Begin Algebra:

## Algebra

where "Algebra" denotes the covariance structure to be used in the analysis.

## Example

For the model depicted in Figure 1.2, the covariance structure used is specified in the input script file as:

Begin Algebra:
Covariance F\& $((\mathrm{I}-\mathrm{A}) \cong \& S)$;

## (ii) Options Sentence

Purpose
To specify options required in the output file.
Syntax
Options <options>
where "<options>" denotes any of the following:
RSidual ReSidual
$\mathrm{nDecimal}=\mathrm{k}$ number of Decimals ( k is an iteger-the required number of decimals)
$\mathbf{C I}=\mathrm{p} \quad$ Confidence $\operatorname{Intervals}$ (equals p, i.e. $\mathrm{p} \%$ confidence interval).
Example
For the model depicted in Figure 1.2, the options are specified as follows:
Options RSidual
Options nDecimal $=3$
Options CI= 90

## (d) END OF GROUP Sentence

## Purpose

To signify the end of the current project.
Syntax
End;
Example
For the model depicted in Figure 1.2, the end of the input script file is specified as:
End;

### 5.2.2 AN Mx INPUT SCRIPT FOR THE MODEL DEPICTED IN FIGURE 1.2

A complete Mx Input Script would appear as shown below.
!Mx Frontend Auto-generated Script. ver 1.0
!Created at 15:56:11 on 29 Dec 2000 by
!SmartUser
! -------------- Group ID 1------------------

## \#NGroups 1

Title The Duncan Haller and Portes Application
Data NInput=10 NObservation=329

```
KMatrix
1.000
0.625 1.000
0.327 0.367 1.000
0.422 0.327 0.640 1.000
0.214 0.274 0.112 0.084 1.000
0.411}00.4040.290 0.260 0.184 1.000
0.324 0.405 0.305 0.279 0.049 0.222 1.000
0.293}00.2410.411 0.361 0.019 0.186 0.271 1.000
0.300}00.2860.519 0.501 0.078 0.336 0.230 0.295 1.000
0.076 0.070 0.278 0.199 0.115 0.102 0.093-0.044 0.209 1.000
#define NumManifest 10
```

Begin Matrices;
S Symm 1818
A Full 1818
F Full 1018
I Iden 1818
End Matrices;
Matrix S
0
00
000
0000
00001
00000.751
00000.750 .751
00000.750 .750 .751
00000.750 .750 .750 .751
00000.750 .750 .750 .750 .751
00000000000
000000000000
0000000000000.75
00000000000000.75
000000000000000.75
0000000000000000.75
00000000000000000.75
000000000000000000.75
Specify S
0
00
000
0000
00007

```
0000813
000091418
000010151922
00001116202325
0000121721242627
00000000000
000000000000
0000000000001
00000000000002
000000000000003
0000000000000004
00000000000000005
000000000000000006
Label Row S
    REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2
E3 E4 Z1 Z2
Label Col S
    REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2
E3 E4 Z1 Z2
```


## Matrix A

00000000000.750100000

000000000010010000
000000000001001000
000000000000.75000100

000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
00000.750 .750 .750 .750000 .75000010
0000000.750 .750 .750 .750 .750000001

000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
Specify A
0000000000280000000
000000000000000000
000000000000000000
0000000000029000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
00003233343500031000000
00000036373839300000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000
000000000000000000

Label Row A
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2
Label Col A
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## Matrix F

100000000000000000
010000000000000000
001000000000000000
000100000000000000
000010000000000000
000001000000000000
000000100000000000
000000010000000000
000000001000000000
000000000100000000
Label Row F
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP
Label Col F
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

Covariance F \& ((I - A)~ \& S);
Options RSidual
Options nDecimals=3
Options CI=90
End Group;

### 5.3 ILLUSTRATIVE EXAMPLE: THE DUNCAN, HALLER AND PORTES' APPLICATION

### 5.3.1 CREATING Mx INPUT SCRIPT FROM PATH DIAGRAM FOR THE DUNCAN, HALLER AND PORTES' APPLICATION

The path diagram drawing software, RAMPATH may be used to generate an Mx script file by simply drawing the path diagram of the model to be fitted to the data. The step by step method for doing this for the Duncan, Haller and Portes' application is outlined below.

- Double-click on the Mx icon
to open the window below:

- Click on the "New Drawing" push button

to open the window below.

- Click on the "Rectangle" push button

to change the cursor into a rectangle.
- Click at the appropriate portion of the window to drop the rectangle to produce the window below.

- Click on the "Default cursor" push button

to stop the duplication of the rectangles.
- Double-click on the default label of the manifest variable to produce a window with part shown below.

- Type in the required variable name to replace the default name as shown below.

- Click outside the rectangle to produce the window shown below.

- Repeat the steps used above to draw the other nine manifest variables of the model to produce the window shown below.

明 Mx - [MxPathDiagram1]
51 File Edit Search MxProject Dutput PathDiagram Preference Window !


| Run | Parse | ToScript | DataMap |
| :---: | :---: | ---: | ---: |
| Manager |  |  |  |
| REOAP | REPAP |  |  |
| REEAP | REINT |  |  |
| BFEAP | RESOE |  |  |
| BFOAP | BFSOE |  |  |

- Click on the "Circle" push button
 to change the cursor into a circle.
- Click on the appropriate part of the window to drop the circle to produce the window below.

- Go through the same steps as above to insert the descriptive name of the latent variable.
- Follow the same steps to draw and label the other latent variable to produce the window below:


## Be' Mx - [MxPathDiagram1]

51 File Edit Search MxProject Qutput PathDiagram Preference Window


| Run | Parse | ToScript | DataMap |
| :--- | :---: | :---: | :---: |
| Manager |  |  |  |
| REOAP | REPAP |  |  |
| REEAP | REINT |  |  |
| BFEAP | RESOE |  |  |

- Click on the "Single Arrow" push button, $\sqrt{+}$ to change the cursor to a single-headed arrow.
- Click on the latent variable, "REAMB".
- Hold the click and drag it to "REOAP" to produce a window such as the one shown below:

- By following the same steps as those used to draw the unidirectional arrow from "REAMB" to "REOAP", you would be able to draw all the required unidirectional arrows needed in the diagram to produce the window below:

- Click on the "Double Arrow" push button

- Click on the manifest variable "REPAP".
- Hold the click and drag it to the manifest variable "REINT" to produce the window shown below:

- Click on the "Default Cursor" push button
 to deselect the double-headed arrow.
- Click on the blue dot in the middle of the double-headed arrow.
- Hold the click.
- Drag it to the right hand side to increase the curvature of the arrow to produce the window shown below:

- Click on the "Double Arrow" push button again.
- Follow the same steps as outlined above to draw another double-headed arrow between "REPAP" and "RESOE".
- Continue with the same steps to draw all the double-headed arrow of the model to produce the window shown below:

- Draw the error terms in the same way as you did for the latent variables to produce the window below:

- Click on the path from "E1" to "REOAP" to select it.
- Double-click on the highlighted path to load the dialog box below:

- Click in the "Start Value" string field.
- Type the number " 1.00 " in the string field.
- Check the "Fix This Parameter" check box.
- Click on the "OK" push button to fix the parameter H2, between "E1" and "REOAP" to 1 .
- Follow the same steps to fix the parameters P and S between REAMB and REOAP, and BFAMB and BFOAP respectively, to 1 .

The same steps could be used to fix or set free any of the default parameters values shown on the path diagram.

- Click on the menu to load the file menu box shown below:

- Click on the "Save As" option to load the dialog box shown below:

- Type the appropriate file name, for example, "pepdhp", say, in the "File name" string field to produce the dialog box shown below:

- Click on the "Save" push button to save the path diagram.
- Click on the "To Script" push button ToScript to load the dialog box shown below:


## Parse Drawing to Job



- Type the appropriate name for the script file in the "Job Name" string field to produce the dialog box shown below:


## Parse Drawing to Job



- Click on the "OK" push button to open the dialog box shown below:

- Click on the "Save" push button to open the saved input script file shown in the window below.

- Type in the matrix to be analyzed or copy and paste from an external source to replace the default identity matrix in the input script.
- Type the correct number of observations to replace the default number 100 to produce the window shown below:

- Click on the "Preference" menu to load the preference menu box shown below:

| Preference | Window |
| :--- | :--- |
| Job Options |  |
| Host Options |  |
| Matrix Options |  |
| Pen Attributes |  |
| Colors |  |
| Fonts |  |
| Grid Color |  |
| Grid Size |  |

- Click on the "Job Options" option to load the dialog box shown below:

- Change any of the options to the desired option.
- Check the "Standardized" check box to produce the dialog box shown below:

- Click on the "OK" push button.
- Click on the "Preference" menu again to load the preference menu box.
- Click on the "Matrix Options" option to load the dialog box shown below:

- Change the "Decimal" value from " 6 " to " 3 ", say.
- Click on the "OK" push button.

The job is now ready to run.

### 5.3.2 RUNNING Mx

With the path diagram drawn and the Mx script generated from the path diagram, clicking on the "Run" push button $\quad$ Run runs Mx.

If there are no syntax errors in the input file the program will run and the message

## Waiting for backend to firish, current counter 241

will appear. The number, which appears after the "current counter", will change very rapidly till the program terminates. When this happens, the "Results Panel" dialog box shown below will appear.

| Results Panel |  |  | 区 |
| :---: | :---: | :---: | :---: |
| Optimization: Appears OK |  |  |  |
| ML Chisq | 27.012 (0.435, 29.430) | Df | 16 |
| Probability | 0.041 | Parameters | 39 |
| AIC | -4.988 (-31.565, -2.570) | Statistics | 55 |
| RMSEA | 0.046 (0.000, 0.051) | Constraints | 0 |
|  | OK | Help |  |

- Click on the "OK" push button to open the window shown below:


In this window you will find the matrices specified in the Input Script file, the order and the type of each matrix. The test statistic values and the parameter estimates can be viewed from the window above by clicking on the "Statistics" or the "Value" push buttons.

### 5.3.3 THE Mx OUTPUT FILE

(1) ** Mx startup successful **
(2)
(I) **MX-PC 1.50** Job started on 12/29/00 at 16:07:53
(II) !Mx Frontend Auto-generated Script. ver 1.0
!Created at 15:56:11 on 29 Dec 2000 by
!SmartUser
! --------------- Group ID 1------------------
(3) The following MX script lines were read for group 1
(4)
(I) \#NGROUPS 1
(II) Note: \#NGroup set number of groups to 1
(III) TITLE THE DUNCAN HALLER AND PORTES APPLICATION
(IV) DATA NINPUT=10 NOBSERVATION=329

## (V)

KMATRIX
1.000
$0.625 \quad 1.000$
$0.327 \quad 0.367 \quad 1.000$
$0.422 \quad 0.327 \quad 0.640 \quad 1.000$
$\begin{array}{lllll}0.214 & 0.274 & 0.112 & 0.084 & 1.000\end{array}$
$\begin{array}{llllll}0.411 & 0.404 & 0.290 & 0.260 & 0.184 & 1.000\end{array}$
$\begin{array}{lllllll}0.324 & 0.405 & 0.305 & 0.279 & 0.049 & 0.222 & 1.000\end{array}$
$\begin{array}{llllllll}0.293 & 0.241 & 0.411 & 0.361 & 0.019 & 0.186 & 0.271 & 1.000\end{array}$
$\begin{array}{lllllllll}0.300 & 0.286 & 0.519 & 0.501 & 0.078 & 0.336 & 0.230 & 0.295 & 1.000\end{array}$
$\begin{array}{llllllllll}0.076 & 0.070 & 0.278 & 0.199 & 0.115 & 0.102 & 0.093 & -0.044 & 0.209 & 1.000\end{array}$
(VI) \#DEFINE NUMMANIFEST 10

## (5)

(I) BEGIN MATRICES;
(II) S SYMM 1818
(III) A FULL 1818
(IV) F FULL 1018
(V) I IDEN 1818
(VI) END MATRICES;
(6)
(I)

MATRIX S
0
00
000
0000
$\begin{array}{lllll}0 & 0 & 0 & 0 & 1\end{array}$
$\begin{array}{llllll}0 & 0 & 0 & 0 & 0.75 & 1\end{array}$
$\begin{array}{lllllll}0 & 0 & 0 & 0 & 0.75 & 0.75 & 1\end{array}$
$\begin{array}{llllllll}0 & 0 & 0 & 0 & 0.75 & 0.75 & 0.75 & 1\end{array}$
$\begin{array}{lllllllll}0 & 0 & 0 & 0 & 0.75 & 0.75 & 0.75 & 0.75 & 1\end{array}$
$\begin{array}{llllllllll}0 & 0 & 0 & 0 & 0.75 & 0.75 & 0.75 & 0.75 & 0.75 & 1\end{array}$
00003000000000
$0 \begin{array}{lllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$
00000000000000000.75
$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0.75$
$0 \begin{array}{lllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.75\end{array}$

$0 \begin{array}{llllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array} 0.75$
0000000000300000000000.75

## (II)

SPECIFY S
0
00
000
0000
00007
0000813
$0 \quad 0 \quad 0 \quad 0 \quad 91418$
$0 \quad 0 \quad 0 \quad 0 \quad 10151922$
$\begin{array}{lllllllll}0 & 0 & 0 & 0 & 11 & 16 & 20 & 23 & 25\end{array}$
$\begin{array}{llllllllll}0 & 0 & 0 & 0 & 12 & 17 & 21 & 24 & 26 & 27\end{array}$
00000003000000
000000000000000
$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1$
$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 00002$

$0 \begin{array}{lllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4\end{array}$
0000000000000000000005
0000000000000000000006

## (III)

LABEL ROW S
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB

BFAMB E1 E2 E3 E4 Z1 Z2

## (IV)

LABEL COL S
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB
BFAMB E1 E2 E3 E4 Z1 Z2

## (7)

(I)

MATRIX A

 000000000000000.750001000 $0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0$
 $0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$
 $0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$ $0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$ 00000000000000000000000
 0000000.750 .750 .750 .750 .7500000001
 $0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$


 000000000000000000000

## (II)

SPECIFY A
00000000000000000000000
00000000000002800000000
00000000000000290000000
$0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$
$0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$


$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$
$0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$


$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 3637383930 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$
0000000000000000000000
00003000000000000000000
$0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$


0000000000000000000000

## (III)

LABEL ROW A
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP REAMB BFAMB E1 E2 E3 E4 Z1 Z2

## (IV)


REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP

MATRIX F

$0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$ $0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$

 $0 \begin{array}{lllllllllllllllll}0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}$ $0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 00000$ $0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$ $0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 00000000$


## (II)

LABEL ROW F
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP

## (III)

LABEL COL F
REOAP REEAP BFOAP BFEAP REPAP REINT RESOE BFSOE BFINT BFPAP
REAMB BFAMB E1 E2 E3 E4 Z1 Z2
(9)
(I) COVARIANCE $F \&((I-A) \sim \& S)$;
(II) OPTIONS RSIDUAL
(III) OPTIONS NDECIMALS=3
(IV) OPTIONS CI=90
(V) OPTION NULL=472.155, 45
(VI) END GROUP;
(10)

PARAMETER SPECIFICATIONS
(I) GROUP NUMBER: 1
(II) Title The Duncan Haller and Portes Application

## (11)

## MATRIX A

| This | $\begin{aligned} & \text { a FULI } \\ & \text { REOAP } \end{aligned}$ | matrix REEAP | BFOAP | $18 \text { by }$ <br> BFEAP | $\begin{gathered} 18 \\ \text { REPAP } \end{gathered}$ | REINT | RESOE | BFSOE | BFINT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REEAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFOAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFEAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REPAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REINT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| RESOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFSOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFINT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFPAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REAMB | 0 | 0 | 0 | 0 | 32 | 33 | 34 | 35 | 0 |
| BFAMB | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 37 | 38 |
| E1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Z1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Z2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | BFPAP | REAMB | BFAMB | E1 | E2 | E3 | E4 | Z1 | Z2 |
| REOAP | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REEAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFOAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFEAP | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 |
| REPAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REINT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| RESOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFSOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFINT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFPAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| REAMB | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFAMB | 39 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Z1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Z2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## (12)

MATRIX F
This is a FULL matrix of order 10 by 18
It has no free parameters specified

## (13)

MATRIX I
This is an IDENTITY matrix of order 18 by 18

## (14)

MATRIX S

|  | REOAP | REEAP | BFOAP | BFEAP | $\begin{aligned} & \text { by } \\ & \text { REPAP } \end{aligned}$ | REINT | RESOE | BFSOE | BFINT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | 0 |  |  |  |  |  |  |  |  |
| REEAP | 0 | 0 |  |  |  |  |  |  |  |
| BFOAP | 0 | 0 | 0 |  |  |  |  |  |  |
| BFEAP | 0 | 0 | 0 | 0 |  |  |  |  |  |
| REPAP | 0 | 0 | 0 | 0 | 7 |  |  |  |  |
| REINT | 0 | 0 | 0 | 0 | 8 | 13 |  |  |  |
| RESOE | 0 | 0 | 0 | 0 | 9 | 14 | 18 |  |  |
| BFSOE | 0 | 0 | 0 | 0 | 10 | 15 | 19 | 22 |  |
| BFINT | 0 | 0 | 0 | 0 | 11 | 16 | 20 | 23 | 25 |
| BFPAP | 0 | 0 | 0 | 0 | 12 | 17 | 21 | 24 | 26 |
| REAMB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BFAMB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Z1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Z2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |


|  | BFPAP | REAMB | BFAMB | E1 | E2 | E3 | E4 | Z1 | Z2 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP |  |  |  |  |  |  |  |  |  |
| REEAP |  |  |  |  |  |  |  |  |  |
| BFOAP |  |  |  |  |  |  |  |  |  |
| BFEAP |  |  |  |  |  |  |  |  |  |
| REPAP |  |  |  |  |  |  |  |  |  |
| REINT |  |  |  |  |  |  |  |  |  |
| RESOE |  |  |  |  |  |  |  |  |  |
| BFSOE |  |  |  |  |  |  |  |  |  |
| BFINT |  |  |  |  |  |  |  |  |  |
| BFPAP | 27 |  |  |  |  |  |  |  |  |
| REAMB | 0 | 0 |  |  |  |  |  |  |  |
| BFAMB | 0 | 0 | 0 |  |  |  |  |  |  |
| E1 | 0 | 0 | 0 | 1 |  |  |  |  |  |
| E2 | 0 | 0 | 0 | 0 | 2 |  |  |  |  |
| E3 | 0 | 0 | 0 | 0 | 0 | 3 |  |  |  |
| E4 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |  |  |
| Z1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |  |
| Z2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |

## (15)

MX PARAMETER ESTIMATES
(I) GROUP NUMBER:
(II) Title The Duncan Haller and Portes Application

## (III)

MATRIX A

| This is a | FULL matrix of | order | 18 | by 18 |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | REOAP | REEAP | BFOAP | BFEAP | REPAP | REINT | RESOE | BFSOE |
| REOAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REEAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFOAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFEAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| RESOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFSOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REAMB | 0.000 | 0.000 | 0.000 | 0.000 | 0.213 | 0.333 | 0.290 | 0.103 |
| BFAMB | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.090 | 0.281 |
| E1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |


|  | BFINT | BFPAP | REAMB | BFAMB | E1 | E2 | E3 | E4 |
| :--- | ---: | :--- | :--- | :--- | :--- | :--- | ---: | ---: |
| REOAP | 0.000 | 0.000 | 1.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 |
| REEAP | 0.000 | 0.000 | 0.813 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 |
| BFOAP | 0.000 | 0.000 | 0.000 | 0.825 | 0.000 | 0.000 | 1.000 | 0.000 |
| BFEAP | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| REPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| RESOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFSOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REAMB | 0.000 | 0.000 | 0.000 | 0.173 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFAMB | 0.437 | 0.196 | 0.187 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|  |  |  |  |  |  |  |  |  |
| REOAP | 0.000 | 0.000 |  |  |  |  |  |  |
| REEAP | 0.000 | 0.000 |  |  |  |  |  |  |
| BFOAP | 0.000 | 0.000 |  |  |  |  |  |  |
| BFEAP | 0.000 | 0.000 |  |  |  |  |  |  |


| BFINT | 0.000 | 0.000 |
| ---: | ---: | ---: |
| BFPAP | 0.000 | 0.000 |
| REAMB | 1.000 | 0.000 |
| BFAMB | 0.000 | 1.000 |
| E1 | 0.000 | 0.000 |
| E2 | 0.000 | 0.000 |
| E3 | 0.000 | 0.000 |
| E4 | 0.000 | 0.000 |
| Z1 | 0.000 | 0.000 |
| Z2 | 0.000 | 0.000 |

## (IV)

MATRIX F

| This is a FULL matrix of order | lo |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | REOAP | REEAP | BFOAP | BFEAP | REPAP | REINT | RESOE | BFSOE |
| REOAP | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REEAP | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFOAP | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFEAP | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REPAP | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 |
| REINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 |
| RESOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 |
| BFSOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| BFINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |


|  | BFINT | BFPAP | REAMB | BFAMB | E1 | E2 | E3 | E4 |
| :--- | ---: | :--- | :--- | :--- | ---: | ---: | ---: | ---: |
| REOAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REEAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFOAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFEAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| REINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| RESOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFSOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFINT | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFPAP | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

## (V)

MATRIX I
This is an IDENTITY matrix of order 18 by 18

## (VI)

MATRIX S

| This is | SYMME | mat | or | 18 | 18 |  | RESOE | BFSOE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | REOAP | REEAP | BFOAP | BFEAP | REPAP | REINT |  |  |
| REOAP | 0.000 |  |  |  |  |  |  |  |
| REEAP | 0.000 | 0.000 |  |  |  |  |  |  |
| BFOAP | 0.000 | 0.000 | 0.000 |  |  |  |  |  |
| BFEAP | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |  |
| REPAP | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |  |  |  |
| REINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.184 | 1.000 |  |  |
| RESOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 0.222 | 1.000 |  |
| BFSOE | 0.000 | 0.000 | 0.000 | 0.000 | 0.019 | 0.186 | 0.271 | 1.000 |
| BFINT | 0.000 | 0.000 | 0.000 | 0.000 | 0.078 | 0.336 | 0.230 | 0.295 |
| BFPAP | 0.000 | 0.000 | 0.000 | 0.000 | 0.115 | 0.102 | 0.093 | -0.044 |
| REAMB | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| BFAMB | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |


|  | BFINT | BFPAP | REAMB | BFAMB | E1 | E2 | E3 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| REOAP |  |  |  |  |  |  |  |
| REEAP |  |  |  |  |  |  |  |
| BFOAP |  |  |  |  |  |  |  |
| BFEAP |  |  |  |  |  |  |  |
| REPAP |  |  |  |  |  |  |  |
| REINT |  |  |  |  |  |  |  |
| RESOE |  |  |  |  |  |  |  |
| BFSOE |  |  |  |  |  |  |  |
| BFINT | 1.000 |  |  |  |  |  |  |
| BFPAP | 0.209 | 1.000 |  |  |  |  |  |
| REAMB | 0.000 | 0.000 | 0.000 |  |  |  |  |
| BFAMB | 0.000 | 0.000 | 0.000 | 0.000 |  |  |  |
| E1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.412 |  |  |
| E2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.338 |  |
| E3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.314 |
| E4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Z2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Z1 Z2
REOAP
REEAP
BFOAP
BFEAP
REPAP
REINT
RESOE
BFSOE
BFINT
BFPAP
REAMB
BFAMB
E1

| E 2 |  |  |
| :--- | :--- | :--- |
| E 3 |  |  |
| E 4 |  |  |
| Z 1 | 0.317 |  |
| Z2 | 0.000 | 0.263 |

(16)

| OBSERVED COVARIANCE MATRIX |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1.000 |  |  |  |  |  |  |  |
| 2 | 0.625 | 1.000 |  |  |  |  |  |  |
| 3 | 0.327 | 0.367 | 1.000 |  |  |  |  |  |
| 4 | 0.422 | 0.327 | 0.640 | 1.000 |  |  |  |  |
| 5 | 0.214 | 0.274 | 0.112 | 0.084 | 1.000 |  |  |  |
| 6 | 0.411 | 0.404 | 0.290 | 0.260 | 0.184 | 1.000 |  |  |
| 7 | 0.324 | 0.405 | 0.305 | 0.279 | 0.049 | 0.222 | 1.000 |  |
| 8 | 0.293 | 0.241 | 0.411 | 0.361 | 0.019 | 0.186 | 0.271 | 1.000 |
| 9 | 0.300 | 0.286 | 0.519 | 0.501 | 0.078 | 0.336 | 0.230 | 0.295 |
| 10 | 0.076 | 0.070 | 0.278 | 0.199 | 0.115 | 0.102 | 0.093 | -0.044 |

910
1
2
3
4
5
6
7
8
$9 \quad 1.000$
$10 \quad 0.209 \quad 1.000$

## (17)

| EXP | $\begin{gathered} \text { ED COVA } \\ 1 \end{gathered}$ | $\begin{gathered} \text { ANCE } \\ 2 \\ 2 \end{gathered}$ | X 3 | 4 | 5 | 6 | 7 | 8 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 0.999 |  |  |  |  |  |  |  |
| 2 | 0.624 | 0.999 |  |  |  |  |  |  |
| 3 | 0.354 | 0.376 | 0.999 |  |  |  |  |  |
| 4 | 0.331 | 0.351 | 0.639 | 0.999 |  |  |  |  |
| 5 | 0.240 | 0.254 | 0.102 | 0.095 | 1.000 |  |  |  |
| 6 | 0.393 | 0.417 | 0.273 | 0.255 | 0.184 | 1.000 |  |  |
| 7 | 0.357 | 0.379 | 0.303 | 0.282 | 0.049 | 0.222 | 1.000 |  |
| 8 | 0.255 | 0.270 | 0.401 | 0.374 | 0.019 | 0.186 | 0.271 | 1.000 |
| 9 | 0.258 | 0.274 | 0.525 | 0.490 | 0.078 | 0.336 | 0.230 | 0.295 |
| 10 | 0.103 | 0.110 | 0.254 | 0.237 | 0.115 | 0.102 | 0.093 | -0.044 |
|  | 9 | 10 |  |  |  |  |  |  |
| 1 |  |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |  |  |
| 9 | 1.000 |  |  |  |  |  |  |  |
| 10 | 0.209 | 1.000 |  |  |  |  |  |  |

## (18)

RESIDUAL MATRIX

## 1

2
3
4
5
6
7
8
$1 \quad 0.001$
20.001
$-0.027 \quad-0.009 \quad 0.001$
$\begin{array}{llll}0.091 & -0.024 & 0.001 & 0.001\end{array}$
$-0.026 \quad 0.020$
$0.018 \quad-0.013 \quad 0.017 \quad 0.005$
$-0.033 \quad 0.026$
$\begin{array}{rrrrr}0.038 & -0.029 & 0.010 & -0.013 & 0.000 \\ 0.042 & 0.012 & -0.006 & 0.011 & 0.000\end{array}$
$\begin{array}{rrrrr}0.042 & 0.012 & -0.006 & 0.011 & 0.000 \\ -0.027 & -0.040 & 0.024 & -0.038 & 0.000\end{array}$
$9 \quad 10$
1
$9 \quad 0.000$
$10 \quad 0.000 \quad 0.000$

## (19)

(I) Function value of this group: 27.002
(II) Where the fit function is Maximum Likelihood
(III) Your model has 39 estimated parameters and 55 Observed statistics
(20)

| (I) | Chi-squared fit of model >>>>>>> | 27.002 |
| :--- | :---: | :---: |
| (II) | Degrees of freedom >>>>>>>>>>>>> | 16 |
| (III) | Probability >>>>>>>>>>>>>>>>>>>> | 0.041 |
| (IV) | Akaike's Information Criterion > | 104.988 |
| (V) | RMSEA >>>>>>>>>>>>>>>>>>>>>>>>>> | 0.046 |


| (21) | (I) | Fit statistic | Estimate |
| :---: | :---: | :---: | :---: |
|  | (II) | Tested Model fit >>>>>>>>>>>>> | 27.002 |
|  | (III) | Tested Model df >>>>>>>>>>>>>> | 16.000 |
|  | (IV) | Null Model fit* >>>>>>>>>>>>>> | 862.555 |
|  | (V) | Null Model df* >>>>>>>>>>>>>>> | 45.000 |
|  | (VI) | Normed fit Index ${ }^{\text {l }}$->>>>>>>>>>>> | 0.943 |
|  | (VII) | Normed fit Index 2 >>>>>>>>>>> | 0.976 |
|  | (VIII) | Tucker Lewis Index >>>>>>>>>>> | 0.927 |
|  | (IX) | Parsimonious Fit Index>>>>>>>> | 0.335 |
|  | (X) | Parsimonious Fit Index 2 >>>>> | 0.021 |
|  | (XI) | Relative Non-centrality Index> | 0.974 |
|  | (XII) | Centrality Index >>>>>>>>>>>>> | 0.983 |

```
* User-supplied null-model statistic
```

```
(21) (I) This problem used 6.0% of my workspace
                                Task Time elapsed (DD:HH:MM:SS)
    (II) Reading script & data 0: 0: 0: 0.49
    (III) Execution 0: 0: 1:12.06
    (IV) TOTAL 0: 0: 1:12.55
    (V) Total number of warnings issued: 0
```


## ENTRIES OF Mx OUTPUT FILE

(1) Message indicating that there is nothing wrong with the input script file.
(2)(I) The date and time that the job started.
(II) Message confirming that a script has automatically been generated from the path diagram drawn.
(3) Message indicating the group from which the script was read.
(4) to (14) The of the Mx Input Script file reproduced.

## (15) Mx PRAMETER ESTIMATES.

(I) Group number.
(II) As (4)(III) above.
(III) Matrix A with the parameter estimates.
(IV) Matrix F reproduced with the descriptive names of the variables provided for the rows and columns.
(V) As (13) above.
(VI) Matrix S with the parameter estimates.
(16) The input matrix or the matrix to be analyzed.
(17) The expected covariance matrix. This is the matrix calculated by Mx using the specified model and parameter estimates.
(18) Residual matrix. This is the difference between the matrices in (16) and (17).
(19)(I) The minimum value of the discrepancy function according to the model specified.
(II) The method of estimation used.
(III) Information about the number of estimated parameters and observed parameters in the model.
(20)(I) The chi-square value.
(II) Degrees of freedom, df. It is computed as total number of parameter minus the number of free parameters.
(III) This is the probability of obtaining a $X^{2}$ value as greater or equal to the value actually obtained, given that the model is correct.
(IV) The Akaike's Information Criterion is computed as:

$$
\mathrm{AIC}=X^{2}-2 \mathrm{df}
$$

(V) The Root Mean Squared Error of Approximation, RMSEA, (Steiger \& Lind, 1980; McDonald, 1989) is computed for single group case by:

$$
\left.R M S E A=\sqrt{\left(\chi^{2}\right.}-d f\right) / n / d f
$$

(VI) Information regarding what happened before the calculation of the confidence intervals.
(21) Column (I): Name of Fit Statistic.

Column (II): Estimate of the statistic.
(I) $\mathrm{As}(\mathbf{2 0})(\mathbf{I})$.
(II) As (20) (II).
(III) A Null Model chi-squared value supplied by the user.
(IV) A Null Model degrees of freedom supplied by the uesr.
(V) The Normed Fit Index, NFI, which is calculated as (Bentler and Bonett, 1980)

$$
N F I=\frac{F_{N}-F_{\tau}}{F_{N}}
$$

where $F_{N}$ and $F_{\tau}$ are goodness-of-fit (chi-squared) statistic respectively obtained under the Null and Tested models.
(VI) The Normed Fit Index $2, \mathrm{NFI}_{2}$, which is calculated as (Bentler and Bonnett, 1980)

$$
N F I_{2}=\frac{F_{N}-F_{\tau}}{F_{N}-d f_{\tau}}
$$

where $d f_{\tau}$ is the degrees of freedom of the Tested model.
(VII) The Tucker Lewis Index, TLI, which is calculated as (Tucker and Lewis, 1973)

$$
T L I=\left[\left(F_{N} / d f_{N}\right)-\left(F_{\tau} / d f_{\tau}\right)\right] /\left[\left(F_{N} / d f_{N}\right)-1.0\right]
$$

where $d f_{N}$ is the degrees of freedom of the Null model.
(VIII) The Parsimonious Fit Index, PFI, which is calculated as (Mulaik et. al., 1989)

$$
P F I=\left(d f_{\tau} / d f_{N}\right) N F I
$$

(IX) The Parsimonious Fit Index 2, $\mathrm{PFI}_{2}$, which is calculated as (Mulaik et. al., 1989)

$$
P F I_{2}=2 N F I \frac{d f_{\tau}}{p(p-1)}
$$

where $p$ is the number of free parameters in the model.
(X) The Relative Non-centrality Index, RNI, which is calculated as (McDonald and Marsh, 1990)

$$
R N I=\left[\left(F_{N}-d f_{n}\right)-\left(F_{\tau}-d f_{\tau}\right)\right] /\left(F_{N}-d f_{N}\right)
$$

(XI) The Centrality Index, CI, which is calculated as (McDonald, 1989)

$$
C I=\exp \left[-0.5\left\{\left(F_{\tau}-d f_{\tau}\right) / N\right\}\right]
$$

where $N$ is the total samople size (over all groups).
(22)(I) Information about the percentage of the workspace used by the problem.
(II) Time used for the reading script and data.
(III) Time used for the execution of the problem.
(IV) Total time used. This is equal to the sum of the times in (22)(II) and (22)(III).
(V) Information on the number of warnings used.

## CHAPTER 6

## RAMONA

### 6.1 HISTORICAL BACKGROUND

The acronym RAMONA stands for Reticular Action MOdel or Near Approximation. RAMONA is influenced greatly by Steiger's suggestion of the use of the ASCII symbols <--: for dependence paths and <--> for variance/covariance paths to create ASCII representations of the path diagrams of Structural Equation Models. This suggestion allows users to specify their models in terms of a path diagram instead of parameter matrices. The program RAMONA implements the RAMONA model (Mels, 1988). Mels (1988) developed the initial version of RAMONA. Browne and Mels $(1990,1992)$ have updated this initial version of RAMONA. A DOS version of RAMONA (Mels, Browne and Coward, 1994) forms part of the statistical software package SYSTAT version 6 for DOS. RAMONA is also available in SYSTAT version 6 for Windows. Browne and Mels (1998) developed the latest stand-alone version for Windows. The SYSTAT versions differ from the other versions in the fact that it uses <- and <-> for dependence and covariance paths, instead of <--: and <-->, respectively.

RAMONA is a program for path analysis with manifest and latent variables and it implements the McArdle and McDonald (1984) Reticular Action Model (RAM). The deviation from RAM is minor in that no distinction is made between residual variables and other exogenous latent variables. The program brought to rest the problem with negative variance and out of bound estimates and was the computer program of its kind to yield correct results whenever the sample correlation matrix instead of sample covariance matrix is analyzed.

RAMONA is intended for users with knowledge of latent variable modeling but can be employed by researchers with no mathematical background. The user only needs to know how to formulate a model in the form of a path diagram. Knowledge of matrix algebra is not essential.

### 6.2 THE RAMONA INPUT FILE

To run RAMONA, the user must prepare an Input File. A RAMONA Input File is a text file that consists of five paragraphs and the data to be analyzed. Each paragraph consists of a sentence(s).

The following general rules apply to the paragraphs and sentences of a RAMONA Input File.

## GENERAL RULES FOR RAMONA INPUT FILES

- Each sentence consists of a maximum of 80 characters.
- Each sentence ends with a slash.
- Each paragraph start with a unique keyword followed by $=$ (equal sign) and ends with a semicolon.
- The five paragraphs may appear in any order.
- The matrix or raw data to be analyzed is the final section of the input file and is preceded with the word DATA, the type of data ("RAW DATA", "COVARIANCE MATRIX" or "CORRELATION MATRIX") and an integer value for the number of cases on three different lines.

A RAMONA Input File may be divided into three sections. These are:

1. Model Information
2. Model Specification
3. Data

### 6.2.1 MODEL INFORMATION

Model information is specified in three paragraphs, namely: TITLE paragraph, MANIFEST variable paragraph and LATENT variable paragraph.

Details of each paragraph are discussed below.
(a) TITLE Paragraph

This paragraph provides a description for the analysis to be performed. It starts with TITLE $=$. For the model depicted in Figure 1.2 we may have a TITLE paragraph as follows:

TITLE = Duncan, Haller and Portes' (1971) Application;
(b) MANIFEST Variable Paragraph

- A manifest variable is represented by means of a rectangle or square on a path diagram.
- The manifest variable paragraph allows the user to give descriptive names to the manifest variables.


## Rules for the MANIFEST Variable paragraph

- The manifest variable paragraph starts with MANIFEST=.
- Each descriptive name of a manifest variable may not exceed eight (8) characters.
- The order of the manifest variables corresponds to the order of the columns of the covariance, correlation or raw data matrix provided in the final section of the input file.
- The descriptive names of the manifest variables are separated by at least one blank space.

For the model depicted in Figure 1.2, we may have a manifest variable paragraph as shown below.

## MANIFEST=REINT REPAP RSOEC REOAP REEAP / <br> BFINT BFPAP BFSOE BFOAP BFEAP;

(c) LATENT Variable paragraph

- Latent variables are indicated on a path diagram by means of circles or ellipses.
- The latent variable paragraph is used to give descriptive names to the latent variables in the model.

Rules for the LATENT Variable paragraph.

- The LATENT variable paragraph starts with LATENT=.
- Each descriptive name of a latent variable may not exceed eight (8) characters.
- The latent variables may be provided in any order.
- The descriptive names of the latent variables are separated by at least one blank space.

For the model depicted in Figure 1.2, the following latent variable paragraph may be used:

LATENT= REAMB BFAMB E1 E2 E3 E4 Z1 Z2;

### 6.2.2 MODEL SPECIFICATION

This is the section of the input file where the path diagram of the model is coded directly with the use of the ASCII symbols <--: (for dependence paths) and <--> ( for covariance paths) and it is specified in the MODEL paragraph of the RAMONA Input file.

Rules for the MODEL Paragraph.

- This paragraph starts with the keyword MODEL=.
- The MODEL paragraph consists of two sub-paragraphs, one for dependence paths and one for variance/covariance paths.
- Dependence paths and covariance paths must be specified in separate subparagraphs and cannot be intermingled.


## (i) DEPENDENCE PATHS

A dependence path is indicated by the symbol <--: which relates directly to the single headed arrow employed in a path diagram. A dependence path is coded as follows:

Dependent Variable <--: (Explanatory Variable, Parameter Number, Starting Value)/

For the model depicted in Figure 1.2 the endogenous manifest variable REOAP receives single headed arrow from the latent variable REAMB and a measurement error E1. These paths are displayed in Figure 6.1 below.


Figure 6.1 Dependence paths between REOAP, E1 and REAMB.

These dependence paths are coded as

$$
\begin{aligned}
& \text { REOAP <--: }(\text { REAMB, } 0,1.0) / \\
& \text { REOAP <--: }(\mathrm{E} 1,0,1.0) /
\end{aligned}
$$

It is not necessary to have a different sentence for each path. Several paths with the same dependent (receiving) variable may be combined into one sentence. The sentence must fit on one line of not more than 80 characters. Otherwise, more than one sentence is necessary.

Since the same endogenous variable, REOAP, is involved in the two dependence paths, the two paths may be coded in a single sentence as:

REOAP <--: (REAMB, 0, 1.0) (E1, 0, 1.0)/
When specifying dependence paths, bear in mind that:

- Dependence paths can be specified in any order.
- A sentence can specify several dependence paths involving the same endogenous variable.
- In some cases, a dependent variable may be involved in too many dependence paths for a single sentence. In this situation, make use of several sentences with the same dependent variable.
- Parameter numbers need not be sequential. If they are not, RAMONA will reassign path numbers.


## (ii) VARIANCE/COVARIANCE PATHS

A variance or covariance path is indicated by the symbol <--> which relates directly to the double headed arrow used in a path diagram. A covariance paths is specified in an input file as follows:

Variable <--> (Name of the other Variable, Parameter number, Starting value)/

Unlike in the case of the dependence paths, it does not matter which variable is given first.
For the model depicted in Figure 1.2, double headed arrows are employed from the manifest variable REPAP to itself to specify a variance and to RESOE, REINT, and BFINT to specify covariances. These paths are shown in the diagram below.


Figure 6.2 Covariance Paths between REPAP, RESOE and REINT.

These paths are specified in the sentences below.

$$
\begin{aligned}
& \text { REPAP <--> (REPAP, *, *)/ } \\
& \operatorname{REPAP~<-->(RESOE,~*,~*)/~} \\
& \text { REPAP <--> (REINT, *, *)/ }
\end{aligned}
$$

Since the same variable, REPAP, is involved in all the three sentences, they can be combined into one sentence as shown below.

> REPAP <--> (REPAP, *, *) (RESOE, *, *) (REINT, *, *)/

When specifying covariance paths bear in mind that:

- Covariance paths can be specified in any order.
- Several covariance paths per sentence can be specified. For example, the variance of an exogenous variable as well as its covariance with other variables can be specified in the same sentence.
- If every endogenous manifest variable has a corresponding measurement error with an unconstrained variance, the coding of these variances can be omitted. When all error path coefficients are fixed, and no error variance paths are specified for the measurement errors, RAMONA will automatically provide the error variance paths.
- If there are exogenous manifest variables and if all their variances and covariances are present in the model and are unrestricted, the coding of these variance and covariance paths may be omitted. When no variance and covariance paths for exogenous manifest variables are specified, the RAMONA will automatically provide them.


### 6.2.3 DATA

The data must be provided last and are preceded by the key word DATA followed by the type of data ("RAW DATA", "COVARIANCE MATRIX" or "CORRELATION MATRIX") and an integer value of the number of cases on separate lines. If a distribution free analysis is required, the raw data must be provided. Otherwise the correlation or covariance matrix may be input. The correlation (covariance) matrix is provided in free format, one row at a time.

For the model depicted in Figure 1.2, the correlation matrix in Table 1.3, may be specified in the RAMONA input file as shown below.

## DATA

CORRELATION MATRIX

## 329

1.0000
0.18391 .0000
0.22200 .04891 .0000
0.41050 .21370 .40471 .0000
0.40430 .27420 .40470 .62471 .0000
0.33550 .07820 .23020 .29950 .28631 .000
0.10210 .11470 .09310 .07600 .07020 .20871 .0000
$\begin{array}{llllllllllllll}0.1861 & 0.0186 & 0.2707 & 0.2930 & 0.2407 & 0.2950 & -0.0438 & 1.0000\end{array}$
$\begin{array}{llllllllllll}0.2598 & 0.0839 & 0.2786 & 0.4216 & 0.3275 & 0.5007 & 0.1988 & 0.3607 & 1.0000\end{array}$
$\begin{array}{llllllllllllllllll}0.2903 & 0.1124 & 0.3054 & 0.3269 & 0.3669 & 0.5191 & 0.2784 & 0.4105 & 0.6404 & 1.0000\end{array}$

Any row of the matrix may be continued on the next line. This facility should be used when a row of the matrix requires more than 80 characters.

### 6.3 ILLUSTRATIVE EXAMPLE

The different sections of the input file discussed so far would be combined in the example that follows. The example is based on the model depicted in Figure 1.2. It is based on Jöreskog's (1997) path analysis model (Figure 5.6) for data of Duncan, Haller and Portes' (1971) Application.

### 6.3.1 VARIABLE NAMES

In Figure 1.2, the six manifest variables,
REPAP -- Respondents Parental Aspiration,
RESOE -- Respondents Socio-economic Status,
REINT -- Respondents Intelligence,
BFINT -- Best Friend's intelligence,
BFSOE -- Best Friend's Socio-economic Status and
BFPAP -- Best Friend's Parental Aspiration, are exogenous, and four,

REOAP -- Respondents Occupational Aspiration,
REEAP -- Respondents Educational Aspiration,
BFEAP -- Best Friend's Educational Aspiration and
BFOAP -- Best Friend's Occupational Aspiration,
are endogenous.

The Latent Variables
REAMB -- Respondent's Ambition and
BFAMB -- Best Friend's Ambition,
are endogenous, and the rest, $\mathrm{E} 1, \mathrm{E} 2, \mathrm{E} 3, \mathrm{E} 4, \mathrm{Z} 1$ and Z 2 are (exogenous) error variables.

### 6.3.2 INPUT FILE

A complete RAMONA input file therefore may be as shown below.

```
TITLE= Duncan, Haller and Portes Model;
    MANIFEST=REINT REPAP RESOE REOAP REEAP/
            BFINT BFPAP BFSOE BFOAP BFEAP;
    LATENT = REAMB BFAMB E1 E2 E3 E4 Z1 Z2;
    MODEL=
        REOAP <--: (REAMB,*,*) (E1,0,1.0)/
        REEAP <--: (REAMB,*,*) (E2,0,1.0)/
        BFEAP <--: (BFAMB,*,*) (E3,0,1.0)/
        BFOAP <--: (BFAMB,*,*) (E4,0,1.0)/
        REAMB <--: (BFAMB,*,*) (REPAP,*,*) (REINT,*,*) /
        REAMB <--: (RESOE,*,*) (BFSOE,*,*) (Z1,0,1.0) /
        BFAMB <--: (BFSOE,*,*) (BFINT,*,*) (BFPAP,*,*) /
        BFAMB <--: (REAMB,*,*) (RESOE,*,*) (Z2,0,1.0);
        REINT <--> (REINT,0,1.0) (RESOE,*,*) (REPAP,*,*)/
        REINT <--> (BFINT,*,*) (BFSOE,*,*) (BFPAP,*,*) /
        REPAP <--> (REPAP,0,1.0) (RESOE,*,*)/
        REPAP <--> (BFSOE,*,*) (BFINT,*,*) (BFPAP,*,*) /
        RESOE <--> (RESOE,0,1.0) /
        RESOE <--> (BFSOE,*,*) (BFINT,*,*) (BFPAP,*,*) /
        BFSOE <--> (BFSOE,0,1.0) (BFINT,*,*) (BFPAP,*,*)/
    BFINT <--> (BFINT,0,1.0) (BFPAP,*,*)/
    BFPAP <--> (BFPAP,0,1.0)/
    REAMB <--> (REAMB,0,1.0)/
    BFAMB <--> (BFAMB,0,1.0)/
    E1 <--> (E1,*,*)/
    E2 <--> (E2,*,*) /
    E3 <--> (E3,*,*)/
    E4 <--> (E4,*,*)/
    Z1 <--> (Z1,*,*)/
    Z2 <--> (Z2,*,*);
```

DATA
CORRELATION MATRIX
329
1.0000
0.18391 .0000
0.22200 .04891 .0000
0.41050 .21370 .40471 .0000
0.40430 .27420 .40470 .62471 .0000
$\begin{array}{llllll}0.3355 & 0.0782 & 0.2302 & 0.2995 & 0.2863 & 1.000\end{array}$
0.10210 .11470 .09310 .07600 .07020 .20871 .0000
$0.18610 .01860 .27070 .29300 .24070 .2950-0.04381 .0000$
$\begin{array}{llllllllll}0.2598 & 0.0839 & 0.2786 & 0.4216 & 0.3275 & 0.5007 & 0.1988 & 0.3607 & 1.0000\end{array}$
$\begin{array}{llllllllllll}0.2903 & 0.1124 & 0.3054 & 0.3269 & 0.3669 & 0.5191 & 0.2784 & 0.4105 & 0.6404 & 1.0000\end{array}$

### 6.3.3 RUNNING RAMONA

To run RAMONA:

- Double click on the RAMONA icon. This action will open the window below.

by
Michael W. Browne and Gerhard Mels
- Click on the RAMONA "File" Menu. This will display the window below.

- Click on the "Input File" option of the RAMONA "File" menu. This action will open the dialog box below.

- Specify the name of the RAMONA Input File by either double clicking on an existing filename or typing the name into the "File name" string field. Click on the "Open" push button when you're done.
- Click on the RAMONA "File" Menu again and select the "Output File" Option. This action will open the following dialog box.

- $\quad$ Specify the name of the RAMONA Output File by either double clicking on an existing filename or typing the name into the "File name" string field and click the "Open" push button.
- Click on the "Analysis" menu of RAMONA to display the window below.

- Click on the "Enter Setup" option of the "Analysis" Menu to activate the "SETUP" dialog box as shown below.

- The dialog box requests the user to specify the various options for the analysis.
- The options are specified by clicking on the various menu fields in the dialog box and then selecting the appropriate option.

Detail descriptions of each of the options follow:

## ANALYSIS

- This option is used to specify the matrix to which the model must be fitted.
- The alternatives available are Covariance Matrix and Correlation Matrix.


## ESTIMATION METHOD

- This option specifies the method of estimation to be used by RAMONA.
- The alternatives available are MWL, GLS, OLS, TGLS, TSLS, ADFG, and ADFU. Each of these is an abbreviation and their full meanings are provided below.
- MWL - Maximum Wishart Likelihood.
- GLS - Generalized Least Squares assuming Wishart distribution for the sample covariance matrix S.
- OLS - Ordinary Least Squares.
- TGLS - True Generalized Least Squares.
- TSLS - Two Stage Least Squares.
- ADFG - an Asymptotically Distribution Free procedure which uses a biased but Gramian (non-negative definite) estimate of the asymptotic covariance matrix, $\Gamma$, of the elements of the sample covariance matrix.
- ADFU - an Asymptotically Distribution Free procedure which uses an Unbiased estimate of the asymptotic covariance matrix, $\Gamma$.
- Default is MWL.


## INITIAL ESTIMATES

- The alternatives for this option are ROUGH and CLOSE.
- If ROUGH is chosen the initial iterations are OLS. After partial convergence, the program switches to the procedure specified by the METHOD option.
- If CLOSE is used the estimation procedure specified by the METHOD option is employed from the start of the iterative procedure.
- The default is ROUGH. This means that if neither ROUGH nor CLOSE is specified the program takes the ROUGH alternative.


## OUTPUT

- This option is used to restrict the amount of output of RAMONA.
- The alternatives available are COMPLETE RAMONA RESULTS, COMPLETE SEM RESULTS or BASIC SEM RESULTS.

If the option "COMPLETE RAMONA RESULTS" is chosen the following information are provided as output.
(a) The job specification system.
(b) Details of the iterative procedure.
(c) The sample covariance or correlation matrix.
(d) The reproduced covariance or correlation matrix.
(e) The matrix of residuals.
(f) A table consisting of path coefficient estimates, $90 \%$ confidence intervals, standard errors and t -statistics (estimate divided by standard error).
(g) A table consisting of variance and covariance or correlation estimates, $90 \%$ confidence intervals, standard errors and $t$ statistics.
(h) Information about equality constraints on variances (if applicable).
(i) Measures of fit of the model.
(j) The asymptotic correlation matrix of the estimators.

If "COMPLETE SEM RESULTS" is chosen, ( j ) is omitted from the list above. If "BASIC SEM RESULTS" is chosen, (b), (d), (e), (h) and (j) are omitted. The default is COMPLETE SEM RESULTS.

## CONVERGENCE

- This option specifies the tolerance limit for the residual cosine employed by the program as a convergence criterion.
- It also controls the number of decimal places provided during output of estimates. If CONVERGENCE $=0.1 \times 10^{\mathrm{k}}$ then k decimal places are provided.
- The default is 0.0001 .


## ITERATIONS

- This option allows the user to specify the maximum number of iterations allowed for the iterative procedure.
- $\quad$ The default value is 100 .


## RESTART FILE

A text file with the same filename as the RAMONA Input File and with extension .RST, that is a duplicate of the RAMONA Input file in which the original parameter estimates are replaced by the final parameter estimates, is created if the "Restart File" check box is activated. Otherwise, this file is not created.

After selecting the required option(s) click on the "Run RAMONA" push button. If there are no syntax errors in the input file, then iteration will proceed. When the iterations are completed, the message box

appears.

### 6.5 THE RAMONA OUTPUT FILE

(1)


## (2)

DATE OF ANALYSIS: November 14, 1998
TIME OF ANALYSIS: 13H29:53
INPUT FILE: C: \RAMONA90\Eg-(9).ram

## (3)

```
TITLE= Duncan, Haller and Portes Model;
MANIFEST=REINT REPAP RESOE REOAP REEAP/
                    BFINT BFPAP BFSOE BFOAP BFEAP;
LATENT = REAMB BFAMB E1 E2 E3 E4 Z1 Z2;
MODEL=
    REOAP <--: (REAMB,*,*) (E1,0,1.0)/
    REEAP <--: (REAMB,*,*) (E2,0,1.0)/
    BFEAP <--: (BFAMB,*,*) (E3,0,1.0)/
    BFOAP <--: (BFAMB,*,*) (E4,0,1.0)/
    REAMB <--: (BFAMB,*,*) (REPAP,*,*) (REINT,*,*) /
    REAMB <--: (RESOE,*,*) (BFSOE,*,*) (Z1,0,1.0) /
    BFAMB <--: (BFSOE,*,*) (BFINT,*,*) (BFPAP,*,*) /
    BFAMB <--: (REAMB,*,*) (RESOE,*,*) (Z2,0,1.0);
    REINT <--> (REINT,0,1.0) (RESOE,*,*) (REPAP,*,*)/
    REINT <--> (BFINT,*,*) (BFSOE,*,*) (BFPAP,*,*) /
    REPAP <--> (REPAP,0,1.0) (RESOE,*,*)/
    REPAP <--> (BFSOE,*,*) (BFINT,*,*) (BFPAP,*,*) /
    RESOE <--> (RESOE,0,1.0) /
    RESOE <--> (BFSOE,*,*) (BFINT,*,*) (BFPAP,*,*) /
    BFSOE <--> (BFSOE,0,1.0) (BFINT,*,*) (BFPAP,*,*)/
    BFINT <--> (BFINT,0,1.0) (BFPAP,*,*)/
    BFPAP <--> (BFPAP,0,1.0)/
    REAMB <--> (REAMB,0,1.0)/
    BFAMB <--> (BFAMB,0,1.0)/
    E1 <--> (E1,*,*) /
    E2 <--> (E2,*,*)/
    E3 <--> (E3,*,*)/
    E4 <--> (E4,*,*)/
    Z1 <--> (Z1,*,*)/
    Z2 <--> (Z2,*,*);
```

(4)

| Iter | Method | Discr. Funct. | Max.R.Cos. | Max. Const. | NRP | NBD | Seconds |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0 | GLS | 0.63750829 |  | 0.000000 |  |  | 0.0 |
| 0 | MWL | 1.69249617 |  | 0.000000 |  |  | 0.1 |
| 1(0) | MWL | 0.27613818 | 0.294233 | 0.171670 | 0 | 0 | 0.1 |
| 2 (0) | MWL | 0.11111666 | 0.315088 | 0.122364 | 0 | 0 | 0.1 |
| $3(0)$ | MWL | 0.08218301 | 0.028722 | 0.007193 | 0 | 0 | 0.1 |
| 4(0) | MWL | 0.08193177 | 0.003176 | 0.000082 | 0 | 0 | 0.1 |
| $5(0)$ | MWL | 0.08192882 | 0.000485 | 0.000002 | 0 | 0 | 0.1 |
| 6 (0) | MWL | 0.08192872 | 0.000129 | 0.000000 | 0 | 0 | 0.1 |
| 7 (0) | MWL | 0.08192871 | 0.000021 | 0.000000 | 0 | 0 | 0.1 |
| 8 (0) | MWL | 0.08192871 | 0.000006 | 0.000000 | 0 | 0 | 0.1 |

TOLERANCE LIMIT FOR RESIDUAL COSINES $=0.000100$ ON 2 CONSECUTIVE ITERATIONS
TOLERANCE LIMIT FOR VARIANCE CONSTRAINT VIOLATIONS $=0.500000 \mathrm{E}-06$
VALUE OF THE MAXIMUM VARIANCE CONSTRAINT VIOLATION $=0.346660 \mathrm{E}-10$

## (5)

| REINT | REPAP | RESOE | REOAP | REEAP | BFINT | BFPAP | BFSOE | BFOAP BFEAP |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| REINT | 1.000 |  |  |  |  |  |  |  |  |  |
| REPAP | 0.184 | 1.000 |  |  |  |  |  |  |  |  |
| RESOE | 0.222 | 0.049 | 1.000 |  |  |  |  |  |  |  |
| REOAP | 0.411 | 0.214 | 0.324 | 1.000 |  |  |  |  |  |  |
| REEAP | 0.404 | 0.274 | 0.405 | 0.625 | 1.000 |  |  |  |  |  |
| BFINT | 0.336 | 0.078 | 0.230 | 0.300 | 0.286 | 1.000 |  |  |  |  |
| BFPAP | 0.102 | 0.115 | 0.093 | 0.076 | 0.070 | 0.209 | 1.000 |  |  |  |
| BFSOE | 0.186 | 0.019 | 0.271 | 0.293 | 0.241 | 0.295 | -0.044 | 1.000 |  |  |
| BFOAP | 0.260 | 0.084 | 0.279 | 0.422 | 0.328 | 0.500 | 0.199 | 0.361 | 1.000 |  |
| BFEAP | 0.290 | 0.112 | 0.305 | 0.327 | 0.367 | 0.519 | 0.278 | 0.411 | 0.640 | 1.000 |

NUMBER OF CASES = 329
(6)

REINT REPAP RESOE REOAP REEAP BFINT BFPAP BFSOE BFOAP BFEAP
REINT 1.000
REPAP $0.184 \quad 1.000$
RESOE $0.222 \quad 0.049 \quad 1.000$

| REOAP | 0.393 | 0.240 | 0.357 | 1.000 |
| :--- | :--- | :--- | :--- | :--- |


| REEAP | 0.417 | 0.254 | 0.379 | 0.624 | 1.000 |
| :--- | :--- | :--- | :--- | :--- | :--- |

$\begin{array}{llllll}\text { BFINT } & 0.336 & 0.078 & 0.230 & 0.258 & 0.274 \\ 1.000\end{array}$

| BFPAP | 0.102 | 0.115 | 0.093 | 0.103 | 0.110 | 0.209 | 1.000 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |


| BFSOE | 0.186 | 0.019 | 0.271 | 0.255 | 0.270 | 0.295 | -0.044 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1.000 |  |  |  |  |  |  |  |

$\begin{array}{lllllllll}B F O A P & 0.254 & 0.095 & 0.282 & 0.330 & 0.351 & 0.489 & 0.237 & 0.374 \\ 1.000\end{array}$

| BFEAP | 0.273 | 0.102 | 0.303 | 0.355 | 0.377 | 0.525 | 0.254 | 0.401 | 0.640 | 1.000 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

## (7)

REINT REPAP RESOE REOAP REEAP BFINT BFPAP BFSOE BFOAP BFEAP
REINT 0.000
REPAP 0.0000 .000
RESOE $0.000 \quad 0.000 \quad 0.000$
REOAP $0.017-0.026-0.033 \quad 0.000$
REEAP-0.013 $0.020 \quad 0.025 \quad 0.001 \quad 0.000$
$\begin{array}{llllll}\text { BFINT } 0.000 & 0.000 & 0.000 & 0.042 & 0.013 & 0.000\end{array}$
BFPAP $0.000 \quad 0.000 \quad 0.000-0.027-0.039 \quad 0.000 \quad 0.000$
BFSOE $0.000 \quad 0.000 \quad 0.000 \quad 0.038 \quad-0.030 \quad 0.000 \quad 0.000 \quad 0.000$
BFOAP 0.005-0.011-0.004 0.091 -0.023 0.011-0.038-0.013 0.000
BFEAP $0.017 \quad 0.010 \quad 0.002-0.028-0.010-0.0060 .024 \quad 0.009 \quad 0.001 \quad 0.000$

VALUE OF THE MAXIMUM ABSOLUTE RESIDUAL $=0.091$

|  | PATH | NUMBER OF PARAMETER | POINT <br> ESTIMATE | $90 \%$ CONFIDENCEINTERVAL |  |  | STANDARD ERROR | $\begin{gathered} \text { T } \\ \text { VALUE } \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REOAP | <--: REAMB | 1 | 0.766 | 0.710 | ; | $0.823)$ | 0.035 | 22.21 |
| REEAP | <--: REAMB | 2 | 0.814 | ( 0.759 | ; | 0.868) | 0.033 | 24.52 |
| BFEAP | <--: BFAMB | 3 | 0.829 | ( 0.781 | ; | 0.877) | 0.029 | 28.49 |
| BFOAP | <--: BFAMB | 4 | 0.772 | ( 0.720 |  | 0.823) | 0.031 | 24.72 |
| REAMB | <--: BFAMB | 5 | 0.175 | ( 0.033 | ; | 0.317) | 0.086 | 2.03 |
| REAMB | <--: REPAP | 6 | 0.214 | ( 0.133 | ; | $0.294)$ | 0.049 | 4.36 |
| REAMB | <--: REINT | 7 | 0.332 | ( 0.248 | ; | 0.417) | 0.051 | 6.47 |
| REAMB | <--: RESOE | 8 | 0.290 | 0.201 | ; | 0.378) | 0.054 | 5.39 |
| REAMB | <--: BFSOE | 9 | 0.103 | ( 0.002 |  | $0.204)$ | 0.061 | 1.69 |
| BFAMB | <--: BFSOE | 10 | 0.282 | ( 0.200 |  | $0.365)$ | 0.050 | 5.62 |
| BFAMB | <--: BFINT | 11 | 0.427 | ( 0.349 | ; | 0.505) | 0.048 | 8.98 |
| BFAMB | <--: BFPAP | 12 | 0.197 | ( 0.121 |  | 0.273) | 0.046 | 4.27 |
| BFAMB | <--: REAMB | 13 | 0.184 | ( 0.055 |  | 0.313) | 0.078 | 2.35 |
| BFAMB | <--: RESOE | 14 | 0.087 | (-0.005 | ; | 0.179) | 0.056 | 1.55 |

## (9)

| VARIABLE | ESTIMATE |
| :--- | :---: |
| ------- | ----- |
| REOAP | 1.000 |
| REEAP | 1.000 |
| BFOAP | 1.000 |
| BFEAP | 1.000 |
| REPAP | 1.000 |
| BFINT | 1.000 |
| BFPAP | 1.000 |
| BFSOE | 1.000 |
| RESOE | 1.000 |
| REINT | 1.000 |

## (10)

|  | PATH | VALUE |
| :---: | :---: | :---: |
| REOAP | <--: E1 | 1.000 |
| REEAP | <--: E2 | 1.000 |
| BFEAP | <--: E3 | 1.000 |
| BFOAP | <--: E4 | 1.000 |
| REAMB | <--: Z1 | 1.000 |
| BFAMB | <--: Z2 | 1.000 |


| PATH |  | NUMBER OF PARAMETER | POINT <br> ESTIMATE | 90\% CONFIDENCE INTERVAL |  | STANDARD ERROR | $\begin{gathered} \text { T } \\ \text { VALUE } \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| REINT | <--> RESOE | 15 | 0.222 | 0.136 | 0.308) | 0.052 | 4.23 |
| REINT | <--> REPAP | 16 | 0.184 | 0.096 | 0.272) | 0.053 | 3.45 |
| REINT | <--> BFINT | 17 | 0.336 | 0.255 | 0.416) | 0.049 | 6.85 |
| REINT | <--> BFSOE | 18 | 0.186 | 0.098 | 0.274) | 0.053 | 3.49 |
| REINT | <--> BFPAP | 19 | 0.102 | 0.012 | $0.192)$ | 0.055 | 1.87 |
| REPAP | <--> RESOE | 20 | 0.049 | -0.042 | 0.140) | 0.055 | 0.89 |
| REPAP | <--> BFSOE | 21 | 0.019 | -0.072 | 0.109) | 0.055 | 0.34 |
| REPAP | <--> BFINT | 22 | 0.078 | -0.012 | 0.168) | 0.055 | 1.42 |
| REPAP | <--> BFPAP | 23 | 0.115 | 0.025 | $0.204)$ | 0.054 | 2.10 |
| RESOE | <--> BFSOE | 24 | 0.271 | 0.187 | 0.355) | 0.051 | 5.29 |
| RESOE | <--> BFINT | 25 | 0.230 | 0.144 | 0.316) | 0.052 | 4.40 |
| RESOE | <--> BFPAP | 26 | 0.093 | 0.003 | 0.183) | 0.055 | 1.70 |
| BFSOE | <--> BFINT | 27 | 0.295 | 0.212 | 0.378) | 0.050 | 5.85 |
| BFSOE | <--> BFPAP | 28 | -0.044 | -0.134 | $0.047)$ | 0.055 | -0.79 |
| BFINT | <--> BFPAP | 29 | 0.209 | 0.122 | $0.296)$ | 0.053 | 3.95 |
| E1 | <--> E1 | 30 | 0.413 | 0.334 | 0.510) | 0.053 | 7.80 |
| E2 | <--> E2 | 31 | 0.338 | 0.259 | 0.439) | 0.054 | 6.25 |
| E3 | <--> E3 | 32 | 0.313 | 0.243 | 0.403) | 0.048 | 6.50 |
| E4 | <--> E4 | 33 | 0.404 | 0.332 | $0.492)$ | 0.048 | 8.40 |
| Z1 | <--> Z1 | 34 | 0.480 | 0.390 | 0.570) | 0.055 | 8.64 |
| Z2 | <--> Z2 | 35 | 0.385 | 0.305 | 0.471) | 0.051 | 7.60 |

## (12)

| PATH |  | VALUE |
| :---: | :---: | :---: |
| REINT | <--> REINT | 1.000 |
| REPAP | <--> REPAP | 1.000 |
| RESOE | <--> RESOE | 1.000 |
| BFSOE | <--> BFSOE | 1.000 |
| BFINT | <--> BFINT | 1.000 |
| BFPAP | <--> BFPAP | 1.000 |

## (13)

| CONSTRAINT |  | VALUE | LAGRANGE MULTIPLIER | STANDARD ERROR |
| :---: | :---: | :---: | :---: | :---: |
| REAMB | <--> REAMB | 1.0000 | 0.0000 | 0.0000 |
| BFAMB | <--> BFAMB | 1.0000 | 0.0000 | 0.0000 |
| REOAP | <--> REOAP | 1.0000 | 0.0000 | 0.0000 |
| REEAP | <--> REEAP | 1.0000 | 0.0000 | 0.0000 |
| BFOAP | <--> BFOAP | 1.0000 | 0.0000 | 0.0000 |
| BFEAP | <--> BFEAP | 1.0000 | 0.0000 | 0.0000 |

## (14)

| Sample Discrepancy Function Value (I) :0.082 ( 0.819287E-01) |  |
| :---: | :---: |
| Population Discrepancy Function Value, Fo |  |
| Bias Adjusted Point Estimate | (II) : 0.033 |
| 90 Percent Confidence Interval | (III) : 0.001 ; 0.089) |
| Root Mean Square Error of Approximation Steiger-Lind : RMSEA = SQRT (Fo/DF) |  |
| Point Estimate | (IV) : 0.046 |
| 90 Percent Confidence Interval | (V) : 0.008 ; 0.075) |
| Expected Cross-Validation Index |  |
| Point Estimate (Modified AIC) | (VI) : 0.320 |
| 90 Percent Confidence Interval | (VII) : 0.288 ; 0.376) |
| ECVI (MODIFIED AIC) for the Saturated Model | (VIII) : 0.335 |
| Test Statistic | (IX) : 26.87 |
| Exceedance Probabilities:- |  |
| Ho: Perfect Fit (RMSEA $=0.0$ ) | (X) : 0.043 |
| Ho: Close Fit (RMSEA <= 0.050) | (XI) : 0.561 |
| Multiplier for obtaining Test Statistic = | 328.0 |
| Degrees of Freedom $=16$ |  |
| Effective Number of Parameters = 39 |  |

## (15)



## (16)



## (17)

| LISREL GFI | : 0.984 |
| :---: | :---: |
| LISREL Adjusted GFI | 0.946 |
| Mulaik Parsimonious GFI | 0.350 |
| Schwarz Bayesian Criterion | : 0.769 |
| Browne-Cudeck Single Sample CVI | 0.326 |
| Bentler-Bonett Normed Fit Index | $: 0.970$ |
| Bentler-Bonett Non-Normed Fit Index | : 0.966 |
| Bentler Comparative Fit Index (CFI) | : 0.988 |
| McDonald-Marsh Relative Noncentrality Index (RNI) | : 0.988 |
| James-Mulaik-Brett Parsimonious Normed Fit Index | $: 0.345$ |
| James-Mulaik-Brett Parsimonious CFI | : 0.351 |
| Bollen Rho (RFI) | : 0.916 |
| Bollen Delta (IFI) | : 0.988 |
| Tucker-Lewis Index (TLI) | : 0.966 |
| McDonald Index for Noncentrality | $: 0.985$ |
| Root Mean Squared Residual (RMR) | $: 0.020$ |
| Standardised Root Mean Squared Residual (SRMR) | 0.020 |

## ENTRIES IN THE RAMONA OUTPUT FILE.

(1) RAMONA For Windows. This gives the full name of the Program and the authors of the Program.
(2) Date and time of Analysis and the Input File name.
(3) Model information
(4) Details of Iterations.

Column 1: The iteration number.
Column 2: The method used for the estimation of the parameters.
Column 3: The discrepancy function value $\mathrm{F}(\underline{\hat{\theta}})$, where $\underline{\hat{\theta}}$ is the estimate of the parameter vector $\underline{\theta}$.

Column 4: The maximum residual cosine.
Column 5: The maximum absolute constraint value.
Column 6: Number of redundant parameters.
Column 7: The number of parameters on the bound. For example, for a correlation the upper and lower bounds are -1 and +1 respectively.
(5) Sample Correlation Matrix.

The Sample correlation matrix, $\mathbf{R}_{(\mathrm{kxk})}$, of the manifest variables $\mathrm{X}_{1}, \mathrm{X}_{2}, \ldots, \mathrm{X}_{\mathrm{k}}$ is computed from a raw data matrix $\mathbf{X}_{(\mathrm{nxk})}$ as

$$
\mathbf{R}=\frac{1}{n-1} \sum_{i=1}^{n} z_{i} z_{i}^{\prime}
$$

where $z_{i}$ denotes the ith standardized observation, i.e.

$$
z_{i}=\mathbf{D}_{\underline{\mathbf{s}}}{ }^{-1}(\underset{-i}{x}-\bar{x})
$$

where $\mathbf{D}_{\mathbf{s}}$ denotes a diagonal matrix with the sample standard deviations of $X_{1}, X_{2}, \ldots, X_{k}$ on the diagonal.
(6) Reproduced Correlation Matrix.

This is the estimated correlation structure (model) $\mathrm{P}(\underline{\hat{\theta}})$.
(7) Residual Matrix (Correlation).

This is the difference between the sample correlation matrix and the reproduced correlation matrix.
(8) Maximum Wishart Likelihood Estimates of Free Parameters in Dependence Paths.

Column 1: The dependence path.
Column 2: Parameters number.
Column 3: Point estimate of the parameter.
Column 4: The $90 \%$ confidence interval estimate of the parameter.
Column 5: The standard error of the estimator of the parameter.
Column 6: The t test statistic, which is the ratio of the estimate and the standard error.
(9) Scaled Standard Deviations (Nuisance Parameters).

Column1: The manifest variable.
Column2: Estimate of the scaled standard deviation.
(10) Values of Fixed Parameters in dependence paths.

A list of the dependence paths with parameter number zero and their values.
(11) Maximum Wishart Likelihood Estimates of Free Parameters in Variance/Covariance Paths.

Column1: Variance/Covariance path.
Column 2: Parameters number.
Column 3: Point estimate of the parameters.
Column 4: The $90 \%$ confidence interval estimate of the parameter.
Column 5: The standard error of the estimator of the parameter.
Column 6: The t test statistic, which is the ratio of the estimate and the standard error.
(12) Values of Fixed Parameters in Variance/Covariance Paths.

A list of the variance/covariance paths with parameter number zero and their values.
(13) Equality Constraints On Variances.

Column1: The variance path of the constraint.
Column2: Value of the constraint.
Column3: Lagrange multiplier.
Column4: Standard error of Lagrange multiplier.

Measures of Fit of the model.
(I) The minimal sample discrepancy function value is given by

$$
\hat{F}=\min _{\gamma} \mathrm{F}(\mathbf{S}, \boldsymbol{\Sigma}(\gamma))
$$

(II) The unbiased point estimator of the population discrepancy function value $F_{\mathrm{o}}$ is given by (Browne \& Mels, 1996)

$$
\hat{F}_{o}=\operatorname{Max}\{F-\hat{d} / n, 0\}
$$

where the discrepancy function $F$ is given by

$$
\mathrm{F}(\mathrm{~S}, \Sigma)=\operatorname{In}|\Sigma|-\operatorname{In}|\mathrm{S}|+\operatorname{tr}\left[\mathrm{S} \Sigma^{-1}\right]-\mathrm{p}
$$

where S is the sample covariance matrix,
$\Sigma$ is the covariance structure and
p is the number of variables.
(III) A $90 \%$ confidence interval on $F_{\mathrm{o}}$ is given by (Browne \& Mels, 1996)

$$
\left(\mathrm{n}^{-1} \delta_{L} ; \mathrm{n}^{-1} \delta_{U}\right)
$$

where $\delta_{L}$, the lower limit, is the solution of $\delta$ of the equation

$$
\Phi(x / \delta, d)=0.95
$$

and $\delta_{U}$, the upper limit, is the solution for $\delta$ of

$$
\Phi(x / \delta, d)=0.05
$$

where $\Phi(x / \delta, d)$ is the cumulative distribution function of a noncentral Chi-squared distribution with noncentrality parameter $\delta$ and $d$ degrees of freedom.
(IV) An estimate of the Steiger-Lind Root Mean Square Error of Approximation RMSEA is given by (Steiger \& Lind, 1980)

$$
\text { RMSEA }=\sqrt{\frac{\hat{F}}{d}}
$$

(V) A $90 \%$ confidence interval of the RMSEA is given by (Browne \& Mels, 1996)

$$
\text { Interval Estimate }(\mathrm{RMSEA})=\left(\sqrt{\frac{\delta_{L}}{n d}} ; \sqrt{\frac{\delta_{U}}{n d}}\right)
$$

where n is the sample size.
(VI) A point estimate of the Expected Cross Validation Index (ECVI) is given by (Browne \& Cudeck, 1993)

$$
\text { Estimate }(\mathrm{ECVI})=\hat{F}+2 q / n
$$

(VII) An approximate $90 \%$ confidence interval on the ECVI is given by (Browne \& Cudeck, 1993)

$$
\text { Interval Estimate }(\mathrm{ECVI})=\left(\frac{\delta_{L}+d+2 q}{n} ; \frac{\delta_{U}+d+2 q}{n}\right)
$$

(VIII) The ECVI of the saturated model where no structure is imposed on $\sum$ is given by (Browne \& Cudeck, 1993)

$$
\operatorname{ECVI}(\text { Saturated model })=\frac{2 x(d+q)}{n}
$$

(IX) The test statistic is calculated as $n \times \hat{F}$.
(X) The exceedance probability for the test of the point hypothesis,

$$
\mathrm{H}_{0}: F_{o}=0
$$

is given by (Browne \& Mels, 1996)

$$
1-\Phi(n \hat{n F \mid 0, d})
$$

where $\Phi(\cdot)$ is the cumulative distribution function of a noncentral chi-squared distribution with noncentrality parameter $\delta$ and $d$ degrees of freedom.
(XI) The exceedance probability for the test of an interval hypothesis of close fit,

$$
\mathrm{H}_{0}: \mathrm{RMSEA} \leq 0.05
$$

which implies that $\delta \leq \delta^{*}=n x d x 0.05^{2}$, is given by (Browne \& Mels, 1996)

$$
1-\Phi\left(n F \mid \hat{\delta}^{*}, d\right)
$$

Extended Measures Of Fit Of The Model.
(I) LISREL Goodness of Fit Index (GFI) is given by (Bentler 1983; Jöreskog \& Sörbom, 1981) by

$$
\mathrm{GFI}=1-\frac{\operatorname{tr}\left(\left[\left\{G\binom{\hat{\theta}}{-}\right\}^{-1} S-I_{P}\right]^{2}\right)}{\operatorname{tr}\left(\left[\left\{G\binom{\hat{\theta}}{-}\right\}^{-1} S\right]^{2}\right)}
$$

where $\boldsymbol{I}_{\boldsymbol{p}}$ is a $\mathbf{p x p}$ identity matrix.
(II) Lisrel Adjusted GFI:

The Adjusted Goodness of fit Index is computed from Jöreskog \& Sörbom 1981:

$$
\mathrm{AGFI}=1-(1-\mathrm{GFI})
$$

(III) Mulaik Parsimonious (GFI) is computed from (James-Mulaik-Brett)

$$
\pi_{k}=\frac{v_{k}}{v_{o}} N F I
$$

where $v_{k}=$ degrees of freedom for the k 'th model,
$v_{o}=$ degrees of freedom for the "Null Model and NFI is the Bentler-Bonett Normed Fit Index given in (VI) below.
(IV) Schwarz Bayesian Criterion is given by (Schwarz, 1978)

$$
S_{k}=F_{M L, k}+\frac{f_{k} \operatorname{In}(N)}{N-1}
$$

where $F_{M L, k}$ is the maximum likelihood discrepancy function, $f_{k}$ is the number of free parameters for the model and $N$ is the sample size.
(V) Browne-Cudeck Single sample CVI is computed from (Browne \& Cudeck, 1989)

$$
C_{k}=\mathrm{F}_{\mathrm{ML}}\left(\mathbf{S}_{\mathrm{v}}, \sum_{k}(\theta)\right)+\frac{2 v_{k}}{N-p-2}
$$

where $v_{k}$ is the number of free parameters in model $\mathrm{k}, \mathrm{p}$ is the number of manifest variables, and $N$ is the sample size.
(VI) Bentler-Bonett Normed Fit Index(NFI) is given by (Bentler, 1995)

$$
\mathrm{NFI}=1-\frac{F(\hat{\theta})}{F\left(\hat{\theta_{I}}\right)}
$$

where ${\underset{-I}{ }}_{\hat{\theta}}$ denotes the estimate of the unknown parameter of the independence model.
(VII) The nonnormed Bentler-Bonnett Fit Index is given by (Bentler, 1995)

$$
\mathrm{NNFI}=\frac{(n-1) F(\underset{-}{\hat{\theta}}) / d_{I}-(n-1) F(\underset{-}{\hat{\theta}}) / d}{(n-1) F(\underset{-}{\hat{\theta}}) / d_{I}-1}
$$

where $d_{I}=p(p-1) / 2$ denotes the degrees of freedom of the independence model.
(VIII) The Bentler Comparative Fit Index CFI is given by (Bentler, 1995)

$$
\mathrm{CFI}=1-\frac{\max \left\{(n-1) F\binom{\hat{\theta}}{-}-d, 0\right\}}{\max \left\{(n-1) F\left(\hat{\theta_{-}}\right)-d_{I}, 0\right\}}
$$

(IX) McDonald's Index for Noncentrality is given by (Bentler, 1995)

$$
\mathrm{MFI}=\exp \left\{-\frac{n}{2}\left[(n-1) F\binom{\hat{\theta}}{-}-d\right]\right\}
$$

(X) The Root Mean Square Residual(RMR) is computed from (Bentler 1995)

$$
\mathrm{RMR}=\sqrt{\frac{2}{p(p+1)} \sum_{i=1}^{p} \sum_{j=1}^{i}\left(S_{i j}-g_{i j}(\hat{\theta})\right)^{2}}
$$

while the Standardized Root Mean Squared Residual(SRMR) is computed as (Bentler 1995)

$$
\operatorname{SRMR}={\left.\sqrt{\frac{2}{p(p+1)} \sum_{i=1}^{p} \sum_{j=1}^{i}\left(\left[S_{i j}-g_{i j}(\hat{\theta}) / \sqrt{S_{i i} S_{i j}}\right]\right.}\right)^{2}}^{2}
$$

(16) Generalized Least Squares Discrepancy Function - Measures Of Fit Of The Model.

These are the measures of fit of the model for Generalized Least Squares Methods. The entries are similar to those described under the Maximum Wishart Likelihood method above, i.e. (14) above.
(17) Extended Measures Of Fit Of The Model.

These are the extended measures of fit values obtained by using the Generalized Least Squared methods. The entries are similar to those described under (15) above.

## CHAPTER 7

SEPATH

### 7.1 HISTORICAL BACKGROUND

Steiger (1989) developed the structural equation modeling program EzPATH as a module of the statistical software package SYSTAT. This program was strongly influenced by Steiger's ideas for user-machine communication. Steiger left SYSTAT and joined forces with the statistical software package STATISTICA to develop the structural equation modeling program known as SEPATH (Steiger, 1995) for Windows. The acronym SEPATH stands for Structural Equations and PATH analysis. This program is strongly influenced by the conventions used in RAMONA and by the ideas contained in Mels (1988).

Steiger used the ASCII symbols -> for dependence paths and -- for variance/covariance paths to create ASCII representations for the path diagrams of Structural Equation Models. These symbols, -> and -- are called arrow and wire respectively.

SEPATH is intended for users with knowledge of latent variable modeling but can be employed by researchers with no mathematical background. The user only needs to know how to formulate a model in the form of a path diagram. Knowledge of matrix algebra is not essential.

### 7.2 THE SEPATH INPUT SYSTEM

The SEPATH input system consists of a data file and a model file.

### 7.2.1 SEPATH DATA FILE

The SEPATH data file is a STATISTICA data file. The STATISTICA data file is a STATISTICA workbook in which the rows and columns refer to the cases and the variables, respectively, of the
data. The data may be raw data, a covariance matrix or a correlation matrix. It can be created in STATISTICA or imported from other files such as MICROSOFT EXCEL files and then saved as STATISTICA data file with extension "STA".

If the data is a covariance or correlation matrix, only the entries in the lower triangle of the matrix are entered. Entering a number at the case name "MATRIX" specifies the type of matrix. The number 1.0000 specifies a covariance matrix whereas the number 4.0000 specify a correlation matrix. The number of cases is also specified as part of the data. The number is typed in the first cell next to case name "No. of Cases" in the data matrix.

### 7.2.2 SEPATH MODEL FILE

The model file is a text file with the extension ".CMD" and is used to specify the structural equation model by means of a text path diagram by using the PATH1 language. The path diagram of the model is coded directly with the use of the ASCII symbols --> (for dependence paths) and -- (for variance/covariance paths). The Model File can be typed manually in any text editor and then imported into STATISTICA. The Model File may also be created in STATISTICA by using the "Path Construction Tool". For specific models such as Confirmatory Factor Analysis (CFA) the model file may be created using the "Path Wizards".

## GENERAL RULES FOR SEPATH MODEL FILES

- Each arrow and wire is represented on a separate line.
- Blanks never count. They are stripped from the line before parsing.
- Blank lines, and any lines beginning with an * (asterisk), are treated as comment lines, and are not analyzed as PATH1 statements.
- Manifest variable names are represented as the FULL variable name enclosed within brackets. The name enclosed in the brackets must not be more than 8 alphanumeric characters in length. Characters must be upper case. The underscore character "_" is also allowed.

$$
\begin{aligned}
\text { Examples. } & {[\text { REOAP }] } \\
\text { or } & {[\text { RE_OAP }] }
\end{aligned}
$$

- Latent variable names are represented by a variable name in parentheses. The name can be up to 20 characters in length. Upper and lower case characters are allowed. Underscores are allowed, but dashes are not allowed.

$$
\begin{array}{ll}
\text { Examples. } & \text { (REAMB) } \\
\text { or } & (\text { REA_M) } \\
\text { or } & (\text { rea_m })
\end{array}
$$

- The syntax for dependence paths is given by

$$
\text { VNAME1-<\#1>\{<\#2>\}->VNAME2 }
$$

where VNAME1 and VNAME2 are valid manifest or latent variable names, <\#1> is an integer representing the coefficient number, and <\#2> is a real value representing the start value. <\#1> is required if the path has a coefficient which is a free parameter. If the coefficient is a fixed value, <\#1> is omitted. Otherwise, <\#1> is the integer value for the parameter number. It must be between 1 and 30000 in value. If the coefficient for the arrow is a free parameter, then $\langle \# 2\rangle$ is the starting value used during iteration. If the coefficient is fixed, then <\#2> represents the fixed value. If both <\#1> and <\#2> are omitted, then the path is assumed to have a fixed coefficient with a value of 1 .

For the model, depicted in Figure 1.2, the endogenous variable REOAP receives single headed arrows from the latent variable REAMB and a measurement error E1. These paths are displayed in Figure 8.1 below.


Figure 7.1 Dependence paths between REOAP, E1 AND REAMB.

These dependence paths are coded as:

$$
\begin{aligned}
& \text { (REAMB)-1->[REOAP] } \\
& (\mathrm{E} 1)->[\mathrm{REOAP}]
\end{aligned}
$$

If VNAME1 is omitted, then the program will find the last preceding line with two variable names and use the first variable name as VNAME1.

- Variance/covariance paths are entered by using the syntax

$$
\text { VNAME1-<\#1>\{\#2\}-VNAME2 }
$$

where VNAME1, VNAME2, <\#1> and <\#2> are the same as in the preceding section.
For the model, depicted in Figure 1.2, double headed arrows are employed from the manifest variable REPAP to itself to specify a variance and to REINT and RESOE to specify covariances. These paths are shown in the diagram below.


Figure 7.2 Variance/covariance paths between REPAP, REINT and RESOE.
These paths are specified in the sentences below.

$$
\begin{aligned}
& \text { [RESOE]--[RESOE] } \\
& \text { [REINT]-- [REINT] } \\
& \text { [REPAP]--[REPAP] } \\
& \text { [REPAP]-22-[REINT] } \\
& \text { [REPAP]-23-[RESOE] } \\
& \text { [RESOE]-24-[REINT] }
\end{aligned}
$$

### 7.3 ILLUSTRATIVE EXAMPLE

The model depicted in Figure 1.2 will now be used to illustrate the use of SEPATH.

### 7.3.1 CREATING THE SEPATH DATA FILE FOR THE DUNCAN, HALLER AND PORTES MODEL DEPICTED IN FIGURE 1.2

The following steps may be followed to enter the sample correlation matrix for the Duncan, Haller and Portes application.

- Double click on the STATISTICA icon on the Desktop.
- In the "STATISTICA Module Switcher" menu select the SEPATH option to produce the menu below.

- Click on the "Switch To" push button (or double click on the SEPATH menu field item) to activate the dialog box which appears below.

- Click on the "File" menu and select "Open other" option, then select the "New Data" option.

The window below then appears.


- Type the data file name in the string field "File name" and click on the "Save" push button. After these actions the blank data file shown below appears.

- Click on the "Vars" (Manifest Variables) push button. Then select the "All Specs" option.

This action opens the window shown below.

| Fixin Variables: Peps.sta 10v $=10 \mathrm{c}$ |  |  |  | - |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Name | MD Code | Format | Long Name | (laE』 |
| 1 | VAR1 | -9999 | 8.3 |  |  |
| 2 | VAR2 | -9999 | 8.3 |  |  |
| 3 | VAR3 | -9999 | 8.3 |  |  |
| 4 | VAR4 | -9999 | 8.3 |  |  |
| 5 | VAR5 | -9999 | 8.3 |  |  |
| 6 | VAR6 | -9999 | 8.3 |  |  |
| 7 | VAR7 | -9999 | 8.3 |  |  |
| 8 | VAR8 | -9999 | 8.3 |  |  |
| 9 | VAR9 | -9999 | 8.3 |  |  |
| 10 | VAR10 | -9999 | 8.3 |  |  |
| 1.1 |  |  |  |  | $\cdot 1$ |

- Type in the manifest variables' names in the "Name" column as shown below.

| Fin Variables: Peps.sta 10y ${ }^{\text { }} 10 \mathrm{c}$ |  |  |  | Long Name |
| :---: | :---: | :---: | :---: | :---: |
|  | Name | MD Code | Format |  |
| 1 | REINT | -9999 | 8.3 |  |
| 2 | REPAP | -9999 | 8.3 |  |
| 3 | RESOE | -9999 | 8.3 |  |
| 4 | REOAP | -9999 | 8.3 |  |
| 5 | REEAP | -9999 | 8.3 |  |
| 6 | BFINT | -9999 | 8.3 |  |
| 7 | BFPAP | -9999 | 8.3 |  |
| 8 | VAR8 | -9999 | 8.3 |  |
| 9 | VAR9 | -9999 | 8.3 |  |
| 10 | VAR10 | -9999 | 8.3 | $\square$ |
| T 1 |  |  |  | $\stackrel{\square}{+}$ |

- Type in the manifest variable names.
- Click on the "Close" push button to produce the window shown below.

- Click on the "Cases" push button to load the dialog box below.

- Click on the "Yes" push button if the number which appears in the dialog box is equal to the number of manifest variables specified above. The window below would then appear.

- Type in the manifest variable names in the same order as above.
- Click on the "OK" push button when all 10 manifest variables are typed in to fill the rows of the matrix with the manifest variable names as shown below.

| Thin Data: Peps.sta 10v ${ }^{\text {a }} 10 \mathrm{c}$ |  |  |  |  |  |  | - |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NJMERIC vALUES |  |  |  |  |  |  | - |
|  | REINT | $\stackrel{2}{\text { REPAP }}$ | RESOE | REOAP | REEAP | $\text { BF }{ }^{6} \mathrm{NT}$ | B] |
| REINT |  |  |  |  |  |  |  |
| REPAP |  |  |  |  |  |  |  |
| RESOE |  |  |  |  |  |  |  |
| REOAP |  |  |  |  |  |  |  |
| REEAP |  |  |  |  |  |  |  |
| BFINT |  |  |  |  |  |  |  |
| BFPAP |  |  |  |  |  |  |  |
| BFSOE |  |  |  |  |  |  |  |
| BFOAP |  |  |  |  |  |  |  |
| BFEAP |  |  |  |  |  |  | $\cdots$ |
| 1.1 |  |  |  |  |  |  |  |

- The sample correlations are then typed in the cells of the STATISTICA workbook. Since the sample correlation matrix is symmetric, only the lower triangle of the matrix is entered.
- Add the "Means", "Std. Dev", "No. Cases" and "MATRIX" case names by using the "Case Name Manager".
- Enter the sample size in the first cell of the case labeled "No. Cases". Enter the number 4.0000 in the first cell of the case labeled "MATRIX".

When all the steps outlined above have been followed, the complete sample correlation matrix for the Duncan, Haller and Portes application is as shown in the window below.

|  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NUMERIC VALUES | SEPATH Electronic Manual Examples \#4 and \#5 |  |  |  |  |  |  |  |  |  |  |
|  | $\begin{gathered} 1 \\ \text { REINT } \end{gathered}$ | $\begin{gathered} 2 \\ \text { REPAP } \end{gathered}$ | $\begin{gathered} 3 \\ \text { RESOE } \end{gathered}$ | $\begin{gathered} 4 \\ \text { REOAP } \end{gathered}$ | REEAP | BFINT | $\begin{gathered} 7 \\ \text { BFPAP } \end{gathered}$ | $\begin{array}{\|c\|} \hline 8 \\ \text { BFSOE } \end{array}$ | BFOAP | $\begin{gathered} 10 \\ \text { BFEAP } \end{gathered}$ |  |
| REINT | 1.0000 |  |  |  |  |  |  |  |  |  |  |
| REPAP | . 1839 | 1.0000 |  |  |  |  |  |  |  |  |  |
| RESOE | . 2220 | . 0489 | 1.0000 |  |  |  |  |  |  |  |  |
| REOAP | . 4105 | . 2137 | .3240 | 1.0000 |  |  |  |  |  |  |  |
| REEAP | . 4043 | . 2742 | . 4047 | . 6247 | 1.0000 |  |  |  |  |  |  |
| BF INT | . 3355 | . 0782 | . 2302 | . 2995 | . 2863 | 1.0000 |  |  |  |  |  |
| BFPAP | . 1021 | . 1147 | . 0931 | . 0760 | . 0702 | . 2087 | 1.0000 |  |  |  |  |
| BFSOE | . 1861 | . 0186 | . 2707 | . 2930 | . 2407 | . 2950 | -. 0438 | 1.0000 |  |  |  |
| BFOAP | . 2598 | . 0839 | .2786 | . 4216 | . 3275 | . 5007 | . 1988 | . 3607 | 1.0000 |  |  |
| BFEAP | . 2903 | . 1124 | . 3054 | .3269 | . 3669 | . 5191 | . 2784 | . 4105 | . 6404 | 1.000 |  |
| Means |  |  |  |  |  |  |  |  |  |  |  |
| Std. Dev. |  |  |  |  |  |  |  |  |  |  |  |
| No.Cases | 329.000 |  |  |  |  |  |  |  |  |  |  |
| Matrix | 4.0000 |  |  |  |  |  |  |  |  |  | $\checkmark$ |
| T |  |  |  |  |  |  |  |  |  |  |  |

### 7.3.2 SEPATH MODEL FILE FOR THE DUNCAN, HALLER AND PORTES' APPLICATION

After the Data File has been completed, the following steps may be used to specify the model.

- Click on the "Startup" push button (or click on the "Analysis Menu" and then select the "Startup Panel" option). This action will open the dialog box shown below.

- Click on the "Edit with Path Tool" push button. This action will activate the "Path Construction Tool" dialog box shown below.

- Click on the "Edit Latent" push button to activate the "Edit Latent Variable Names" dialog box shown below.

- Type in the Latent Variable names in the string fields provided and click the "OK" push button. The dialog box below then appears.



## - $\quad$ Specifying the dependence paths.

The diagram below is part of the path diagram depicted in Figure 1.2.


Figure 7.3 Dependence paths between variables

To enter the dependence paths in Figure 7.3 by using the "Path Construction Tool" dialog box, the following steps may be followed.

* Select the "X-->Y" button from the "Path Type" radio button field.
\& $\quad$ Highlight the Latent variable REAMB as the "From" variable.
* Highlight the manifest variable REOAP as the "To" variable.
\& $\quad$ Click on the "Add" push button.

With these actions SEPATH will create the dependence path between the latent variable REAMB and the manifest variable REOAP shown below.
[REAMB]-1->[REOAP]
\& $\quad$ Highlight the manifest variable REEAP as the "To" variable.

* Click on the "Add>>" push button. SEPATH then creates the dependence path shown below.
[REAMB]-2->[REEAP].
Continue these actions until all the dependence paths are specified.


## - Specifying the dependence paths between the error terms and the manifest variables, and the variances for each error term with itself.

The steps below are followed to specify the dependence paths between the measurement errors and their indicators, and the variances for each error term with itself in Figure 7.3.
\& Select the "Residual" button from the "Path Type" radio button field. This will activate the "Base Name" and "Base Number" string fields under the "Residual Vars" label field

* Type "E" in the "Base Name" string field.
* Enter " 1 " in the "Base Number" string field.
\& $\quad$ Set the "Par \#" to 5.
* Highlight the manifest variable REOAP. Click on the "Add>>" push button.

With these steps SEPATH will create the covariance and variance paths respectively, as shown below.

$$
\begin{aligned}
& \text { (E1)--> [REOAP] } \\
& \text { (E1)-5-(E1). }
\end{aligned}
$$

The "Base Name" remains "E" whereas the "Base Number" increases by one to 2. The "Par \#' also increases by one to 6 .

* Highlight the manifest variable REEAP and then click on the "Add>>" push button. After these steps are followed, SEPATH will create the following additional covariance and variance paths respectively,

$$
\begin{aligned}
& \text { (E2)--> [REEAP] } \\
& \text { (E2)-6-(E2). }
\end{aligned}
$$

The "Base Name" remains "E" whereas the "Base Number" increases by one to 3. The "Par \#' also increases by one to 7 . The paths created by following the actions above actions are shown in the string field "Paths" in the dialog box shown below.


Continue with this process until similar paths have been formed with E3 (and then E4 found in Figure 1.2).

* $\quad$ Select the "Latent" field from the "To" menu field.
* $\quad$ Highlight the latent variable REAMB.
* Change the "Base Name" from "E" to "Z" and the "Base Number" from whatever value to " 1 ".
* Click on the "Add>>" push button.

SEPATH then creates the paths shown below.

$$
\begin{aligned}
& \text { (Z1)--> (REAMB) } \\
& (\mathrm{Z} 1)-17-(\mathrm{Z} 1) .
\end{aligned}
$$

The "Base Name" remains "Z" whereas the "Base Number" increases by 1 to 2 . The "Par \#" also increases by 1 to 18 .

* Highlight the latent variable BFAMB and then click on the "Add" push button. With this action, SEPATH will create the paths shown below.

$$
\begin{aligned}
& \text { (Z2)--> (BFAMB) } \\
& \text { (Z2)-18-(Z2). }
\end{aligned}
$$

The paths created by following the actions above are shown on lines 7 and 8 , and the last two lines in the "Paths" string field in the dialog box shown below.


* $\quad$ Select the "Latent" option from the "From" menu field.
\& Highlight the latent variable REAMB as the "From" variable and BFAMB as the "To" variable.
\& Click on the "Add" push button so that SEPATH will create a dependence path between the latent variables REAMB and BFAMB as indicated below.
REAMB-19-> BFAMB.
* Repeat the steps above except this time highlight BFAMB as the "From" variable and REAMB as the "To" variable. The path created is as shown below.
BFAMB-20->REAMB.

The dialog box below shows some of the paths created as a result of the actions described so far.


## - Specifying the Variance/Covariance paths

The diagram in Figure 7.4 shows some of the variance/covariance paths depicted in Figure 1.2.


Figure 7.4 Variance/Covariance paths between REPAP, REINT and RESOE.

The "Path Construction Tool" dialog box may be used as follows to enter the paths in Figure 7.4.
\& $\quad$ Select the button "X--Y" from the "Path Type" radio button field.
\& Select the "Manifest" fields from the "From:" and "To:" menu fields. The resulting dialog box is as shown below.


* Highlight REPAP, REINT and RESOE as the "From" and "To" variables.

Click on the "Add" push button. SEPATH will then create variance paths on lines 21 to 29 in the "Paths" string field of the "Path Construction Tool" dialog box shown below.

\& The above steps are repeated until all the covariance and variance paths between the manifest variables in Figure 1.2 are specified.

* The path number for variances must be removed since they are fixed as per the path diagram in Figure 1.2. For example in the path [REPAP]-21-[REPAP], the path number 21 must be removed to give
[REPAP]--[REPAP].

When the above steps have been followed for all the dependence, variance and covariance paths in the path diagram depicted in Figure 1.2, the complete model file for the Duncan, Hallers and Portes application would appear as shown in next section.

### 7.3.3 MODEL FILE

The complete SEPATH model file for the model depicted in Figure 1.2 follows:

```
(REAMB)-1->[REOAP]
(REAMB)-2->[REEAP]
(BFAMB)-3->[BFOAP]
(BFAMB)-4-> [BFEAP]
(E1)-->[REOAP]
(E1)-5-(E1)
(E2)-->[REEAP]
(E2)-6-(E2)
(E3)-->[BFEAP]
(E3)-7-(E3)
```

(E4)-->[BFOAP]
(E4)-8-(E4)
[REPAP]-9->(REAMB)
[REINT]-10->(REAMB)
[RESOE]-11->(REAMB)
[BFSOE]-12->(REAMB)
(Z1)-->(REAMB)
(Z1)-13-(Z1)
[RESOE]-14->(BFAMB)
[BFSOE]-15->(BFAMB)
[BFINT]-16->(BFAMB)
[BFPAP]-17->(BFAMB)
(Z2)-->(BFAMB)
(Z2)-18-(Z2)
(REAMB)-19->(BFAMB)
(BFAMB)-20->(REAMB)
[REPAP]--[REPAP]
[REPAP]-22-[REINT]
[REPAP]-23-[RESOE]
[REPAP]-24-[BFSOE]
[REPAP]-25-[BFINT]
[REPAP]-26-[BFPAP]
[REINT]--[REINT]
[REINT]-28-[RESOE]
[REINT]-29-[BFSOE]
[REINT]-30-[BFINT]
[REINT]-31-[BFPAP]
[RESOE]--[RESOE]
[RESOE]-33-[BFSOE]
[RESOE]-34-[BFINT]
[RESOE]-35-[BFPAP]
[BFSOE]--[BFSOE]
[BFSOE]-37-[BFINT]
[BFSOE]-38-[BFPAP]
[BFINT]--[BFINT]
[BFINT]-40-[BFPAP]
[BFPAP]--[BFPAP]
[BFPA

| nalysis Parameters |  |  | ? $\times 1$ |
| :---: | :---: | :---: | :---: |
| $\left[\begin{array}{l\|l\|}\text { Data to Analyze } \\ \text { C Covariances } \\ \text { C Correlations } \\ \text { CMoments }\end{array}\right]$Output Options <br> No. Decimal $\quad 3$ <br> Places: <br> V Standard Errors |  | Convergence Criteria <br> Max. Residual Cosine: <br> . 0001 <br> Relative Funct. Change: <br> .000000 | OK [Accept parameters] <br> Cancel [No changes] <br> Restore Defaults |
| Discrepancy FunctionMaximum Likelihood [ML]Generalized Least Squares [GLS]GLS->MLOrdinary Least Squares [OLS]ADFGADFU |  | Global Iteration Parameters <br> Maximum No. of Iterations: $\square$ <br> Maximum Step Length: <br> Steepest Descent Iterations: <br> 0 <br> Step Tolerance: <br> .001 |  |
| Standardization <br> C New <br> OOld <br> $\odot$ None | Manifest Exogenous Free Fixed User | Line Search Method <br> $\odot$ Cubic Interpolation <br> $\bigcirc$ Golden Section <br> Simple Stephalving | Cubic LS $\boxed{0001}$ <br> Alpha: - <br> Giolden $\boxed{-5}$ <br> Search Tau:  <br> Golden Srch. -1 <br> Grecision: $\boxed{-1}$  <br>   |

## ANALYSIS PARAMETERS

The "Analysis Parameters" dialog box shown above allows the user to specify the numerous parameters and options for the analysis.

## DATA TO ANALYZE

The options here are

## - Covariances

If this option is selected, and the covariance matrix can be reconstructed from the data, SEPATH will analyze the covariance matrix of the input variables, regardless of what kind of data are input.

- Correlations

If this option is selected, SEPATH will calculate the correlation matrix from the input data and analyze it.

## - Moments

If this option is selected, SEPATH will analyze the augmented product-moment matrix instead of the covariance matrix. This option is selected when you are analyzing models involving intercepts or structured means.

In this section of the "Analysis parameters" dialog box, the user specifies the estimation method to yield parameter estimates. The options available are

- Maximum Likelihood (ML)
- Generalized Least Squares (GLS)
- GLS --> ML (GLS followed by ML). This is the default option.
- Ordinary Least Squares (OLS)
- Asymptotically Distribution Free Gramian (ADFG)
- Asymptotically Distribution Free Unbiased (ADFU)


## STANDARDIZATION

In this section of the "Analysis Parameters" dialog box, the user chooses to generate either a standardized solution (where latent variables all have unit variances) by one of two methods, or an unstandadized solution. The three options are

- New.

If this option is selected, SEPATH estimates a standardized solution via constrained estimation.

- Old.

If this option is selected, SEPATH estimates a standardized solution without using constrained estimation.

- None.

If this option is selected, an unstandardized solution is calculated.

## MANIFEST EXOGENOUS

## The options available are

- Fixed

If this option is selected, the variances and covariances for manifest exogenous variables are fixed (at the value of the observed variances and covariances) during iteration, then treated as if they were free parameters at the end of the iteration.

## - Free

If this option is selected, the variances and covariances among the manifest exogenous variables are treated as free parameters and added to the model, although their values are not shown.

## - User

If this option is selected, the user must account for the variances and covariances of all manifest exogenous variables, using standard PATH1 syntax.

## INITIAL VALUES

In this section of the "Analysis Parameters" dialog box, the user selects the method employed to find initial values for free parameters. The options available are:

## - Default.

The default method uses 0.5 for all free parameters, except variances and covariances (or correlations) of manifest exogenous variables.

## - Automatic

If this option is selected, the initial values are obtained by using a minor adaptation of the technique described by McDonald and Hartmann (1992).

## CONVERGENCE CRITERIA

In this box of the "Analysis Parameters" dialog box, you can adjust constants that can directly affect the point during iteration at which the program decides convergence has occurred. The default values produce desirable results for a wide variety of problems, and you will seldom need to adjust these criteria. The options available are:

- Maximum residual cosine criterion.

The default value for this option is 0.0001 .

## - Relative function change criterion.

In general, the value here must be kept very low, or it may cause iteration to terminate prematurely.

## GLOBAL ITERATION PARAMETERS.

In this section of the "Analysis Parameters" dialog box, you enter parameters that control the basic iterative process. The options available are:

## - Maximum number of iterations.

In this field, you enter the maximum number of iterations allowed. The default number is 30 .

## - Maximum step length.

In this field, you enter the maximum length of the step vector that will be allowed. The default number is 10000 .

## - Number of steepest descent iterations.

In this field, you enter a number of Steepest Descent Iterations to proceed the standard iterations. The default value is 0 .

- $\quad$ Step tolerance.

In this field, you enter a tolerance value at which a parameter is temporarily eliminated from the iterative process. The tolerance value is basically one minus the squared multiple correlation of a parameter with the other parameters. The default value is 0.0001 .

## LINE SEARCH METHOD

In this section of the "Analysis Parameters" dialog box, you choose a basic line search method. There are three methods for choosing the length of the steps. These are:

## - Cubic interpolation.

This method is reasonably fast and rather robust. It works well in a vast majority of circumstances.

- Golden section.

This method tries to solve the one dimensional minimization problem exactly on each iteration. It often converges in slightly less iteration than cubic interpolation, but takes longer, because it requires more function evaluations on each iteration.

- Simple stephalving.

This method is the fastest, but will fail to converge for a fair number of problems on which the other two, more sophisticated methods succeed.

## LINE SEARCH PARAMETERS.

In this section of the "Analysis Parameter" dialog box, you choose numerical parameters that control the performance of the line search method you have chosen. The options available are:

- Max. no. of stephalves.

This parameter sets the maximum number of stephalves allowed on a single iteration if the Simple stephalving line search method is used.

- Stephalve fraction

This parameter sets the fraction by which the current step is multiplied when Simple Stephalving is used as the line search method.

## - Cubic LS alpha.

This parameter controls how large a reduction in the discrepancy function has to be made before a step is considered acceptable when the Cubic Interpolation line search is used. The default value is 0,0001 .

- Golden section tau.

This parameter controls the width of the range to which the Golden Section line search is limited.

- Golden search precision.

This parameter controls the precision of estimation in a Golden Section line search.

## OUTPUT OPTIONS

The options in this section of the "Analysis Parameters" dialog box allow you some preliminary control over the appearance of your output. The options available are:

- No. of decimal places.

Here you can set the number of decimal places displayed by default in the text output. The number can be any integer from 1 to 6 .

- Standard error

If this box is checked, the program will display estimated standard errors for all parameters in the PATH1 text output, and Model Summary Scrollsheet. However, if OLS estimation is performed, or the "old" standardization method is employed, standard errors will not be available.

- Select the required parameters by clicking on the right Check Boxes and then click on the "OK (accept parameters)" push button.
- The above action will again activate the "Startup" dialog box shown below again.

- To run the program, click on the "OK (Execute Current Model)" push button.
- If there are no syntax errors, iteration will commence until the dialog box below appears.



## 7．3．5 THE SEPATH OUTPUT FILE FOR THE DUNCAN，HALLER AND PORTES APPLICATION

The output of SEPATH for the Duncan，Haller and Portes＇application are provided in various dialog boxes that can be accessed by clicking on the push buttons in the＂Structural Equation Modeling Results＂dialog box shown below．

| Atstructural Equation Modeling Results | ？$\times$ |
| :---: | :---: |
| Method of Estimation：GLS $\rightarrow$ ML <br> Discrepancy Function： 0.082 <br> Maximum Residual Cosine：4．29E－005 <br> Max．Abs．Gradient： $1.09 \mathrm{E}-005$ <br> Max．Abs．Constraint：4．16E－009 <br> ICSF Criterion：1．29E－008 <br> ICS Criterion：4．61E－006 <br> Boundary Conditions： 0 | Chi－Square Statistic： 26.8929 <br> Degrees of Freedom： 16 <br> Chi－Square p－level： 0.042690 <br> Steiger－Lind RMSEA  <br> －－－＞Point Estimate： 0.044 <br> －－＞Lower 90\％Bound： 0 <br> －－＞Upper 90\％Bound： 0.0734 <br> RMs Stand．Residual： 0.0203 |
|  |  |
| 费曲 Noncentrality－B ased Indices | 费贯 Basic Summary Statistics |
| 费 | Analysis of Residuals |
| 㵒 LaGrange Multiplier Statistics | 费 Standardized Residuals |
| Tests of Assumptions | 费围 Normalized Residuals |
| 㵋 Univariate Skewness 㵋 Multivariate Kurt | N－Normal Probability Plot |
| 费 Univariate Kurtosis 费贯 Reflector Matrix | 惯 |
| Iteration History | 费 |

Summaries of the results appear in the string field of the＂Structural Equation Modeling Results＂ dialog box．

1．Method of Estimation：GLS－＞ML
This indicates that SEPATH starts the analysis with GLS estimation and switches over to ML estimation．

2．The Discrepancy Function Value： 0.082
This is the minimal value of the discrepancy function $\mathrm{F}(\mathbf{S}, \Sigma(\theta)$ ），
where $\mathbf{S}$ is the sample covariance matrix，$\theta$ contains the unknown parameters of the Structural Equation Model and $\sum(\underset{-}{(\theta)}$ is the structural model for the population covariance matrix $\sum$ ．

3．The Maximum Residual Cosine value．
4．The Maximum Absolute Constraint value．
5．The Acronym ICSF stands for Invariance under a Constant Scaling Factor．
6. The Acronym ICS stands for Invariance under Change of Scale.
7. Value of the Chi-square Statistic. This value is obtained as $(\mathrm{N}-1) \mathrm{F}_{\mathrm{ML}}\left(\mathbf{S}, \sum(\vec{\theta})\right)$, where N denotes the sample size and $\vec{\theta}$ is the estimate of $\theta$.
8. The Degrees of Freedom of the Chi-square distribution of $(\mathrm{N}-1) \mathrm{F}\left(\mathbf{S}, \sum(\hat{\theta})\right.$ ) is given by $[p(p+1) / 2]-q$, where $p$ is the number of manifest variables and $q$ denotes the number of free parameters.
9. Chi-square significance level. This is the area under the chi-square distribution curve to the right hand side of the chi-square statistic.
10. Steiger-Lind RMSEA (Root Mean Square Error of Approximation) point estimate. This value is obtained by using the formula $\mathrm{R}^{*}=\sqrt{\frac{F^{*}}{v}}$, where $v$ is the degrees of freedom and $F^{*}$ is given by $F^{*}=\frac{1}{2} \mathbf{T} r\left[\left(\mathbf{S}-\sum(\hat{\theta})\right)\left\{\sum(\hat{\theta})\right\}^{\}^{1}}\right]^{2}$.
where $\operatorname{Tr}[\mathbf{A}]$ is the trace of the square matrix $\mathbf{A}$.
11. The lower and upper limits of the $90 \%$ confidence interval for the RMSEA.
12. RMS (Root Mean Square) Standardized Residual.

## GOODNESS OF FIT INDICES

Under this heading we have the "Noncentrality-Based Indices", "Other Single Sample Indices" and the "LaGrange Multiplier Statistics as" shown in the dialog box above.

- Click on the "Noncentrality-Based Indices" push button to load the dialog box shown below.

* $\quad$ The Point estimate of the Population Noncentrality Parameter is given by NF* The $90 \%$ confidence interval for the Population Noncentrality Parameter is also given in the string field the of "Structural Equation Modeling Results" dialog box.
\& The Steiger-Lind RMSEA Index point estimate and confidence interval are as
described in 10 above.
* $\quad$ The McDonald Noncentrality Index is given by

$$
\operatorname{Exp}\left(\frac{F^{*}}{2}\right)
$$

* $\quad$ The estimated Population Gamma Index is given by

$$
\hat{\Gamma}_{1}=\frac{p}{\operatorname{Tr}\left[\sum\left\{\sum(\hat{\theta})\right\}^{-1}\right]^{2}}
$$

* $\quad$ The estimated Adjusted Population Gamma Index is given by

$$
\mathrm{P}_{2}=1-\frac{\bar{\xi}^{\prime} W \varepsilon / V}{\partial^{\prime} W \exists / p^{*}}
$$

where $\hat{\varepsilon}=(\hat{\sigma}-S), \hat{\sigma}=\operatorname{vecs}\left(\sum(\hat{\theta})\right), \quad \&=\operatorname{vec}(S)$, and $\operatorname{Vecs}(S)$ denotes the $\frac{1}{2} p(p+1) \times 1$ vector formed by stacking the non-duplicated elements of the $\mathrm{p} \times \mathrm{p}$ symmetric matrix S .

- To view the other Goodness of fit Indices, click on the "Continue" push button. This action will load the "Structural Equation Modeling Results" dialog box.
- Click on the "Other Single Sample Indices" push button to load the dialog box shown below.


$$
\hat{\Gamma}_{2}=\frac{p}{\operatorname{Tr}\left[\mathbf{S}\left\{\Sigma\left(\hat{\theta_{M L}}\right)\right\}^{-1}\right]^{2}}
$$

* $\quad$ The J\&keskog - S\&bom AGFI is given by

$$
1-\left(\mathrm{p}^{*} / v\right)\left(1-\hat{\gamma}_{M L}\right)
$$

where $\hat{\gamma}_{M L}$ is the GFI index $\hat{\gamma}_{M L}=\frac{p}{\operatorname{Tr}\left[\mathbf{S}\left\{\Sigma\left(\hat{\theta_{M L}}\right)\right\}^{-1}\right]^{2}}$.

* $\quad$ The rescaled Akaike Information Criterion is computed from

$$
\mathrm{A}_{k}=\hat{F}_{\mathrm{ML}, \mathrm{k}}+\frac{2 f_{k}}{N-1}
$$

where $\hat{F}_{\text {ML,k }}$ is the minimal value of the maximum likelihood discrepancy function, $\mathrm{f}_{\mathrm{k}}$ is the number of free parameters for the model and N is the sample size.

* $\quad$ Schwarz's Bayesian Creterion is computed from

$$
\mathrm{S}_{\mathrm{k}}=\hat{F} \quad \mathrm{ML}, \mathrm{k}+\frac{f_{k} \operatorname{In}(N)}{N-1}
$$

* The Browne-Cudeck Cross Validation Index is computed from

$$
\mathrm{C}_{\mathrm{k}}=\mathrm{F}_{\mathrm{ML}}\left(S_{v}, \sum_{k}(\hat{\theta})\right)+\frac{2 v_{k}}{N-p-2}
$$

where $v_{k}$ is the degrees of freedom for the $k^{\prime} t h$ model.

* The Independence Model Chi-square and df are the Chi-square goodness-of-fit statistic, and associated degrees of freedom, for the hypothesis that the population covariances are all zero. Under the assumption of multivariate normality, this hypothesis can only be true if the variables are all independent. The "Independence Model" is used as the "Null Model" in several comparative fit indices.
* $\quad$ The Bentler-Bonett Normed Fit Index is computed from

$$
B_{k}=\frac{\hat{F}_{o}-\hat{F}_{k}}{\hat{F}_{o}}
$$

where $\hat{F}_{o}$ is the minimal discrepancy function value for the "Null Model"
$\hat{F}_{k}$ is the minimal discrepancy function value for the $k^{\prime} t h$ model.

* $\quad$ The Bentler-Bonett Non-Normed Fit Index is computed from

$$
B N N_{K}=\frac{\frac{\hat{F}_{o}}{v_{o}}-\frac{\hat{F}_{k}}{v_{k}}}{\frac{\hat{F}_{o}}{v_{o}}-\frac{1}{N-1}}
$$

where $v_{o}$ is the degrees of freedom for the "Null Model"

* The Bentler Comparative Fit Index $\left(\mathrm{CFI}_{\mathrm{k}}\right)$ is computed as

$$
\mathrm{CFI}_{\mathrm{k}}=1-\frac{\hat{\tau_{k}}}{\hat{\tau_{o}}}
$$

where $\hat{\tau_{k}}$ is the estimated non-centrality parameter for the k'th model $\hat{\tau_{o}}$ is the estimated non-centrality parameter for the "Null Model".

* $\quad$ The James-Mulaik-Brett Parsimonious Fix Index is computed from the formula

$$
\hat{\pi}_{k}=\frac{v_{k}}{v_{o}} B_{k}
$$

- $\quad$ Bollen's Rho is computed as:

$$
\hat{\rho}_{k}=\frac{\frac{\hat{F}_{o}}{v_{o}}-\frac{\hat{F}_{k}}{v_{k}}}{\frac{\hat{F}_{o}}{v_{o}}}
$$

- $\quad$ Bollen's Delta is computed from:

$$
\hat{\Delta}_{k}=\frac{\hat{F}_{o}-\hat{F}_{k}}{\hat{F}_{o}-\frac{v_{k}}{N}}
$$

- To view the remaining Goodness of fit Indices, click on the "Continue" push button to reload "Structural Equation Modeling Results" dialog box.
- Click on the "LaGrange Multiplier Statistics" push button to load the dialog box shown below.

|  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |
| 1.00000001288365 |  | 頤圖 | Columns Rows © | Q 田排蒥 |  |
| 10， | Continue．．． |  | Variance | LaGrange Multiplier | Standard Error |
| （10） | REOAP |  | 1.000 | 0 － 0.000 | －． 000 |
| V | REEAP |  | 1.000 | 0.000 | －． 000 |
| 開 | BFOAP |  | 1.000 | $0-.000$ | －． 000 |
| 会 | BFEAP |  | 1.000 | $0-.000$ | 000 |

＊The values of the Lagrange multipliers that were used to constrain the variances of the endogenous manifest variables to unity and the corresponding standard errors are shown in the dialog box above．
－To view the＂Model Summary＂，click on the＂Continue＂push button to reload the ＂Structural Equation Modeling Results＂dialog box．
－Click on the＂Model Summary＂push button to load the dialog box shown below．


The＂Model Summary＂dialog box presents model output in a Scrollsheet form that is convenient for further analyses．For each path of the model，the following information is given：
\＆$\quad$ Path representation
\＆Parameter estimate
＊$\quad$ Standard error
\＆$\quad$ T－statistic
\＆$\quad$ Probability level．
－To view the＂Basic Summary Statistics＂，click on the＂Continue＂push button to reload the
＂Structural Equation Modeling Result＂dialog box．
－Click on the＂Basic Summary Statistics＂push button to load the dialog box shown below．


The information above are the same as those found in the string field of the＂Structural Equation Modeling Results＂dialog box．

## ANALYSIS OF RESIDUALS

Under this heading，we have the＂Standardized Residuals＂，＂Normalized Residuals＂，＂Normal Probability Plot＂，＂Input Matrix＂and＂Reproduced Matrix＂push buttons as shown in the＂Structural Equation Modeling Results＂dialog box．

To view the output under the＂Analysis of Residuals＂do the following：
－Click on the＂Continue＂push button of the＂Basic Summary Statistics＂dialog box to load the ＂Structural Equation Modeling Results＂dialog box．
－Click on the＂Standard Residuals＂push button to load the dialog box shown below．

| 駺S | ATISTICA：St | al Equatio | deling－ | ardized | als［dhplp | WW｜ | 4 － | X |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| \％ | File Edit Yiew | ysis Graphs | ptions Whin | Help |  |  | －吕 |  |
| 0. |  | 區（10） | ns Rows | Q $-\leftrightarrow \rightarrow\| \| c$ | ［500 9 |  |  |  |
| － | Continue．．． | REINT | REPAP | RESOE | REOAP | REEAP | BFINT | － |
| 0 | REINT | 0.000 | －． 000 | 0.000 | －． 000 | 018 | －． 013 |  |
| 0 | REPAP | －． 000 | 0.000 | －． 000 | －． 000 | －． 026 | 020 |  |
| 關 | RESOE | 0.000 | －． 000 | 0.000 | －． 000 | －． 033 | 025 |  |
| （2） | REOAP | －． 000 | －． 000 | －． 000 | 0.000 | 038 | －． 030 |  |
| S | REEAP | 018 | －． 026 | －． 033 | 038 | 001 | 001 |  |
| 5 | BFINT | －． 013 | 020 | 025 | －． 030 | 001 | 001 |  |
| 凮 | BFPAP | 0.000 | －． 000 | 0.000 | 0.000 | 042 | 013 |  |
|  | BFSOE | 0.000 | 0.000 | 0.000 | －． 000 | －． 027 | －． 039 |  |
| $\square$ | BFOAP | 005 | －． 011 | －． 004 | －． 013 | 091 | －． 023 |  |
| 回 | BFEAP | 017 | 010 | 003 | 009 | －． 027 | －． 009 |  |

The matrix above represents the difference between the sample correlation matrix and the fitted （reproduced）correlation matrix．
－Click on the＂Continue＂push button of the＂Standard Residuals＂dialog box above to reload the＂Structural Equation Modeling Results＂dialog box．
－Click on the＂Normalized Residuals＂push button to load the dialog box shown below．

|  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  |
| Fi：File Edit View Analysis Graphs Options Window Help |  |  |  |  |  |  |  |  |  |  |
| （1） | Continue．．． | REINT | REPAP | RESOE | REOAP | REEAP | BFINT | BFPAP | BFSOE | BF |
|  | REINT | 0.000 | 0.000 | 0.000 | 0.000 | 295 | －． 218 | 0.000 | 0.000 |  |
| 5 | REPAP | 0.000 | 0.000 | 000 | －． 000 | －． 454 | 350 | 0.000 | 0.000 | －．． |
| 門 | RESOE | 0.000 | 000 | 0.000 | 0.000 | －． 564 | 432 | 0.000 | 0.000 | －． 1 |
| 20 | REOAP | 0.000 | －． 000 | 0.000 | 0.000 | 675 | －． 518 | 0.000 | 000 | －．： |
|  | REEAP | 295 | －． 454 | －． 564 | 675 | 009 | 022 | 731 | －． 491 | 1 |
| 4 | BFINT | －． 218 | 350 | 432 | －． 518 | 022 | 010 | 219 | －． 710 | －． |
| 風 | BFPAP | 0.000 | 0.000 | 0.000 | 0.000 | 731 | 219 | 0.000 | 0.000 |  |
|  | BFSOE | 0.000 | 0.000 | 0.000 | 000 | －． 491 | －． 710 | 0.000 | 0.000 | － |
| 0 | BFOAP | 093 | －． 200 | －． 063 | －． 222 | 1.574 | －． 395 | 186 | －． 671 | 1 |
| 固 | BFEAP | 301 | 189 | 045 | 159 | －． 467 | －． 158 | －． 094 | 426 | 1 |

The matrix is the normalized residuals．These residuals are divided by estimates of their standard errors，to provide a measure that，in large samples，is approximately normally distributed when the model fits perfectly in the population．
－Click on the＂Continue＂push button of the＂Normalized Residuals＂dialog box above to reload the＂Structural Equation Modeling Results＂dialog box．
－Click on the＂Normal Probability Plot＂push button to load the dialog box shown below．


The normal probability plot of the residuals may be used to detect departures from normality，perfect fit or both．
－Click on the＂Continue＂push button of the＂Normal Probability Plot＂dialog box above to reload the＂Structural Equation Modeling Results＂dialog box．
－Click on the＂Input Matrix＂push button to load the dialog box shown below．

| 医缶 | TISTICA：St | tural Equ | ion Mod | ng－In | Matrix | －dhp． |  |  |  | 回 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| \％： | File Edit View | Analysis G | hs Opt | wind | Help |  |  |  |  | 回 | x |
| 1. |  | 區甸 | Columns | Hows | Q $\leftrightarrow$ | （it）＋i， <br> 0.0 <br> 0 | 14 |  |  |  |  |
| （5） | Continue．．． | $\begin{aligned} & \text { Correl } \\ & \mathrm{N}=32 \end{aligned}$ | $\text { tion } \mathrm{Ma}$ |  |  |  |  |  |  |  | － |
| 15 |  | REINT | REPAP | RESOE | REOAP | REEAP | BFINT | BFPAP | BFSOE | BF |  |
| 絾 | REINT | 1.000 | 184 | 222 | 410 | 404 | 336 | 102 | 186 |  |  |
| （1） | REPAP | 184 | 1． 000 | 049 | 214 | 274 | 078 | 115 | 019 |  |  |
|  | RESOE | 222 | 049 | 1． 000 | 324 | 405 | 230 | 093 | 271 |  |  |
| ［謁 | REOAP | 410 | 214 | 324 | 1.000 | 625 | 299 | 076 | 293 |  |  |
| 泀 | REEAP | 404 | 274 | 405 | 625 | 1． 000 | 286 | 070 | 241 |  |  |
| － | BFINT | 336 | 078 | 230 | 299 | 286 | 1.000 | 209 | 295 |  |  |
| 0 | BFPAP | 102 | 115 | 093 | 076 | 070 | 209 | 1.000 | $-.044$ |  |  |
| ［國 | BFSOE | 186 | 019 | 271 | 293 | 241 | 295 | $-.044$ | 1． 000 |  |  |
| 5 | BFOAP | 260 | 084 | 279 | 422 | 327 | 501 | 199 | 361 | 1.1 |  |
| \％ | BFEAP | 290 | 112 | 305 | 327 | 367 | 519 | 278 | 410 | ＇ |  |

This is the sample correlation matrix used in the analysis．
－Click on the＂Continue＂push button of the＂Input Matrix＂dialog box above to reload the ＂Structural Equation Modeling Results＂dialog box shown below．

| WSTATISTICA：Structural Equation Modeling－［Reproduced Matrix［pep－dhp．sta）］ |  |  |  |  |  |  |  | $\begin{aligned} & \text { - 回 } \\ & - \text { a } x \end{aligned}$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| F：／：F Eile Edit View Analysis Graphs Options Whindow Help |  |  |  |  |  |  |  |  |  |  |
| 1. |  | R區（10 |  | Rows © | REOAP |  |  | BFPAP | BFSOE | BF |
| 國 | Continue．．． |  | REPAP | RESOE | REOAP | REEAP | BFINT |  |  |  |
| ［10］ | FEINT | 1.000 | ． 184 | ． 222 | ． 393 | ． 417 | ． 336 | ． 102 | ． 186 |  |
| 5 | REPAP | 184 | 1.000 | 049 | 239 | 254 | 078 | 115 | 019 | 1 |
| 關 | RESOE | 222 | 049 | 1． 000 | 357 | 379 | 230 | 093 | 271 |  |
| （2） | REOAP | 393 | 239 | 357 | 999 | 623 | 258 | 103 | 255 |  |
|  | REEAP | 417 | 254 | 379 | 623 | 999 | 274 | 110 | 270 |  |
| － | BFINT | 336 | 078 | 230 | 258 | 274 | 1.000 | 209 | 295 |  |
| 䀛 | BFPAP | 102 | 115 | 093 | 103 | 110 | 209 | 1.000 | －． 044 |  |
|  | BFSOE | 186 | 019 | 271 | 255 | 270 | 295 | －． 044 | 1.000 |  |
| 0 | BFOAP | 255 | 095 | 282 | 330 | 351 | 489 | 237 | 374 | ＇ |
| 圆 | BFEAP | 273 | 102 | 303 | 354 | 376 | 525 | 254 | 401 | 1 |

－$\quad$ Click on the＂Reproduced Matrix＂push button to load the dialog box shown below．
This is the correlation matrix calculated from the model by using the final parameter estimates as the parameter values of the model．

# CHAPTER 8 <br> CONCLUSIONS AND RECOMMENDATIONS 

### 8.1 INTRODUCTION

In this treatise the use of six Structural Equation Modeling programs, namely: AMOS, EQS, LISREL, Mx, RAMONA and SEPATH have been reviewed. The six programs were reviewed in terms of general application. In addition, the use of the software for fitting the Duncan, Haller and Portes' model Figure 1.2 to the Sample Correlation matrix in Table 1.3 are illustrated.

When using each of the programs to fit the model depicted in Figure 1.2 to the correlation matrix in Table 1.3, the positive impressions and the difficulties encountered with each program were noted. In the next six sections of this chapter, the positive impressions and the difficulties encountered with each program are provided. In addition, some recommendations are made based on the difficulties encountered as a first time user of these programs.

### 8.2 AMOS

The following impressive observations were made on using AMOS to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3.

1. I found the drawing of the path diagram in Figure 1.2 in AMOS very easy.
2. The resulting path diagram is of excellent quality.

3 I admired the display of the degrees of freedom at any stage in the drawing of a path diagram. It helped me to see whether I was doing the right thing or not at each stage of drawing the path diagram in Figure 1.2 in AMOS.
4. The modeling laboratory was very useful to me as a first time user. It allowed me to enter an arbitrary choice of parameter values, and then observe the resulting implied moments and the
resulting value of the discrepancy function. This unique feature could only be found in AMOS.

Certain difficulties were encountered on using AMOS to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3. The difficulties are given below.

1. I was unable to draw the variances of the variables on the path diagram.
2. Although it was very easy to add error terms to variables in a path diagram, it took quite an effort and time to get the error terms into positions to improve the appearance of the path diagram. Moving an error term around in the diagram was not a straightforward matter for me.
3. I had to fix the regression coefficients for the paths between "REAMB" and "REOAP", and "BFAMB" and "BFOAP" to one (1) before I could successfully run the job.
4. I was unable to open the input file with the extension ".amj" generated from the path diagram in AMOS. I had to use Microsoft Word and Windows explorer to open this file.
5. I had to type the variances of the variables manually in the ".amj" file to complete the model specification prior to running the job.
6. I found the User's Guide too comprehensive. It took me a very long time to read through all the relevant portions.
Based on my experience of using AMOS for the first time, I would like to propose the following recommendations:
7. The inclusion of features, which would enable users to draw the variances of variables, would allow the user to draw more comprehensive path diagrams.
8. The feature, which enables the error terms to be moved around in a path diagram, should, if possible, be improved to make it easier and faster to use.
9. The AMOS input file created from the path diagram is saved with an automatic extension ".amj". It would be a nice idea if this could be replaced by ".ami" to reflect the fact that it is an "AMOS Input" file.
10. It would be a good idea if the AMOS input file is reproduced in the AMOS output file. This would assist users in finding the parameter estimates in the output file because the input file indicates which parameters are to be estimated as well as their paths.
11. I would like to suggest that a summarized version of the User's Guide be made for first time users so that they may not have to read big volumes to know how to use the program.
12. A feature, which allows users to open their input files within AMOS, will improve the userfriendliness of AMOS.

### 8.3 EQS

The following impressive observations were made on using EQS to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3.

1. I found the use of equations to specify the model very easy.
2. I found the structural equations very clear and unambiguous.
3. I found the specification of the model not complex at all. The structural equations were as such that they were written for the paths as they appear in the path diagram of the model.
4. With the use of the "Create New Equations" window, I did not have to type the lines of the structural equations for the model. This I found very useful in that it reduced the chance of making a typing mistake to zero.
5. When I specified the model by typing in all the structural equations, it did not take long at all since variables used in the structural equations are coded into V's for manifest variables and F's for latent variables.
6. The input file is reproduced as part of the output file and numbered sequentially. This, I found very helpful when reading the parameter estimates in the output file because the input file indicated which parameters were to be estimated and on which path that was.

There were certain difficulties I encountered on using EQS to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3. These were:

1. I had to manually enter the fixed parameters in the model, because the fixing of the parameters could not be done when specifying the structural equations in the input file. This took a bit of time to do.
2. I had to manually enter the labels in the input file after the input file had been created.
3. I had to enter all the specifications of the correlations between the independent variables in the path diagram in the input file since those were not automatically generated as part of the input file.
4. I had to fix the regression coefficients for the paths between "REAMB" (F1) and "REOAP" (V4), and "BFAMB" (F2) and "BFOAP" (V10) to one (1) before I could successfully run the job.
5. I found that it was not possible to get back to the "Create New Equations" window after it has been used once to create the structural equations for the model. This meant that I had to
restart the specification of the structural equations whenever I found that a mistake had been made.
6. I found the User's Guide too comprehensive. It took me a very long time to read through all the relevant portions.

Based on my experience on using EQS for the first time, I would like to propose the following recommendations:

1. It would be a nice idea if the file name for files created in EQS could have more than eight characters. There are times when one has to provide a file name, which has more than eight characters, for identification purposes. This is not possible in EQS at the moment.
2. The inclusion of a feature, which would enable users to specify fixed parameters as the structural equations are being constructed, would improve the user-friendliness of EQS.
3. The keyword "/DATA=" is included automatically in the input file even when it has been indicated that a separate data file has not been provided. A way should be found to stop this "redundant" keyword from appearing.
4. The inclusion of a feature, which would enable users to provide labels for the input variables at the start of the model specification, would improve the user-friendliness of EQS.
5. The user-friendliness of EQS would be further enhanced if users are allowed to get back to the "Create New Equations" window which is used to create the structural equations of the model.
6. I would like to suggest that a summarized version of the User's Guide be made for first time users so that they may not have to read big volumes to know how to use the program.

### 8.4 LISREL

The following impressive observations were made on using LISREL to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3.

1. I was immensely impressed by the fact that there are three different ways of fitting Structural Equation Models to data with LISREL 8.30.
2. I could generate the path diagram in Figure 1.2 from the SIMPLIS input file and also from the LISREL input file. I could also do the reverses of these, that is, generate the SIMPLIS or the LISREL input file from the drawing of the path diagram in Figure 1.2 in LISREL.
3. It was very easy to type the input file for the model depicted in Figure 1.2 in the SIMPLIS command language. The SIMPLIS command language is very easy to understand and use. This quality allowed me to specify the model in the input file by directly translating the path diagram into the input commands.
4. It was easier for me to create the SIMPLIS input file interactively.
5. I found it very easy to draw the path diagram in Figure 1.2 in LISREL. The path diagram I drew was of excellent quality.
6. I could easily display the initial values and fixed values on the path diagram.
7. I found the dialog boxes, which I used to specify the model in terms of the eight parameter matrices of the LISREL model, very user-friendly.
8. I found that the LISREL 8.30 output file contained several goodness-of-fit statistics that are well arranged.
9. The arrangement of the parameter estimates and the goodness-of-fit statistics in the output file is very impressive.
10. The LISREL syntax or the SIMPLIS syntax in the input file was reproduced in the output file. The presence of the reproduced input file helped me a lot to locate the parameter estimates easily.

I encountered certain difficulties on using LISREL 8.30 to fit the model depicted in Figure 1.2 to the correlation matrix in Table 1.3. The difficulties included:

1. It was extremely difficult for me to know how to partition the parameters to be able to specify the model in terms of the eight parameter matrices of the LISREL model.
2. I also found the specification of the model depicted in Figure 1.2 in the LISREL syntax too theoretical. I only managed to get the model right after several trials.
3. I found the User's Guide too comprehensive. It took me a very long time to read through all the relevant portions.
4. I had to fix the factor loading for the paths between REAMB and REOAP, and BFAMB and BFOAP to 1 before the program ran.

Based on my experience of using LISREL for the first time, I would like to propose the following recommendations:

1. I would like to strongly recommend that a way be found to make it easier for a user to specify the eight parameter matrices of the LISREL model differently from what it is currently. Getting to know which of the variables goes into which of the matrices: Eta, Beta, Gamma, and so on is too mathematical.
2. I would like to suggest that a summarized version of the User's Guide be made for first time users so that they may not have to read big volumes to know how to use the program.

### 8.5 Mx

The following impressive observations were made on using Mx to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3.

1. It was very easy to type the input script file of the model depicted in Figure 1.2.
2. I found the final input script file created for the model depicted in Figure 1.2, very easy to read.
3. I found the use of the path diagram to generate the input script file of the model depicted in Figure 1.2 easy.
4. The quality of the path diagram I drew was excellent.
5. I found the feature in $M x$, which automatically assigns a starting value to a free parameter, very helpful.
6. I found the feature, which enabled me to change the default starting values to the required value, very helpful.
7. I was impressed with the fact that Mx provided an identity matrix as the matrix to be analyzed in the graphics file created from the drawing of the path diagram for the model depicted in Figure 1.2.
8. I like the fact that the $M x$ input script file was reproduced as part of the output file.

Certain difficulties were encountered on using Mx to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3. The difficulties are given below.

1. Since Mx uses the RAM model specification, I had to reorganize the order of the manifest variables in the correlation matrix provided in Table 1.3 to reflect the variable order of the RAM model before the job ran successfully.
2. Getting to know how to enter the values and numbers which were used to specify the model in the matrices proved very difficult for me at the beginning. It took several trials before I got things right.
3. Typing the Mx commands and keywords to form the input script was very time consuming. All the required entries and the numerous zeros for all the four matrices of the RAM model had to be entered.
4. The input script which was generated from the path diagram I drew for the model depicted in Figure 1.2, had the number of manifest variable correctly as 10 but the number of observations was automatically assigned to 100 . I had to change it to the correct number 329 .
5. I found the User's Guide too comprehensive. It took me a very long time to read through all the relevant portions.
6. Mx ran for a long time before it terminated.
7. I had to fix the factor loading for the paths between REAMB and REOAP, and BFAMB and BFEAP to 1 before the program ran.

Based on my experience of using Mx for the first time, I would like to propose the following recommendations:

1. The Mx input script file for the model depicted in Figure 1.2 was saved with an automatic extension of ".mx". All the other file extensions have three letters. I would like to suggest that the extension ".mx" be made ".mxi" to reflect that the file is an Mx input file.
2. The Mx script file is generated automatically from the drawing of a path diagram. If the reverse of this can be done, i.e. generating the path diagram form a script file, it would be very helpful. It would help to easily identify errors if they occur, especially, in the script file.
3. If possible, changes should be made to the program so that user would not have to deal directly with matrices as it is now. Figuring out which matrices to use and how to specify the few required entries was very difficult for me.
4. It may be a good idea to have a blank, instead of the automatic " 100 " for the number of observations in the input script generated from the path diagram. This may help to avoid the possibility of a user making a mistake of using the number of observations of 100 instead of another number.
5. I would like to suggest that a summarized version of the User's Guide be made for first time users so that they may not have to read to volumes of material before they can use the program.
6. The time it took before Mx terminated was very long. If this could be reduced, it would improve the efficiency of the program.

### 8.6 RAMONA

The following impressive observations were made on using RAMONA to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3.

1. I like the explanations and examples given in the RAMONA User's Guide. The explanations in the guide are precise. I did not have to read volumes of material before I figured out the various paragraphs in the RAMONA Input System.
2. Typing the various commands, keywords and options in the input system for the model depicted in Figure 1.2 was not difficult at all.
3. I did not have to make reference to any matrix in the typing of the various commands and options.
4. I like the fact that the RAMONA input file was reproduced as part of the output file.
5. I found that the RAMONA output file contained a lot of goodness-of-fit statistics and that it was very nicely arranged.

I encountered some difficulties on using RAMONA to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3. These included:

1. Every path in the path diagram had to be typed manually in the input file. I found this very time consuming.
2. The fact that I had to type the variable name as many times as they occur in the path diagram of the depicted in Figure 1.2 meant that I had to be very careful not to make typing errors. That made me go very slow in the typing.
3. I found the typing very time consuming since every path in the path diagram had to be specified in the input file.
Based on my experience of using RAMONA for the first time, I would like to propose the following recommendations:
4. Improvements should be made to the program, if possible, to enable users to specify paths between variables by simple clicks of push buttons.
5. The inclusion of a feature, which would enable users to enter the variable names only once and be able to use them by simply selecting the variable needed, would help reduce the time spent to type the input file.

### 8.7 SEPATH

The following impressive observations were made on using SEPATH to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3.

1. I had the option of either typing the necessary commands to specify the model in the input file or use the path tools available to generate the input file.
2. I found the use of the path tools to generate the input files to be very easy.
3. I typed the variable names once and used those I needed by simply selecting them.
4. I could specify several paths in the input file within a very short time.
5. I found the set up of the path tools very simple and it did not take long before I could use it successfully.
6. I did not have to make reference to any matrix during the specification of the model in the input file.
7. The single-headed and double-headed arrows are presented as check boxes. I only had to check the required one to get it into the input file.
8. With just little care, I completed the specification of the model without errors.

I encountered some difficulties on using SEPATH to fit the model depicted in Figure 1.2 to the correlation matrix provided in Table 1.3. These included:

1. The output files produced in dialog boxes look excellent. What I did not like about them, is that one has to scroll up and down and/or left and right to be able to read a complete file.
2. I had to manually delete the parameter numbers of all the double-headed arrows before the program ran successfully.
3. I found the Text output file difficult to read. It is too compact.
4. I found the User's Guide too comprehensive. It took me a very long time to read through all the relevant portions.

Based on my experience of using SEPATH for the first time, I would like to propose the following recommendations:

1. The presentation of the output files in the dialog boxes should be improved to provide users with access to view all parts of each dialog box at a time.
2. The layout of the text output file should be improved to make it clearer than at present.
3. Only a few goodness-of-fit statistics appear in the Text output file, as compared with the output files in the dialog boxes. This should be checked so that the same information is found in both types of output.
4. I would like to suggest that a summarized version of the User's Guide be made for first time users so that they may not have to read volumes of material before they can use the program.

### 8.8 COMPARING PARAMETER ESTIMATES OBTAINED FROM AMOS, EQS, LISREL, Mx, RAMONA AND SEPATH

The parameter and standard error estimates, produced by AMOS, EQS, LISREL, Mx, RAMONA and SEPATH for the Duncan, Haller and Portes SEM Application, are listed in Table 8.1

Table 8.1: Parameter Estimates produced by AMOS, EQS, LISREL, Mx, RAMONA and SEPATH.

|  | PATH |  | PROGRAM |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | AMOS | EQS | LISREL | Mx | RAMONA | SEPATH |
| 1 | REAMB | $\rightarrow$ REOAP | 0.767 | 0.767 | 0.767 | 1.000 | 0.766 | 0.766 |
| 2 | REAMB | REEAP | 0.813 | 0.814 | 0.813 | 0.813 | 0.814 | 0.814 |
| 3 | BFAMB | BFEAP | 0.825 | 0.828 | 0.825 | 0.825 | 0.829 | 0.828 |
| 4 | BFAMB | $\rightarrow$ BFOAP | 0.774 | 0.772 | 0.774 | 1.000 | 0.772 | 0.772 |
| 5 | BFAMB | $\longrightarrow$ REAMB | 0.174 | 0.176 | 0.174 | 0.176 | 0.175 | 0.175 |
| 6 | REAMB | $\longrightarrow$ BFAMB | 0.184 | 0.184 | 0.184 | 0.187 | 0.184 | 0.184 |
| 7 | REPAP | $\longrightarrow$ REAMB | 0.214 | 0.213 | 0.214 | 0.213 | 0.214 | 0.214 |
| 8 | REINT | $\longrightarrow$ REAMB | 0.333 | 0.332 | 0.333 | 0.333 | 0.332 | 0.332 |
| 9 | RESOE | $\longrightarrow$ REAMB | 0.290 | 0.290 | 0.290 | 0.290 | 0.290 | 0.290 |
| 10 | RESOE | $\longrightarrow$ BFAMB | 0.088 | 0.087 | 0.088 | 0.090 | 0.087 | 0.087 |


| 11 | bFSOE | $\longrightarrow$ REAMB | 0.104 | 0.103 | 0.103 | 0.103 | 0.103 | 0.103 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 12 | bFSOE | $\longrightarrow$ BFAMB | 0.282 | 0.283 | 0.282 | 0.281 | 0.282 | 0.282 |
| 13 | BFINT | $\longrightarrow$ BFAMB | 0.428 | 0.427 | 0.438 | 0.437 | 0.427 | 0.427 |
| 14 | BFPAP | $\longrightarrow$ BFAMB | 0.196 | 0.197 | 0.197 | 0.196 | 0.197 | 0.197 |
| 15 | REPAP | $\longleftrightarrow$ REINT | 0.184 | 0.184 | 0.184 | 0.184 | 0.184 | 0.184 |
| 16 | REPAP | $\longleftrightarrow$ RESOE | 0.049 | 0.049 | 0.049 | 0.049 | 0.049 | 0.049 |
| 17 | REPAP | $\longleftrightarrow$ BFSOE | 0.019 | 0.019 | 0.019 | 0.019 | 0.019 | 0.019 |
| 18 | REPAP | $\longleftrightarrow$ BFINT | 0.078 | 0.078 | 0.078 | 0.078 | 0.078 | 0.078 |
| 19 | REPAP | $\longleftrightarrow$ BFPAP | 0.115 | 0.115 | 0.115 | 0.115 | 0.115 | 0.115 |
| 20 | REINT | $\longleftrightarrow$ RESOE | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 |
| 21 | REINT | $\longrightarrow$ BFSOE | 0.186 | 0.186 | 0.186 | 0.186 | 0.186 | 0.186 |
| 22 | REINT | $\rightarrow$ BFINT | 0.336 | 0.336 | 0.336 | 0.336 | 0.336 | 0.336 |
| 23 | REINT | $\longrightarrow$ BFPAP | 0.102 | 0.102 | 0.102 | 0.102 | 0.102 | 0.102 |
| 24 | RESOE | $\longrightarrow$ BFSOE | 0.271 | 0.271 | 0.271 | 0.271 | 0.271 | 0.271 |
| 25 | RESOE | $\longleftrightarrow$ BFINT | 0.230 | 0.230 | 0.230 | 0.230 | 0.230 | 0.230 |
| 26 | bFSOE | $\longleftrightarrow$ BFPAP | 0.093 | 0.093 | 0.093 | 0.093 | 0.093 | 0.093 |
| 27 | bFSOE | $\longrightarrow$ BFINT | 0.295 | 0.295 | 0.295 | 0.295 | 0.295 | 0.295 |
| 28 | bFSOE | $\rightarrow$ BFPAP | 0.044 | -0.044 | 0.044 | -0.044 | -0.044 | -0.044 |
| 29 | BFINT | $\longleftrightarrow$ BFPAP | 0.209 | 0.209 | 0.209 | 0.209 | 0.209 | 0.209 |

Table 8.2: Standard Error Estimates produced by AMOS, EQS, LISREL, Mx, RAMONA and SEPATH.



Table 8.3: Measures of Fit produced by AMOS, EQS, LISREL, Mx, RAMONA and SEPATH.

|  |  | PROGRAM |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | MEASURES OF FIT | AMOS | EQS | LISREL | Mx | RAMONA | SEPATH |
| 1 | Minimum Fit Function Chi-Square | 26.803 | 26.840 | 26.833 | 27.002 | 26.870 | 26.893 |
| 2 | Degrees of Freedom | 16 | 16 | 16 | 16 | 16 | 16 |
| 3 | p value | 0.043 | 0.044 | 0.051 | 0.041 | 0.043 | 0.043 |
| 4 | Normal Theory weighted least square chisquare |  | 26.084 | 26.197 |  |  |  |
| 5 | Minimum Fit Function Value | 0.083 |  | 0.082 |  | 0.082 | 0.082 |
| 6 | Population Discrepancy Function Value ( $\mathrm{F}_{\mathrm{o}}$ ) | 0.033 |  | 0.031 |  | 0.033 |  |
| 7 | Root Mean Square Error of Approximation (RMSEA) | 0.045 |  | 0.044 | 0.046 | 0.046 | 0.044 |
| 8 | p-value for Test of Close Fit (RMSEA <0.05) |  |  | 0.591 |  | 0.561 |  |
| 9 | Chi-square for Independence | 862.753 | 872.155 | 862.637 | 862.155 |  | 872.001 |
| 10 | Degrees of Freedom | 45 | 45 | 45 | 45 |  | 45 |
| 11 | Expected Cross-validation Index (ECVI) | 0.320 |  | 0.318 |  | 0.320 |  |
| 12 | ECVI for Saturated Model | 0.335 |  | 0.335 |  | 0.335 |  |
| 13 | ECVI for Independence Model | 2.691 |  | 2.691 |  |  |  |
| 14 | Independence AIC | 882.753 | 782.155 | 882.637 |  |  |  |
| 15 | Model AIC | 104.830 | 104..801 | 104.197 | 104.988 |  |  |
| 16 | Saturated AIC | 110.000 |  | 110.000 |  |  |  |
| 17 | Independence CAIC |  | 930..484 | 930.597 |  |  |  |
| 18 | Model CAIC | 291.877 | 291.444 | 291.243 |  |  |  |
| 19 | Saturated CAIC | 373.783 |  | 373.783 |  |  |  |
| 20 | Normed Fit Index (NFI) | 0.969 | 0.969 | 0.969 | 0.943 | 0.969 | 0.969 |
| 21 | Non-Normed Fit Index (NNFI) |  | -0.406 | 0.963 | 0.976 | 0.963 | 0.963 |
| 22 | Parsimony Normed Fit Index (PNFI) |  |  | 0.344 | 0.335 | 0.345 | 0.345 |


| 23 | Comparative Fit Index (CFI) | 0.987 | 0.969 | 0.987 |  | 0.987 | 0.987 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 24 | Incremental Fit Index (IFI) | 0.987 |  | 0.987 |  | 0.987 | 0.987 |
| 25 | Relative Fit Index (RFI) | 0.913 |  | 0.913 |  | 0.913 | 0.913 |
| 26 | Critical N (CN) |  |  | 392.159 |  |  |  |
| 27 | Estimated Non-centrality Parameter (NCP) |  |  | 10.197 |  |  |  |
| 28 | Root Mean Square Residual (RMR) | 0.021 |  | 0.021 |  | 0.020 | 0.020 |
| 29 | Standardized RMR |  |  | 0.021 |  | 0.020 | 0.020 |
| 30 | Goodness of Fit Index (GFI) | 0.984 |  | 0.984 |  | 0.984 | 0.984 |
| 31 | Adjusted Goodness of Fit Index (AGFI) | 0.946 |  | 0.946 |  | 0.946 | 0.946 |
| 32 | Parsimony Goodness of Fit Index (PGFI) | 0.350 |  | 0.351 |  | 0.350 |  |
| 33 | Tucker-Lewis Index (TLI) | 0.963 |  |  |  | 0.963 |  |
| 34 | BCC | 107.537 |  |  |  |  |  |
| 35 | BIC | 342.677 |  |  |  |  |  |
| 36 | Relative Non-centrality Index |  |  |  | 0.974 | 0.987 |  |
| 37 | Centrality Index |  |  |  | 0.983 |  |  |
| 38 | Schwarz Bayesian Criterion |  |  |  |  | 0.771 | 0.771 |
| 39 | Browne-Cudeck Single Sample Index (CVI) |  |  |  |  | 0.328 | 0.328 |
| 40 | James-Mulaik-Brett Parsimonious CFI |  |  |  |  | 0.345 |  |
| 41 | McDonald Index for Noncentrality |  |  |  |  | 0.984 | 0.985 |
| 42 | Population Noncentrality Parameter |  |  |  |  |  | 0.031 |
| 43 | Population Gamma Index |  |  |  |  |  | 0.994 |
| 44 | Adjusted Population Gamma Index |  |  |  |  |  | 0.979 |
| 45 | Akaike Information Criterion |  |  |  |  | 0.320 | 0.320 |

The following observations were made from the parameter estimates produced by the six SEM programs, parts of which are shown in Table 8.1, Table 8.2 and Table 8.3 above.

1. RAMONA and SEPATH, which have the ability to analyze sample correlation matrix correctly, produce estimated standard errors for the standardized parameter estimators while AMOS, EQS, LISREL and Mx, which treat correlation structures as if they were covariance structures, only produce the standardized parameter estimates.
2. The parameter estimates produced by AMOS, EQS, LISREL, Mx, RAMONA and SEPATH are very close to each other.
3. All the six programs produced the same standardized solutions for the correlations between the variables.
4. For all the measures of fit indices produced by more than one of the programs, the values obtained are almost the same.

### 8.9 RECOMMENDATIONS FOR FUTURE RESEARCH

There are many other Structural Equation Modeling programs that were not used in this study. These include, amongst others, COSAN, LINCS, LISCOMP, MECOSA, SAS PROC CALIS. A study on the use of these programs by a first time user to fit the model depicted in Figure 1.2 to the data in provided in Table 1.3 would be interesting. The comments and recommendations would complement those made in this study to give a comprehensive overview of the problems that first time users encounter when using Structural Equation Modeling programs. The resulting recommendations could be used to improve the user-friendliness of these SEM software packages.

All the six programs used in this study, except for RAMONA, can perform multi-group analyses. A study in which the SEM programs with a multi-group analysis facility are compared in terms of the experiences of a first time user in performing a multi-group analysis would be of interest.

A study in which a survey is conducted amongst users of Structural Equation Modeling programs with the objective of assessing the user-friendliness and the difficulties encountered by them would be interesting. Users could be asked to give their personal comments and recommendations on the programs. Such a study could assist the authors of Structural Equation Modeling programs to determine possible areas for improvements.

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