indices means would suggest that, at a minimum, researchers would want to consider the issues of absolute fit, comparative fit, and parsimonious fit for each model tested. Fit indices therefore should be chosen so as to reflect each of these concerns (i.e., choosing one or two indices of each type of fit).

Finally, it is important for researchers to recognize that "model fit" does not equate to "truth" or "validity." The fit of a model is, at best, a necessary but not sufficient condition for the validity of the theory that generated the model predictions. Although the question of model fit is important, it is by no means the most important or only question we should ask about our data.

Note

1. Recall the previous discussion about the arbitrariness of such guidelines and the resultant need for cautious interpretation.

CHAPTER 4

Using LISREL

Having considered the general approach to be used in structural equation modeling, it is now time to consider the specifics of using LISREL to estimate and evaluate such models. It should be noted that other programs (e.g., EQS and EZPATH) are available to evaluate structural equation models. LISREL remains, however, a popular and widely available software package for structural equation modeling.

LISREL works by defining eight matrices; within each matrix are free and fixed parameters. Free parameters are unknowns to be estimated by the program, whereas fixed parameters are set to some predetermined value (usually zero).

For example, a typical LISREL matrix might contain three rows and two columns, as follows.

	K1	K2
X1	Free	Fixed
X2	Free	Fixed
X3	Fixed	Free

In this case, matrix elements (1, 1), (2, 1) and (3, 2) are going to be freely estimated by the program. Matrix elements (1, 2), (2, 2), and (3, 1) are fixed (set to zero). Researchers would specify the model to be tested by manipulating these matrices and whether their elements were fixed or free. Using the matrix formulation of LISREL, the researcher's task is to translate the model (i.e., the path diagram) into the LISREL matrices.

To do so, one has to understand what matrices are involved in the analyses and what forms they take.

The current release of LISREL (LISREL VIII) incorporates the SIMPLIS command language. Essentially, the SIMPLIS command language is an attempt to move away from the matrix formulation of the LISREL model and toward a more natural language approach to defining LISREL models. The researcher's task using the SIMPLIS language is to translate the model into SIMPLIS syntax.

We will focus on the matrix approach, rather than the SIMPLIS approach, to defining LISREL models. Although the reader is welcome to choose either approach to LISREL syntax, it should be noted that references to LISREL matrices continue to appear in the literature, and it is helpful to know the underlying structure of the program. Readers interested in using the SIMPLIS language are referred to Jöreskog and Sörbom (1992).

Whether one is using the matrix formulation or the SIMPLIS language, setting up a structural equation model in the LISREL environment involves three types of specification. First, you must tell LISREL how to read the data. Second, you have to specify the model to be estimated. Finally, you have to specify the type of output you want from your analysis.

The Matrix Formulation

To assist in the translation from path diagrams to matrices, it helps to remember a couple of points:

1. A *free* element in a LISREL matrix is the same as a path connecting the variables represented by the column and the row.
2. A *fixed* element in a LISREL path is the same as a hypothesis of no path between the variables represented by the column and the row.
3. To refer to the elements of a matrix, we always refer to the row, then the column [e.g., (1, 4) means the element in the first row and the fourth column].
4. In path diagrams, the direction of the relationship is given by the direction of the arrow. In LISREL matrices, columns always cause (predict) rows.

The LISREL model consists of the measurement model for the *X* (exogenous) variables, the measurement model for the *Y* (endogenous)

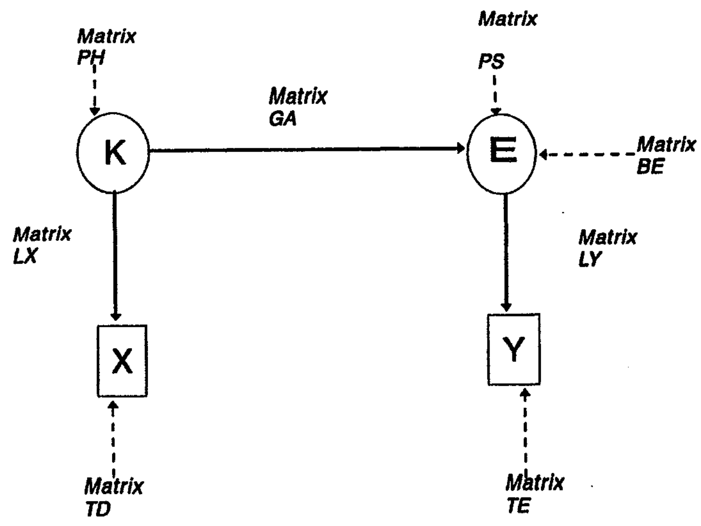

Figure 4.1.

variables, and the structural model, which relates the two. The full LISREL model comprises eight matrices (see Figure 4.1).

By specifying a subset of these matrices, the user can tailor LISREL to specific problems. For example, if you are interested in a factor analysis of the exogenous (X) variables, you need only be concerned with the LX (factor loadings; i.e., loadings of variables on common factors), PH (factor covariances or correlations), and TD (unique factors for each variable; i.e., residuals) matrices, which compose the measurement model for the exogenous variables (see Figure 4.2).

In the model, there are *NK* (*N* = number, *K* stands for latent variables on the exogenous side of the LISREL model) latent variables or factors. They are related through a series of paths (found in the LX matrix) to a series of *NX* (number of observed variables) observed variables/measures. The intercorrelations or covariances of the factors are contained in the matrix PH.

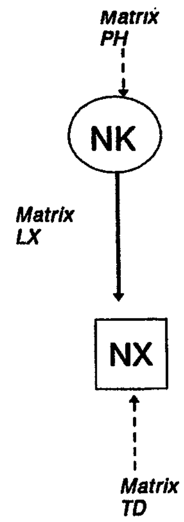

Figure 4.2.

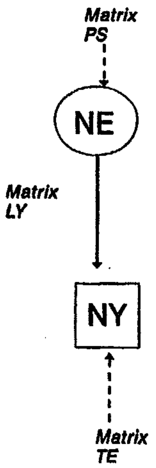

Figure 4.3.

The unique factors (residuals) fo each observed variable are in matri TD.

Similarly, the measuremen model for the *Y* variables consists o the **LY** (factor loadings), **PS** (facto covariances), and **TE** (residuals matrices (see Figure 4.3). There ar *NE* (number of latent endogenou variables) latent variables or factors They are related through a series o paths (found in the **LY** matrix) to series of *NY* (number of observe endogenous variables) observed vari ables/measures). The intercorrela tions or covariances of the factor are contained in the matrix **PS**. Th unique factors (residuals) for each observed variable are in matrix **TE**.

The structural model relating exogenous (*X*) and endogenous (*Y* variables consists of the **GA** (structural coefficients relating *X* to Y variables) and **BE** (structural coefficients relating *Y* to *Y* variables matrices (see Figure 4.4).

NX observed variables are related (**GA** contains the path values) tc *NY* observed variables. The endogenous (*Y*) observed variables may alsc predict other *Y* variables. These paths are found in the **BE** matrix. Finally the unexplained variances (i.e., residuals) of the *Y* predicted variables are found in matrix **PS**.

Each of the eight matrices in LISREL can be thought of as a matrix of free and fixed values. A free value is an unknown, that is, a value that

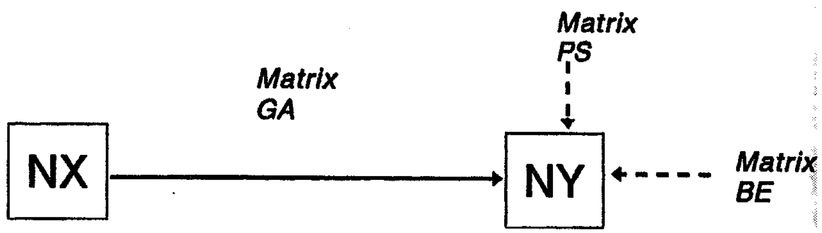

Figure 4.4.

TABLE 4.1 LISREL Matrices

Matrix	*Order*	*Form*	*Alternates*	*Mode*	*Comments*
1. LY	*NY* × *NE*	FU	ID, IZ ,ZI, DI, FU	FI	Relates *Y*s to *E*s (factor loadings)
2. LX	*NX* × *NK*	FU	ID, IZ, ZI, DI, FU	FI	Relates *X*s to *K*s (factor loadings)
3. BE	*NE* × *NE*	ZE	ZE, SD, FU	FI	Relates *E*s to *E*s (structural coefficients)
4. GA	*NE* × *NK*	FU	ID, IZ, ZI, DI, FU	FR	Relates *E*s to *K*s (structural coefficients)
5. PH	*NK* × *NK*	SY	ID, DI, SY, ST	FR	Relates *K*s to *K*s (factor covariances)
6. PS	*NE* × *NE*	SY	ZE, DI, SY	FR	Residuals of *E*s (factor covariances in a factor analysis of *Y* variables or errors of prediction in a structural model)
7. TE	*NY* × *NY*	DI	ZE, DI, SY	FR	Residuals of *Y*s (unique factors)
8. TD	*NX* × *NX*	DI	ZE, DI, SY	FR	Residuals of *X*s (unique factors)

NOTE: For Order, *NX* = number of observed exogenous (source) variables, *NY* = number of observed endogenous (downstream) variables, *NK* = number of latent exogenous variables, and *NE* = number of latent endogenous variables. For Forms, ZE = zero matrix (a matrix filled with zeros), ID = identity matrix (a zero matrix with 1s in the diagonal), IZ = partitioned identity and zero, ZI = partitioned zero and identity, DI = diagonal matrix (only the diagonal elements are stored), SD = subdiagonal matrix (elements below the diagonal), SY = symmetric matrix that is not diagonal (diagonal elements do not equal 1), ST = symmetric matrix with 1s in the diagonal (e.g., correlations), and FU = a rectangular or square nonsymmetric matrix. For modes, FI = fixed and FR = free.

you want LISREL to estimate for you. A fixed value is set to a predetermined value (often 0) and is not estimated by the program. Table 4.1 gives a summary of the eight matrices, their default forms, and the various alternate forms they can assume.

It's All Greek to Me!

To be totally fluent in LISREL, Hayduk (1987) suggests that we should know the Greek names for the LISREL matrices. This allows one to make puns such as "LISREL is all Greek to me." Should your taste in humor run along these lines, you may be interested to know that

LX = Lambda X
LY = Lambda Y
BE = Beta
GA = Gamma
PH = Phi
PS = Psi
TD = Theta-Delta
TE = Theta-Epsilon

LISREL Keywords

The matrix form of LISREL operates through keywords that allow the user to specify the forms of the relevant matrices. For most commands, only the first two letters are necessary.

To run LISREL, you create a list of commands in which you

1. specify the data,
2. specify the model, and
3. specify the output.

LISREL command files often begin with an optional **TItle** statement. This command is optional but recommended. If used, LISREL will print the title throughout the output file, thereby providing the user with a means of documenting the analysis.

Specifying the Data

DAta

The **DAta** statement is used to define the data. The following may be specified:

NGroups = number of groups (default = 1),
NInpvar = number of input variables (default = 0),
NObs = number of observations,

XM = a missing value label (used when reading in raw data; by default, LISREL uses listwise deletion of missing values), and
MAtrix = the type of matrix to be analyzed. (Note that this is not necessarily the same type as the matrix that you read into LISREL. For example, you can request that LISREL read in a covariance matrix and then analyze the correlation matrix.)

MAs can assume the following values:

MM = matrix of moments about 0,
CM = a covariance matrix (default),
KM = a correlation matrix,
AM = an augmented moment matrix,
OM = a correlation matrix of optimal scores produced by PRELIS, or
PM = a matrix of polychoric or polyserial correlations.

For example, a typical DAta statement might look like:

```
DA NI = 10 NO = 100 MA = CM.
```

LISREL will read the statement as saying that you have 10 variables (NI = 10) and 100 observations (NO = 100), and you want the analyses to be based on the covariance matrix (MA = CM).

LAbels

The **LAbel** statement is used to assign labels to the variables being read. Although LISREL will read LAbels from an external file, I've typically found it useful to include the labels in the command file.

A typical LAbel statement might look like this:

```
LA
    'Label 1' 'Label 2' 'Label 3'
```

Note that LISREL expects to read as many labels as the number of input variables specified on the DAta statement.

If you only want to label some of the variables, then you can use a "/" to terminate reading the labels. For example:

```
DA NI = 10 NO = 200 MA = CM
LA
 'Behavior' 'Intentions' 'Norms' 'Attitudes' 'Beliefs'/
```

The DAta statement tells LISREL to read 10 variables, but labels are provided for only the first five variables.

RAw Data

The **RAw** data statement is used when you want to read raw data into the LISREL program. It is typically followed by both (a) the filename in which the raw data are stored and (b) a Fortran variable format statement (if not contained in the data file).

For example:

```
RA FI= data.dat FO
(5F7.3)
```

tells LISREL that the raw data are found in the file called "data.dat" and that the next line in the command file is the Fortran variable definition statement (in this case specifying five variables in fields of seven columns with three places behind the decimal). The Fortran format statement may be replaced by an asterisk (*) indicating that the data are in free format (i.e., separated by columns or spaces).

CM, KM, MM, OM, and PM

These commands tell LISREL to read a specified matrix using the conventions described earlier (e.g., **CM** = covariance matrix). In addition to the type of matrix, you must specify the form of the matrix, either symmetrical (elements including and below the diagonal, SY) or full (all elements in the matrix, FU). For example, to read in a correlation matrix, you might write


```
KM SY
 1.00
  .50  1.00
  .40   .30  1.00
```

You also can use the FI command (as described earlier) to read the matrix from an external file.

ME and SD Commands. These commands read in a vector of either means (ME) or standard deviations (SD). Again, the FI command may be used to read data from an external file. Given our earlier focus on analysis of the covariance matrix, it is useful to note that given a correlation matrix, a vector of means, and a vector of standard deviations, LISREL can compute the covariance matrix prior to analysis.

SElect

The **SElect** command is used to reorder the variables in the matrix. This is a useful feature because LISREL expects to read the endogenous variables first, followed by the exogenous variables. You also can use the SElect command to drop variables from the analysis. For example, given that you have read in six input variables, the statement

```
SE
     6 5 4 3 2 1
```

reverses the order of the variables, while

```
SE
     6 5 4 2 1/
```

both reorders the variables and deletes the third variable from the analysis. Note that the "/" is used to terminate variable selection before the number of input variables is reached.

Specifying the Model

The LISREL model specification commands follow the data in the command file. Models are specified using the **MOdel** command. You can specify

NY = number of observed endogenous variables,
NX = number of observed exogenous variables,
NE = number of latent endogenous variables, or
NK = number of latent exogenous variables.

Specifying a subset of these parameters will result in specification of a LISREL submodel. For example, if you specify

NK and NX:	You are doing a factor analysis of exogenous variables involving matrices **LX, PH,** and **TD.**
NE and NY:	You are doing a factor analysis of endogenous variables involving matrices **LY, PS,** and **TE.**
NX and NY:	You are doing a path model using only observed variables and involving matrices **BE, GA,** and **PS.**
NX, NY, NK, and NE:	You are doing a full latent variable model using all eight of the LISREL matrices.

For each matrix involved in the model selected, you can either use the default form (see Table 4.1 on page 45) or specify an alternate form with the MOdel command. You specify an alternate form by typing (on the same line as the MOdel command)

```
MN = AA, BB
```

where MN = a name of a parameter matrix,
AA = a valid alternate form for that matrix, and
BB = either FIxed or FRee.

In general, LISREL is set up so that the default forms of each parameter matrix are the ones most often used. You can modify the default forms by (a) selecting a new form as shown above or (b) modifying the **FIxed/FRee** status of individual elements of a parameter matrix. To modify these elements, you use the FR and FI commands. For example:


```
FIx LX(1,2) LX(2,2)
```

modifies two elements in the **LX** matrix by setting them to be a fixed value. The modified elements are located at matrix coordinates (1, 2) and (2, 2).

Similarly,

```
FRee LX(1,2) LX(2,2)
```

modifies the same two elements by setting them as free (to be estimated values). In addition to setting elements to be FRee or FIxed, you also can set them up to be EQual to another element. Each group of elements that are constrained to be equal are defined on a separate **EQ** command. For example:

```
EQ LY(3,4) LY(4,4) BE(2,1) GA(4,6)
```

defines all the listed elements as being equal to the same value. Typically, the first element listed will be a free parameter—LISREL will estimate the free parameter and set the remaining values to be equal to it.

The **VAlue** and **STarting value** commands are used to define nonzero values for fixed parameters and to set the starting values for free parameters. The commands are equivalent and can be used interchangeably. For example:

```
VA 1.5 LX(2,1) LY(6,2) GA (1,2)
```

assigns the value 1.5 to the listed elements. If the elements are fixed, this becomes an assigned value; if they're free, it becomes a start value.

The **LE** and **LK** commands are used to supply labels for the latent endogenous (LE) and latent exogenous (LK) variables. The format for these commands is exactly the same as for the LA command described earlier.

Specifying the Output

The user can specify the amount and quality of LISREL output by using the **OUtput** subcommand. You specify the estimation method by one of the following keywords:

IV = instrumental variable method,
TS = two-stage least squares,
UL = unweighted least squares,
GL = generalized least squares,
ML = maximum likelihood (this is the default),
WL = generally weighted least squares, or
DL = diagonally weighted least squares.

Additional options provided by LISREL are

RC = ridge constant: matrix will be multiplied repeatedly by 10 until the matrix becomes positive definite;
SL = significance of modification procedures expressed as a percentage (see AM below);
NS = do not compute starting values (must be supplied by the user);
RO = ridge option: used with RC, invoked automatically if the covariance matrix is not positive definite;
AM = automatic model modification: LISREL will automatically modify the model by sequentially freeing the fixed parameter with the largest modification index; and
SO = scaling check off: turns off LISREL's capacity to check for scale assignment to latent variables.

LISREL always provides standard output consisting of the information you provide, the initial estimates, the LISREL estimates (ML or UL) and the overall goodness-of-fit measures. Additional output can be requested by the following keywords:

SE = standard errors;
TV = *t* values;
PC = correlations of estimates;
RS = residuals, normalized residuals, and Q plot;
EF = total effects and indirect effects;
MR = miscellaneous results, equivalent to RS, EF, and VA;

MI = modification indices;
FS = factor scores regressions;
SS = standardized solution;
SC = solution completely standardized;
AL = print everything;
TO = print 80 characters/line (normal printer);
WP = print 132 characters/line (wide carriage printer); and
ND = number of decimals (0-8) in printed output.

LISREL also allows you to save specified matrices to external files at termination. The required syntax is

```
OU matrix name = file
```

where matrix name can be LY, LX, BE, GA, PH, PS, TE, TD, TY, TX, AL, or KA. In addition, LISREL will allow you to save the following matrices:

MA = reordered input matrix,
SI = sigma (implied covariance matrix),
RM = regression matrix of latent on observed variables (factor scores), and
EC = estimated asymptotic covariance matrix of LISREL estimates.

Finally, several commands allow you to control the iterative procedure used by LISREL. You can specify

TM = maximum number of CPU seconds allowed for current problem (e.g., TM = 60);
IT = maximum number of iterations (default is 3 × number of free parameters);
AD = check the admissibility of the solution after *m* iterations, and stop the procedure if the check fails (e.g., AD = 10); and
EP = convergence criterion (epsilon); a default value (EP = .000001) usually results in a solution accurate to three decimal places.