Latent variables in linear stochastic models
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SUMMARY AND CONCLUSIONS

In this thesis the statistical properties of two methods, which are designed for the analysis of the relationships between latent variables and indicators, are critically examined. The thesis consists of two parts.

Chapter 1 of the first part contains a discussion of Lisrel. This method fits the theoretical covariance matrix of the indicators to their sample covariance matrix. The fitting is done by the maximization of the likelihood function, using the assumption of normality of the indicators as a working hypothesis. In the first five sections of chapter 1 estimation of parameters and latent variables is discussed. The fact is stated and stressed that the asymptotic distribution of Lisrel estimators is robust against deviations from normality. § 6 concerns tests of hypotheses and it is shown by means of a simple example that tests based on first order derivatives may be misleading. The last section gives a few miscellaneous notes and remarks, including a brief indication of the applicability of Lisrel to economics.

The second chapter of part I deals with various aspects of PLS. Users of this method try to find proxies for the latent variables by means of one of the PLS-algorithms. Once the proxies are obtained, they are used as stand-in's for the latent variables, acting as directly observed variables. Parameters of equations expressing the relationships between indicators and latent variables are then estimated "straight-forwardly", using standard tools.

Chapter two contains a number of new results. The more important ones may be summarized as follows:
1 The proxies are interpreted and it is shown that they are less strongly correlated with the latent variables than the proxies obtainable with Lisrel.
2 One of the canonical likelihoods is shown to be obtained.
(A canonical likelihood is shown to be obtained.
3 It is posed, whether the probabilities are increased.
4 PLS estimators are shown to be normal, asymptotically.
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6 Using a normal, asymptotically.

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2 One of the PLS-algorithms, "mode B", is shown to yield canonical variables and it is explained how maximum likelihood can also be used to produce canonical variables. (A canonical variable is perfectly correlated with the most likely "value" of its corresponding latent variable, given the latter's indicators).

3 It is proven that the PLS-algorithms converge with a probability tending to one if the number of observations increases.

4 PLS estimators are shown to possess probability limits which may be quite different from the "true" parameter values. The inconsistency is a decreasing function of the correlations between proxies and corresponding latent variables.

An explanation is given how consistent estimators can be obtained using the PLS algorithms.

5 PLS estimators are under mild conditions asymptotically normal, centered around their probability limits. However, asymptotic covariance matrices are difficult to find. Indeed, they appear to be intractable.

6 Using a modified concept of "mean square error", it is shown that the PLS estimators for the correlations between the latent variables are less accurate than the Lisrel estimators, under not too restrictive conditions.

We do not recommend PLS for inference purposes unless exact sample results, not yet available, dictate otherwise. PLS may, however, be profitably used to obtain starting values for Lisrel, because the algorithms usually converge fast.

The third and last chapter of part I contains an attempt to explain the logic of a test which is heavily used in PLS. This test is shown to be very similar to classical likelihood ratio tests. However, the latter tests are easier to calculate, have simpler distributional properties and allow the researcher to choose his own significance level. For these reasons the test is not recommended.
The second part of this thesis contains simple extensions of the Generalized Least Squares method: some of the asymptotic properties of GLS estimators satisfying incorrect parameter restrictions are found. The results are used in part I but they may be relevant also outside of that limited framework, e.g. for the analysis of pre-test estimators. We refer to pages 117, 118 and 119 for an introduction and summary of part II.