Covariance-based Structural Equation Modeling: Foundations and Applications

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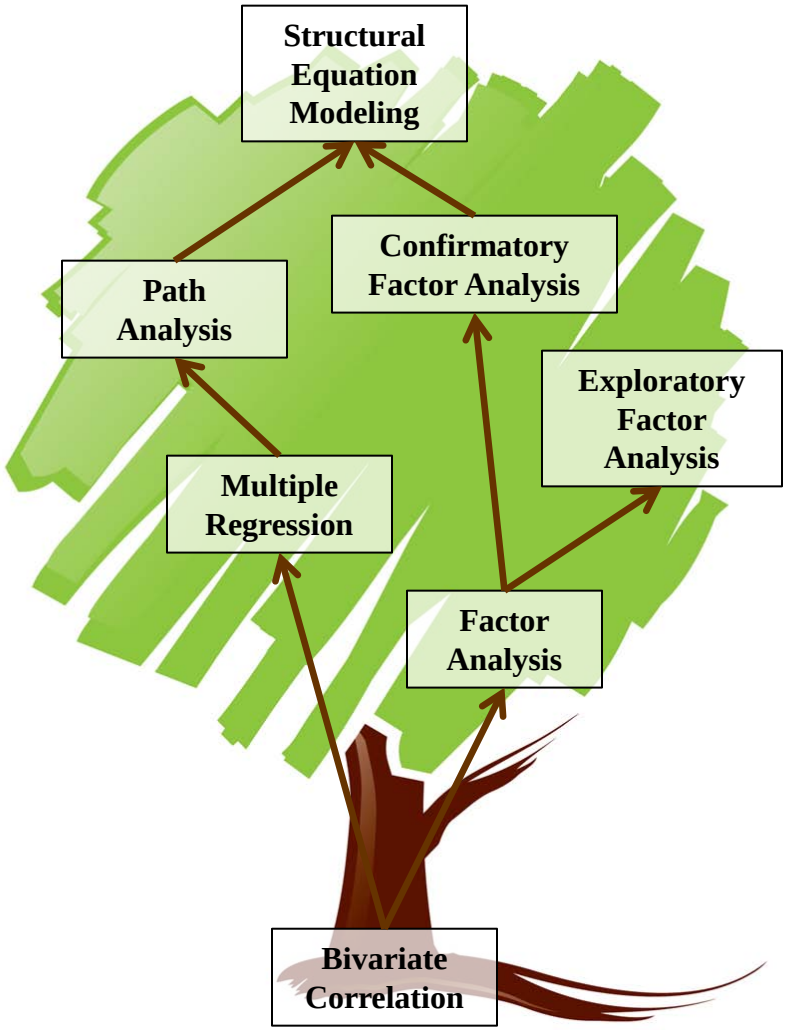
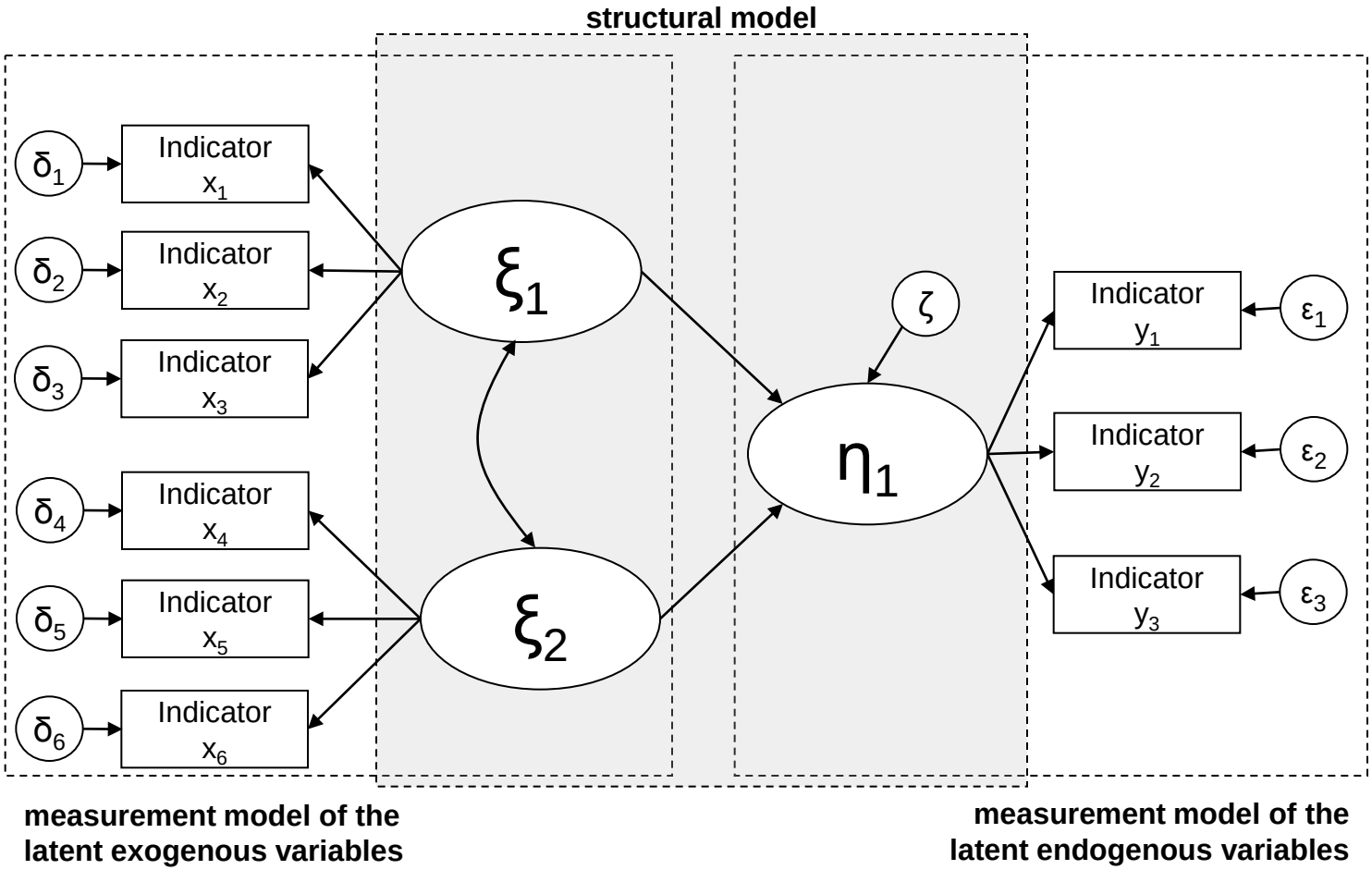
Overview

1. What is CBSEM?
2. How does CBSEM work?
3. What can CBSEM do for you?
4. Examples
5. Conclusions

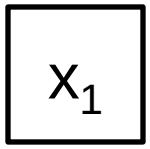
Family Tree of SEM



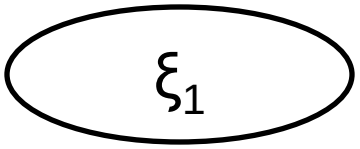
Schematic Representation of a Structural Equation Model

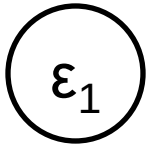


Symbols Used

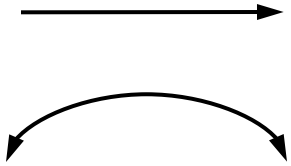


Indicators are normally represented as squares. For questionnaire based research, each indicator would represent a particular question.





Latent variables are normally drawn as circles. In the case of error terms, for simplicity, the circle is sometimes left off. Latent variables are used to represent phenomena that cannot be measured directly. Examples would be beliefs, intention, motivation.



Arrow connections represent linear relationships; curved double-ended arrows denote covariances (or correlations).

The Idea of Estimating SEM

Estimate the parameters so that the discrepancy between the sample covariance matrix and the implied covariance matrix is minimal.

$$\Sigma(\theta) \overset{approximate}{=} S$$

Σ: implied covariance matrix of observed variables

θ: model parameters

S: sample covariance matrix of observed variables

How SEM and Traditional Approaches Are Different

- Multiple equations can be estimated simultaneously
- Latent (unobservable) variables can be constructed
- Non-recursive models are possible
- Correlations among disturbances are possible
- Formal specification of a model is required
- Measurement and structural relations are separated, with relations among latent variables rather than measured variables
- Assessing of model fit is not as straightforward
- Model fit gets a different meaning

The Concept of "Fit" Revisited

Example: A theory states that two variables are unrelated. We empirically test the theory.

Results from Correlation or Regression:

$R^2 = 0$

Thus, no fit!

Results from CBSEM:

$\Sigma = S$

Thus, perfect fit!

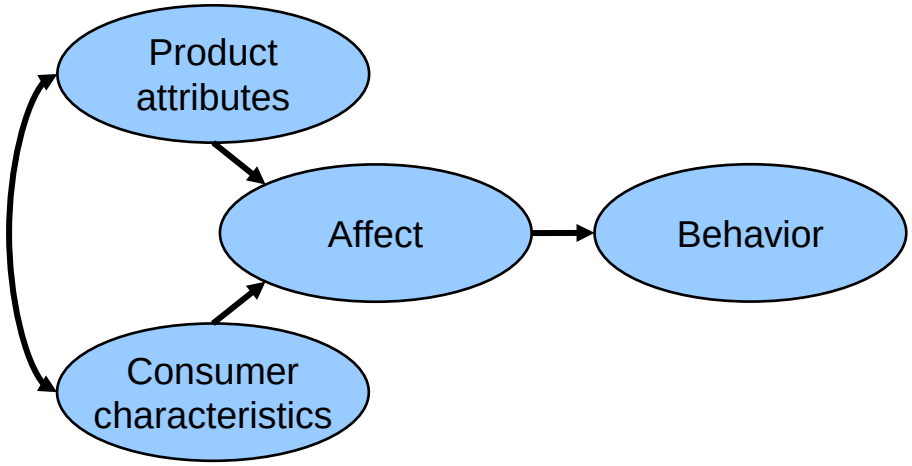
Theory Testing

Covariance-based structural equation modeling facilitates three types of theory testing:

- ✓ strictly confirmatory
- ✓ alternative models
- ✓ model generating

Strictly Confirmatory Theory Testing

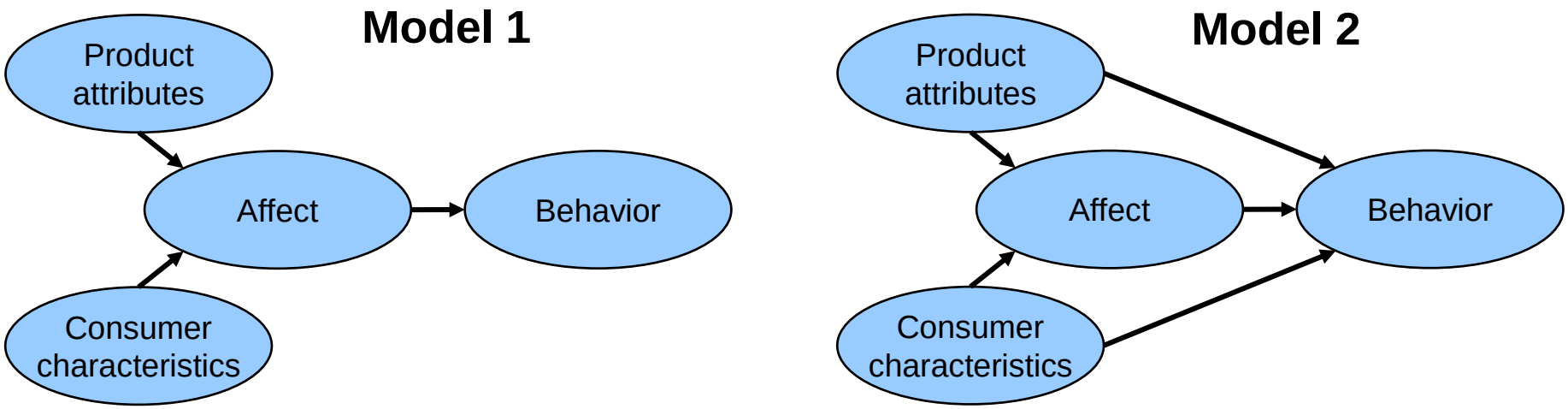
In a strictly confirmatory situation, the researcher has formulated one single model and has obtained empirical data to test it. The model should be either accepted or rejected.



The model is supported if its implied covariance-matrix does not differ significantly from the empirical covariance matrix.

Theory Testing: Alternative Models

The researcher has specified several alternative models (or competing models) and, on the basis of an analysis of a single set of empirical data, one of the models should be selected.

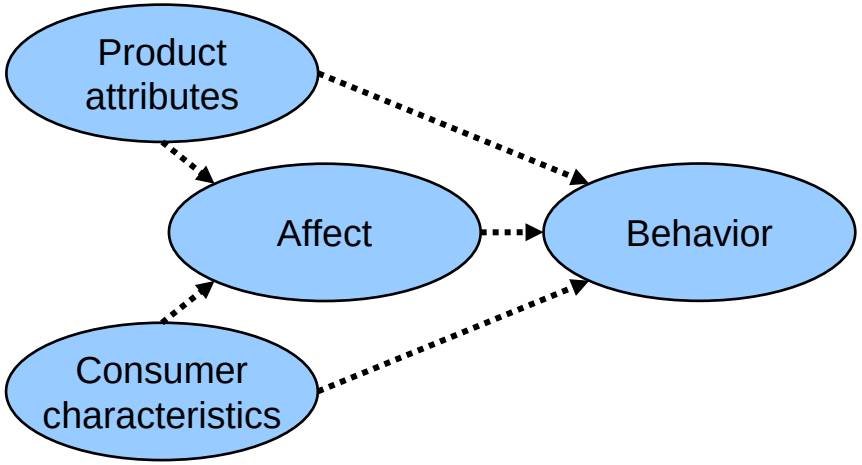


Model 1 is supported if its fit is not significantly worse.

Theory Testing: Model Generating

The researcher has specified a tentative initial model. If the initial model does not fit the given data, the model should be modified and tested again using the same data. Several models can be tested.

Finding of a model that fits the data well from a statistical point of view and additionally every parameter of the model can be given a substantively meaningful interpretation.



The re-specification of each model may be theory driven or data driven. Although a model may be tested in each round, the whole approach is model generating, rather than model testing. Depending on the circumstances, the chances to identify the true model can be quite small (MacCallum 1986).

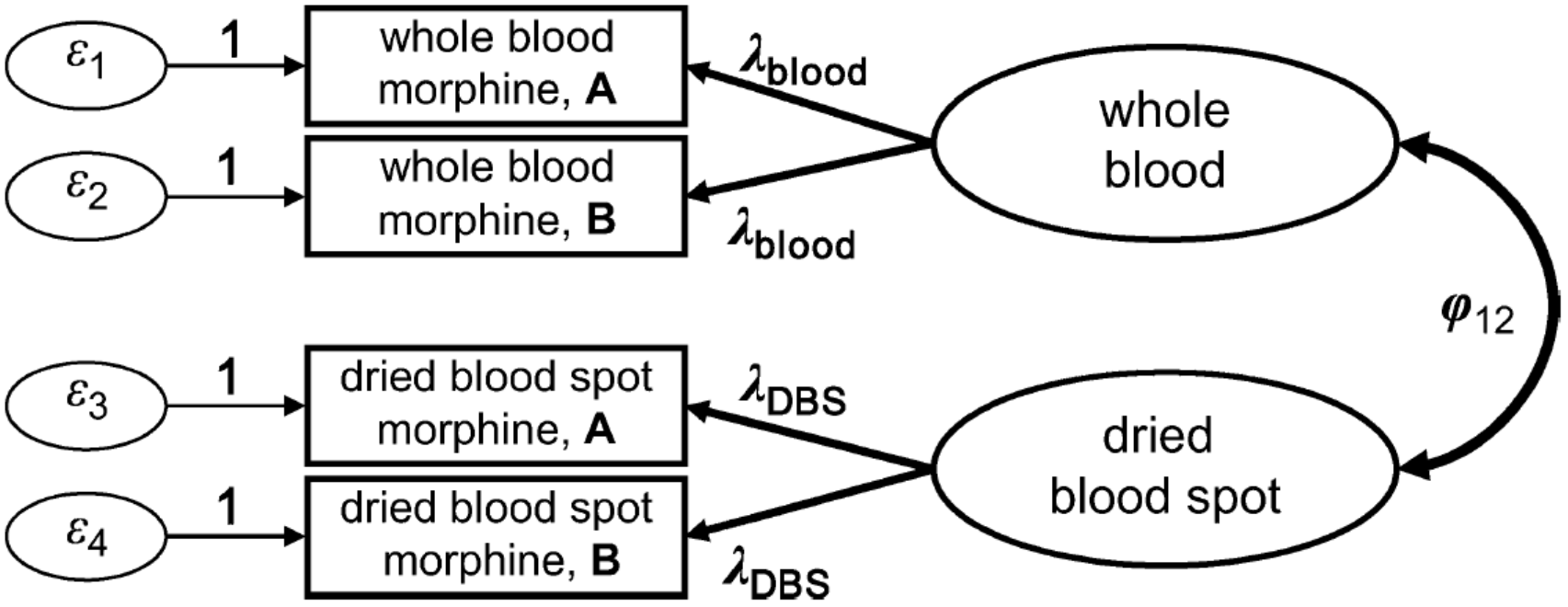
Example 1

Research question:

Does the analysis of whole blood and dried blood spots lead to equivalent conclusions in terms of heroine consumption?

Garcia Boy, R.; Henseler, J.; Mattern, R.; Skopp, G. (2008). Determination of Morphine and 6-Acetylmorphine in Blood With Use of Dried Blood Spots. *Therapeutic Drug Monitoring*, Vol. 30, No. 6, pp. 733-739.

Example 1



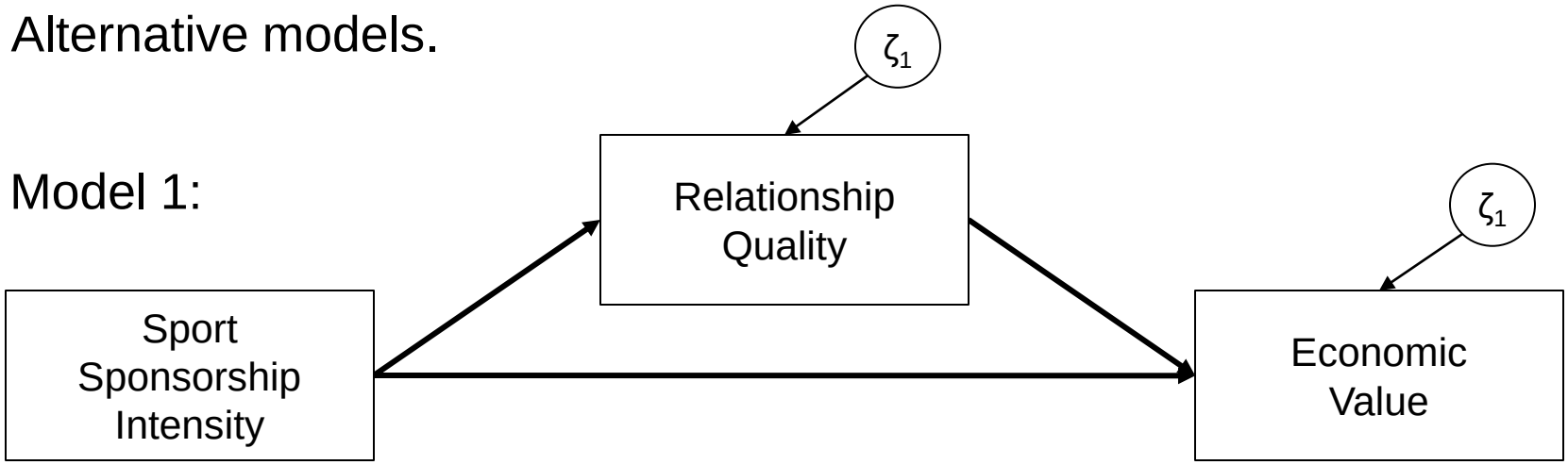
Strictly confirmatory.

Theory: Measurement instruments have constant reliability, and both ways of conserving blood lead to equal conclusions (φ_{12}=1).

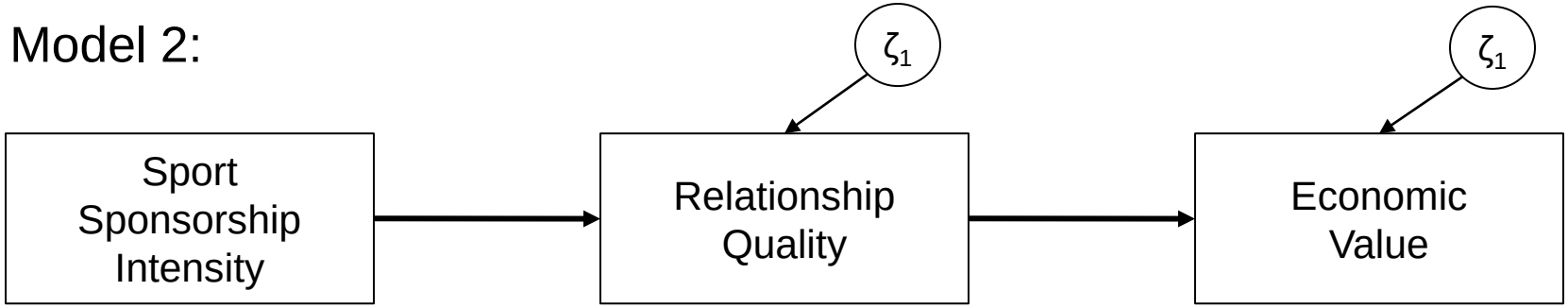
Example 2

Alternative models.

Model 1:

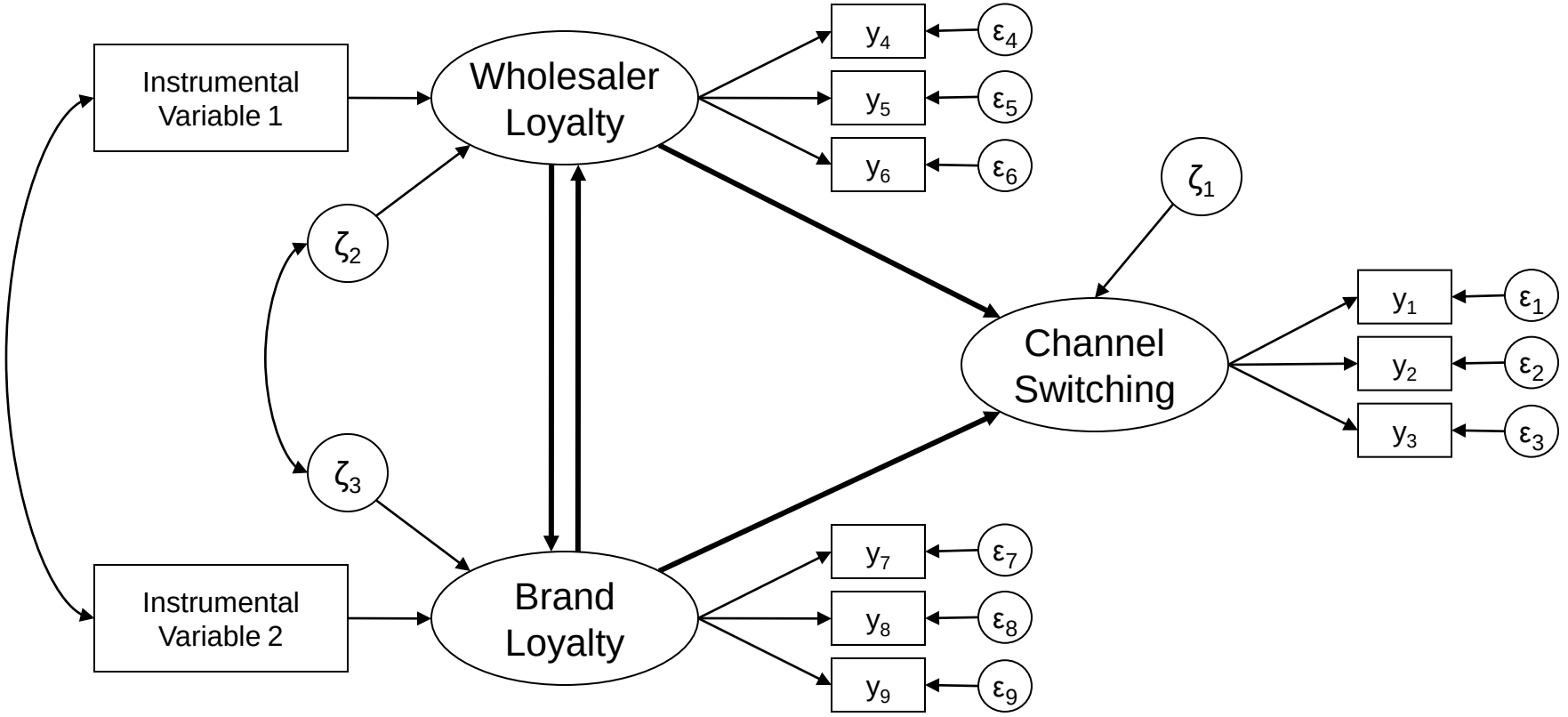


Model 2:



Wilson, B.; Henseler, J. The Mediating Role of Relationship Quality Impacting Sponsorship Effects on Perceived Economic Outcomes. ANZMAC Conference, December 4-6, 2006, Brisbane, Australia.

Example 3



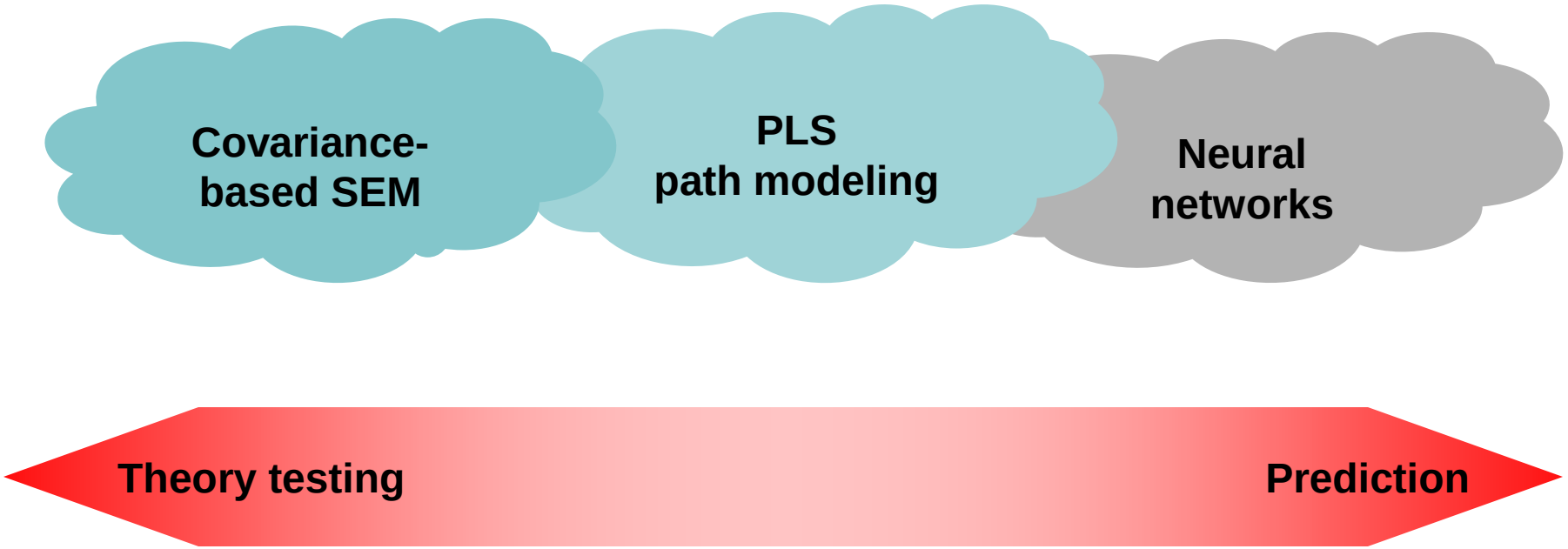
Model generating.

Eggert, A.; Henseler, J.; Hollmann, S. Who Owns the Customer? Disentangling Customer Loyalty in Indirect Distribution Channels. 17th International Colloquium in Relationship Marketing, September 16-19, 2009, Maastricht, The Netherlands.

Conclusions

- CBSEM lets you test entire theories.
- CBSEM may help to develop sensometric theories.
- CBSEM allows to explicitly model measurement error.
- Caution:
  - CBSEM does not focus on explaining variance.
  - CBSEM does not focus on prediction.

Theory testing vs. prediction



Thank you.

Available Software for Covariance-Based Structural Equation Modeling / CFA

- LISREL
- AMOS (graphical interface)
- EQS
- MPLUS (includes latent class modeling)
- Mx
- R: **sem** package
- ...
- Streams (meta-language for LISREL/EQS/MPLUS)