Important concepts and definitions:

Notation, vectors, matrices and structure of models

Outline

0. Introductory remarks
1. Formation of hypotheses
2. Path diagram and the specification of models
3. Identification of the structure of models

0.Introductory remarks

This course unit is on the *formal foundation* of structural equation modeling and on the *preparation for the statistical investigation*

- **it reaches out to the first stage of an investigation**
- **it assures that the statistical investigation is in line with the plan that so far guided the research**

0.Introductory remarks

Research means

- **creating new knowledge**
- **providing answers to research questions**
- **providing empirical evidence in favor or against hypotheses**
- **(comparing controversial ideas / theories)**

0.Introductory remarks

Research means

- creating new knowledge
- providing answers to research questions
- providing empirical evidence in favor or against hypotheses
- (comparing controversial ideas / theories)

Conducting empirical research means …

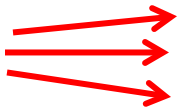
- selecting a research question / hypothesis

- designing a research plan

- data collection

- statistical investigation

- drawing conclusions



Structural equation modeling

0.Introductory remarks

These steps of empirical research must show *consistency*!

0.Introductory remarks

These steps of empirical research must show *consistency*!

- formation of research question (hypothesis)

(prepares for)

- designing a research plan

(prepares for)

- data collection

(prepares for)

- statistical investigation

Structural equation modeling

0.Introductory remarks

These steps of empirical research must show *consistency*!

Otherwise: structural equation modeling may *not be* possible!

For example: there may not be enough indicator variables

(there must be at least two of them)

0.Introductory remarks

Variables are important ingrediants of the formal foundation

- there are different types
- these types have different roles
- they should not be confused

0.Introductory remarks

Manifest variables - variables that refer to data observed by means of measurement scales applied to a sample (directly observable)

Latent variables - variables that are hypothetical in nature and are not directly observable

- access to these variables is possible by means of indicators (that are mostly manifest variables)

Endogenous variables - to be explained variables of the statistical model (criterion variables; dependent variables)

Exogenous variables - variables used for explaining the criterion in the statistical model (predictors $x_1 \ldots x_p$; independent variables)

1. Formation of hypotheses

1. **Formation of hypotheses**
2. Path diagram and specification of model
3. Identification of the structure of the model
4. Estimation of parameters
5. Evaluation of the results
6. (modification of the structure of the model)

1. Formation of hypotheses

The formation requires being concerned with …

- research questions
- hypotheses
- constructs
- indicators
- associations of constructs and indicators

1. Formation of hypotheses

The formation usually starts with a research question!

- the researcher selects a topic that he/she perceived as interesting/important …

1.Formation of hypotheses

Typical research questions that can be investigated in the factor-analytic framework of SEM ...

… are questions regarding a relationship:

Is extraversion related to professional success?

… are questions concerning a differential construct:

Is extraversion an empirical (= measureable) attribute?

1.Formation of hypotheses

Typical research questions that can be investigated in the factor-analytic framework of SEM …

… are questions regarding a relationship:

Is extraversion related to professional success?

… are questions concerning a differential construct:

Is extraversion an empirical (= measureable) construct?

But questions regarding effects are excluded:

Does noise impair performance in completing cognitive tests?

1.Formation of hypotheses: examples

Research question 1:

Is the conscientiousness of a person related to the professional success of this person?

Conscientiousness *means* being careful in working / completing something / etc.

Research question 2:

Is the work motivation of a person related to the professional reputation of this person?

Work motivation *means* how the person feels pressured to do a good job out of itself.

1.Formation of hypotheses: examples

There is a tradition to conduct research on the basis of hypotheses instead of research questions.[1,2,3]

Therefore, the research question has to be transformed into a hypothesis in the first step.

_____

Reasons:

(1) the research question reflects the motivation of the researcher that has to be eliminated

(2) The question can be answered by a Yes or No response; the hypothesis may demand a more differentiated outcome

(3) Knowledge has the structure of a statement but not a question.

1.Formation of hypotheses: examples

- **H1:** The more conscientious a person is, the larger the professional success of this person.

  Is the conscientiousness of a person related to the professional success of this person?

- **H2:** The larger the work motivation of a person is, the larger the professional reputation of this person.

  Is the work motivation of a person related to the professional reputation of this person?

1.Formation of hypotheses: examples

A note.

In psychological research we have a new tend regarding the research strategy.

- old strategy: investigation of a single hypothesis
- new strategy: consideration of several hypotheses and comparing them

1.Formation of hypotheses: examples

- **H1:** The more conscientious a person is, the larger the professional success of this person.

  (**Alternative hypothesis 1**: there is a linear relationship between consientiousness and professional success)

  (**Alternative hypothesis 2**: there is a logistic relationship between consientiousness and professional success)

  (**Alternative hypothesis 3**: there is no relationship between consientiousness and professional success)

- **H2:** The larger the work motivation of a person is, the larger the professional reputation of this person.

  (**Alternative hypothesis**: there is no relationship between work motivation and reputation)

1.Formation of hypotheses: examples

The identification of the relevant constructs:

- **H1:** The more conscientious a person is, the larger the professional success of this person is.
- **H2:** The larger the work motivation of a person is, the larger the professional reputation of this person.

… meaning conscientiousness

The constructs have to be represented by latent variables.

1.Formation of hypotheses: examples

The identification of the relationships:

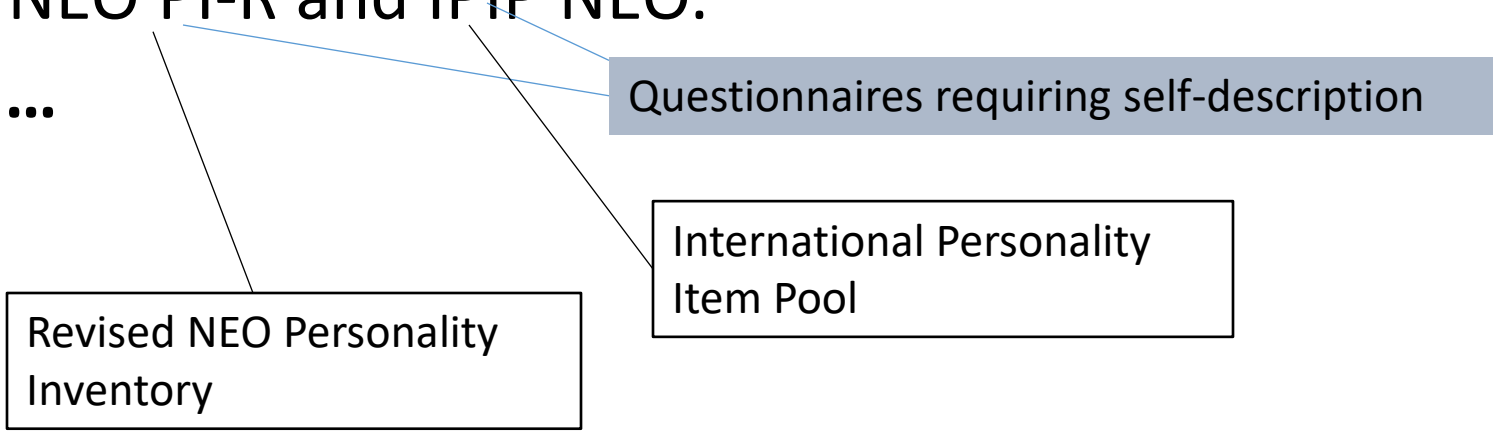
- **H1:** The more conscientious a person is, the larger the professional success of this person is.
- **H2:** The larger the work motivation of a person is, the larger the professional reputation of this person.

The relationships have to be identified
… and the direction.

1.Formation of hypotheses: examples

The selection of indicators:

- Conscientiousness is, for example, measured by NEO PI-R and IPIP NEO.
- …



1.Formation of hypotheses: examples

The state: what is available …

- hypotheses
- constructs …
- structure of model
- indicators

2.Path diagram and specification of model

1. Formation of hypothesis
2. **Path diagram and specification of models**
3. Identification of the structure of the model
4. Estimation of parameters
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2.Path diagram and specification of model

A path diagram is an illustration of a model that prepares for the mathematical description

Such a model shows a complex structure

2. Path diagram and specification of model

Components of a complete structural equation model (three parts):

- **Structural model**:
  … includes the theoretially assumed relationships between latent variables
  → Regression analysis / Path analysis

- **Models of measurement** of the latenten variables:
  - includes the indicators originating from the operationalization of the constructs
  - is specified according to the assumed relationships between the indicators and the latent variables

    → Confirmatory factor analysis

2. Path diagram and specification of model

A complete structural equation model includes three parts:

- **Structural model**:
  … includes the theoretially assumed relationships between latent variables
  → Regression analysis / Path analysis

- **Models of measurement** of the latenten variables:
  - one for the *endogenous part* of the complete structural equation model
  - one for the *exogenous part* of the complete structural equation model

> Composition of path diagram (1)

- The latent variables are depicted as ellipses and accompanied by lower case greek letters.

- The manifest variables are depicted as rectangles and accompanied by lower case latin letters.

> Composition of path diagram (2)

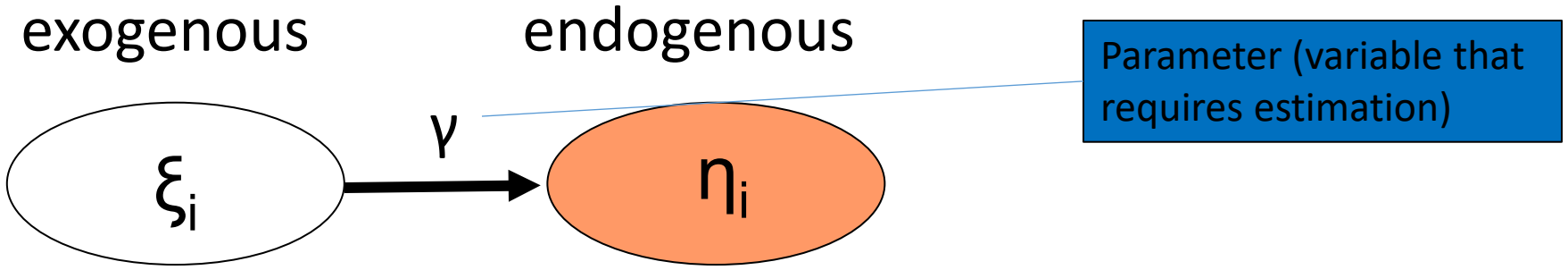
- Directed relationships are depicted by arrows:

The arrow head points to the variable that is influenced.

- Non-directed relationships are depicted by bended double-headed arrows:

> Structural model

Illustration of the relationships between the latent variables:



ξ = „ksi“ η = „eta“

γ = „gamma“

> Structural model

Illustration of the relationships between the latent variables with example (H1):

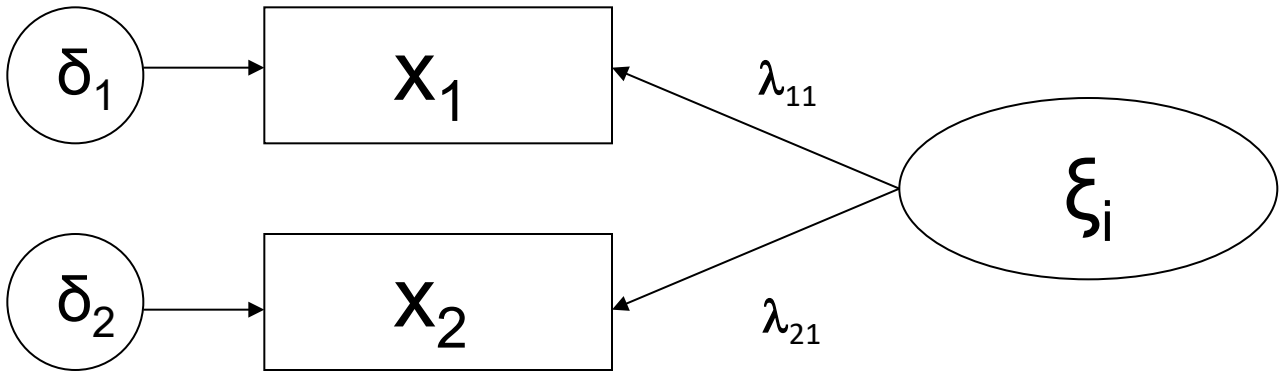
Conscientiousness Professional success

> Structural model

Illustration of the relationships between the latent variables with example (H1):

> Model of measurement

Operationalization of latent variable (exogenous part):

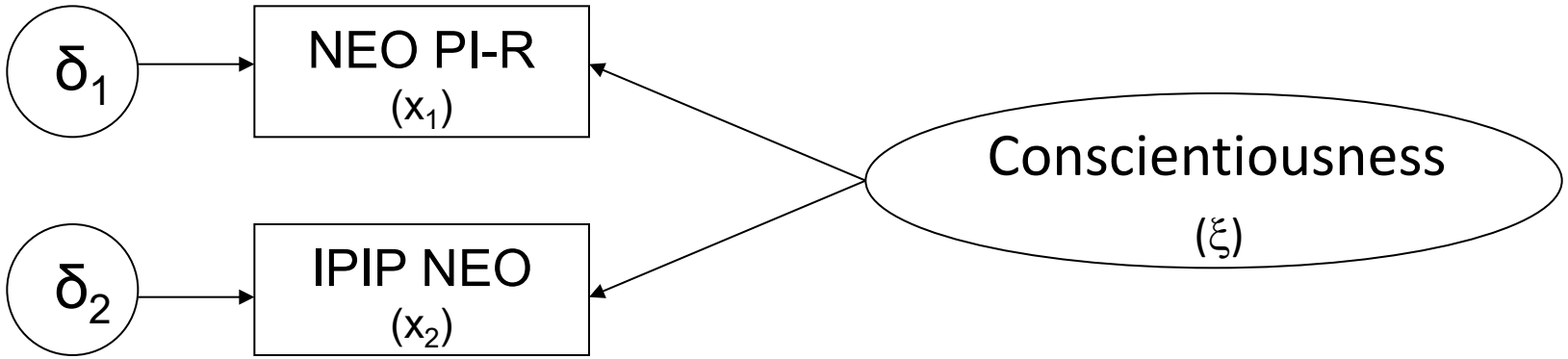


δ = „delta“

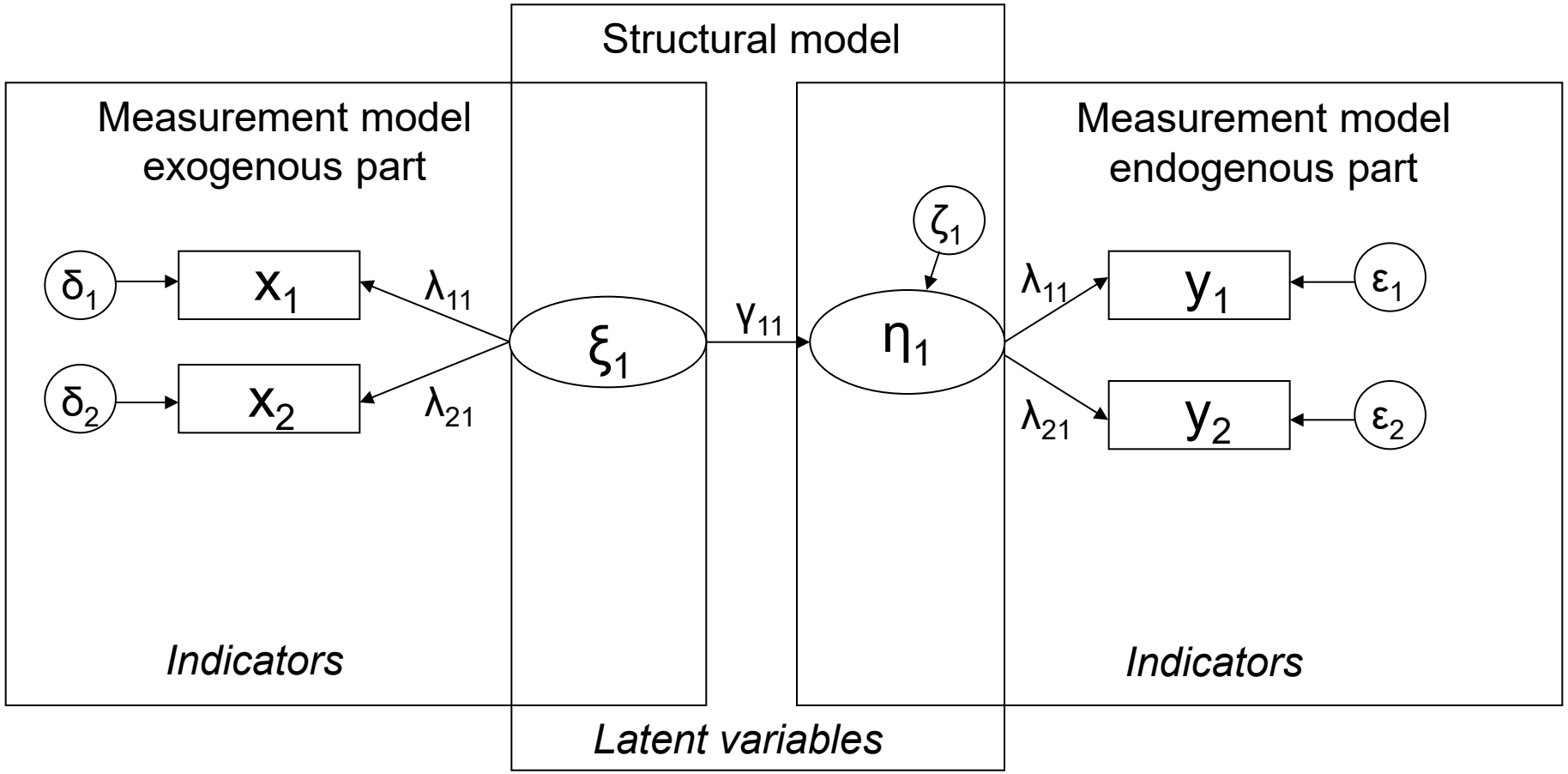
λ = „lambda“

> Model of measurement

Operationalization of latent variable with example (exogenous part):



> Complete structural equation model



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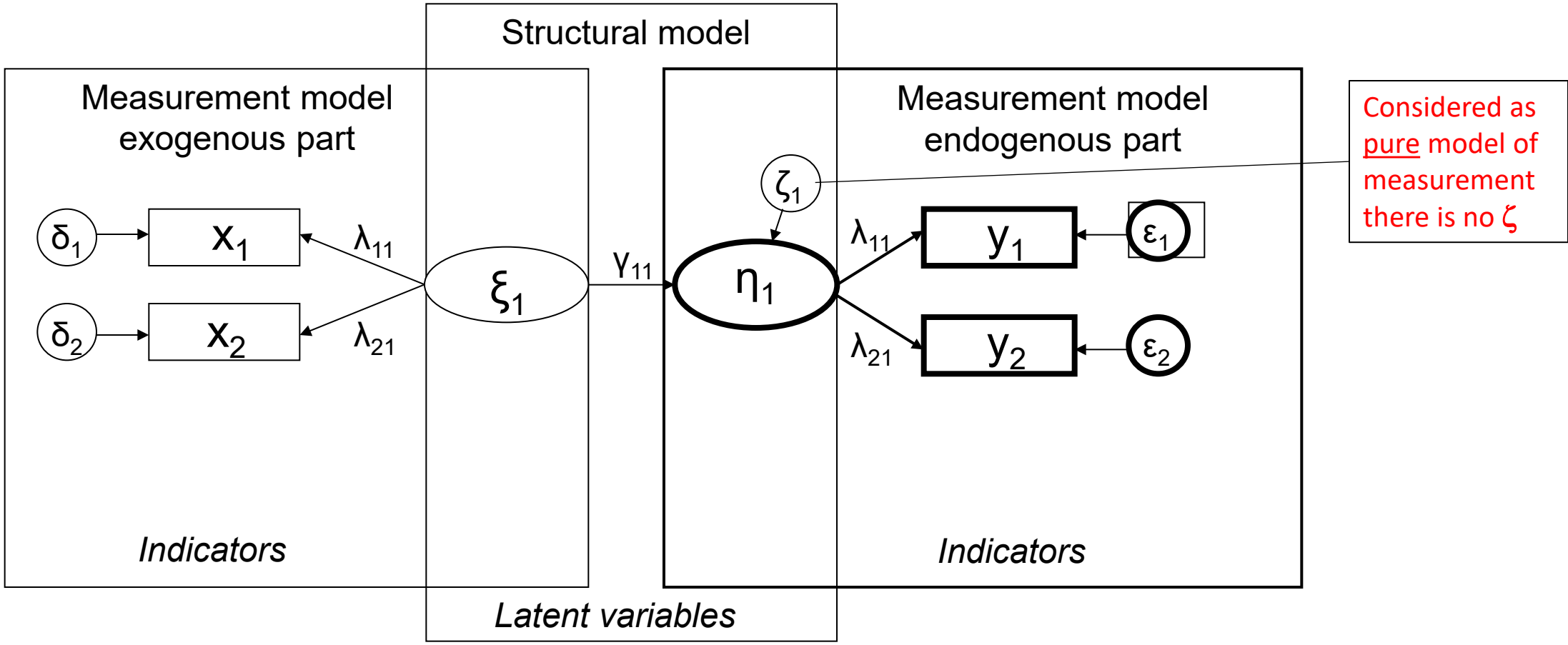

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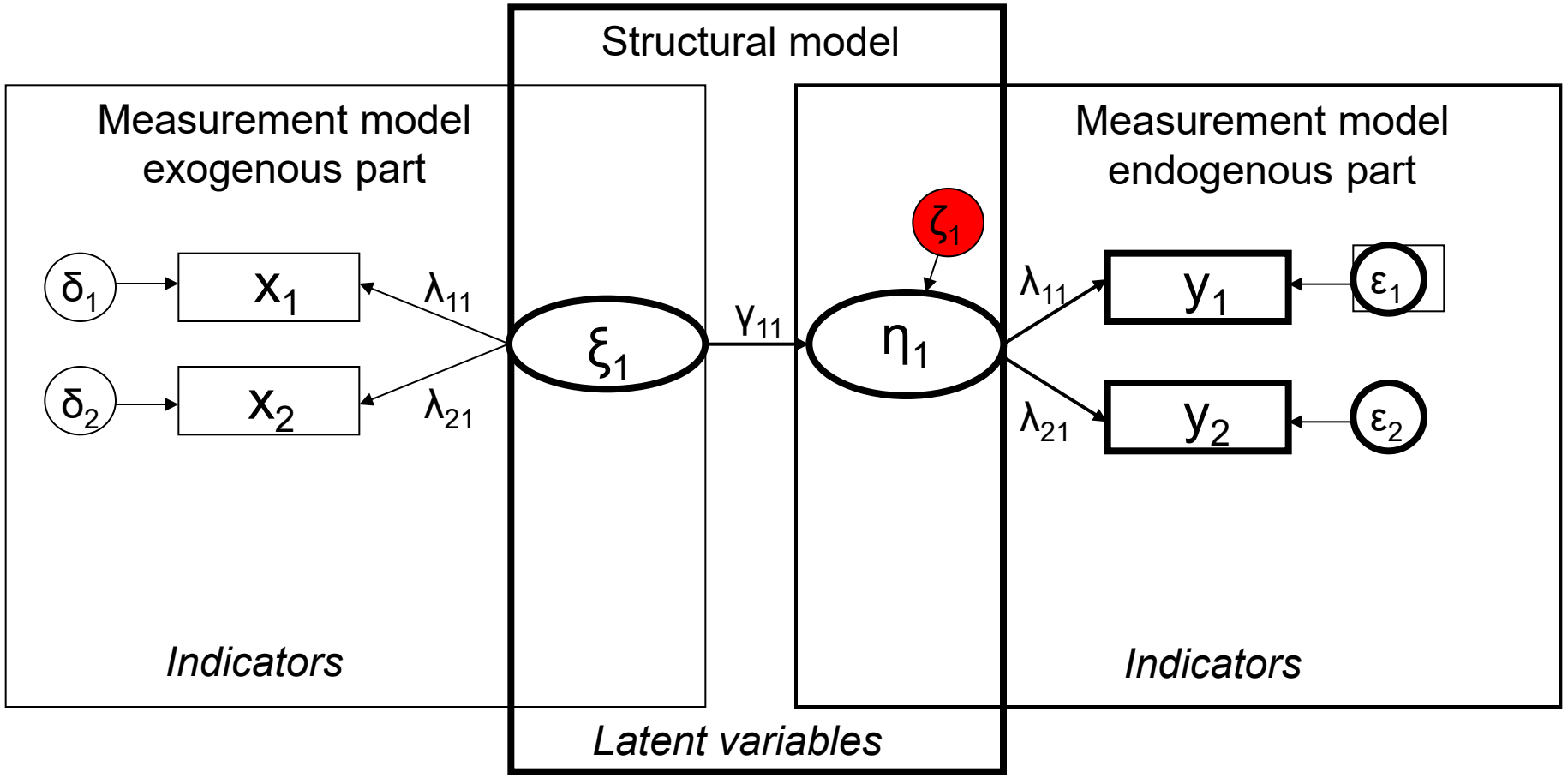

Since ξ_1 does normally not completely predict η_1 there is a remainder that is represented by ζ

> Notation

ξ_i	Ksi	Latent *exogenous* variable
η_i	Eta	Latent *endogenous* variable
ζ_i	Zeta	Residual variable associated with latent *endogenous* variable
γ_i	Gamma	Path coefficient regarding the relationship of *exogenous and endogenous* latent variables
β_{ij}	Beta	Path coefficient regarding two *endogenous* latent variables

Alternative denotation **„regression weight“**

x_i		Indicator variable for *exogenous* variable
λ_{ij}	Lambda	Path coefficient between observed indicators x_i and latent variable ξ_j
δ_i	Delta	Residual variable for an *exogenous* Indikator variable

y_i		Indicator variable for *endogenous v*ariable
λ_{ij}	Lambda	Path coefficient between observed indicators y_i and latent variablen η_j
ε_i	Epsilon	Residual variable for an *endogenous* Indikator variable

Alternative denotation **„factor loading “**

> Notation

Parameters

ξ_i	Ksi	Latent *exogenous* variable
η_i	Eta	Latent *endogenous* variable
ζ_i	Zeta	Residual variable associated with latent *endogenous* variable
γ_i	Gamma	Path coefficient regarding the relationship of *exogenous and endogenous* latent variables
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y_i		Indicator variable for *endogenous v*ariable
λ_{ij}	Lambda	Path coefficient between observed indicators y_i and latent variablen η_i
ε_i	Epsilon	Residual variable for an *endogenous* Indicator variable

> Notation regarding matrices and vectors

More complex structural equation models require the use of vectors and matrices instead of individual variables and parameters!

> Notation regarding matrices and vectors

$$\mathbf{v}_{(p\times 1)} = \begin{bmatrix} v_1 \\ v_2 \\ . \\ v_p \end{bmatrix} \qquad \mathbf{M}_{(p\times q)} = \begin{bmatrix} m_{11} & & m_{1q} \\ m_{21} & & \\ & & \\ m_{p1} & & m_{pq} \end{bmatrix}$$

Printed bold!

> Switch to the formal (mathematical) model

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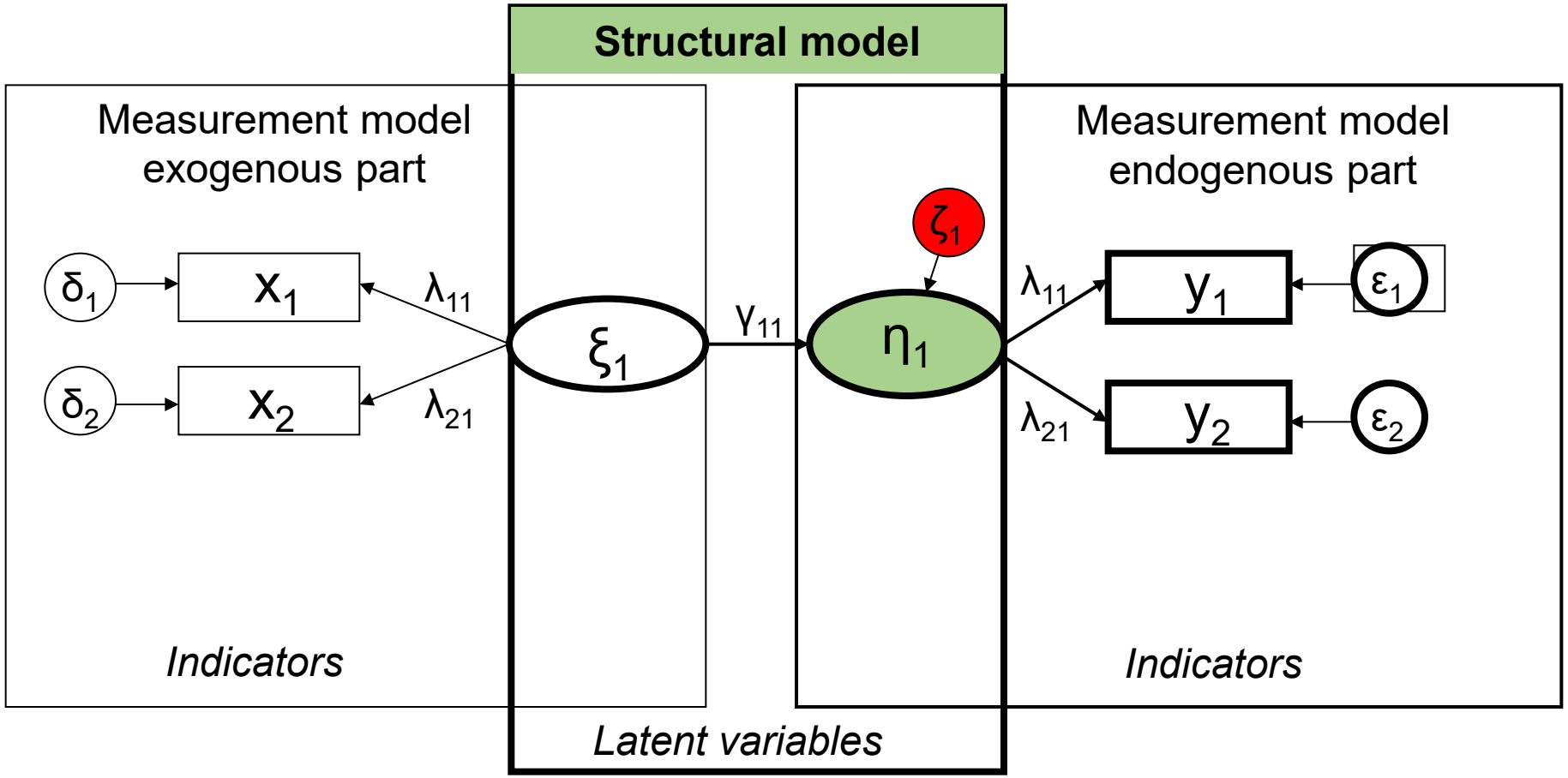


> Switch to the formal (mathematical) model

- Equation of measurement model of latent *exogenous* variables:

$$\eta_1 = \gamma_{11} \times \xi_1 + \zeta_1$$

Generalization

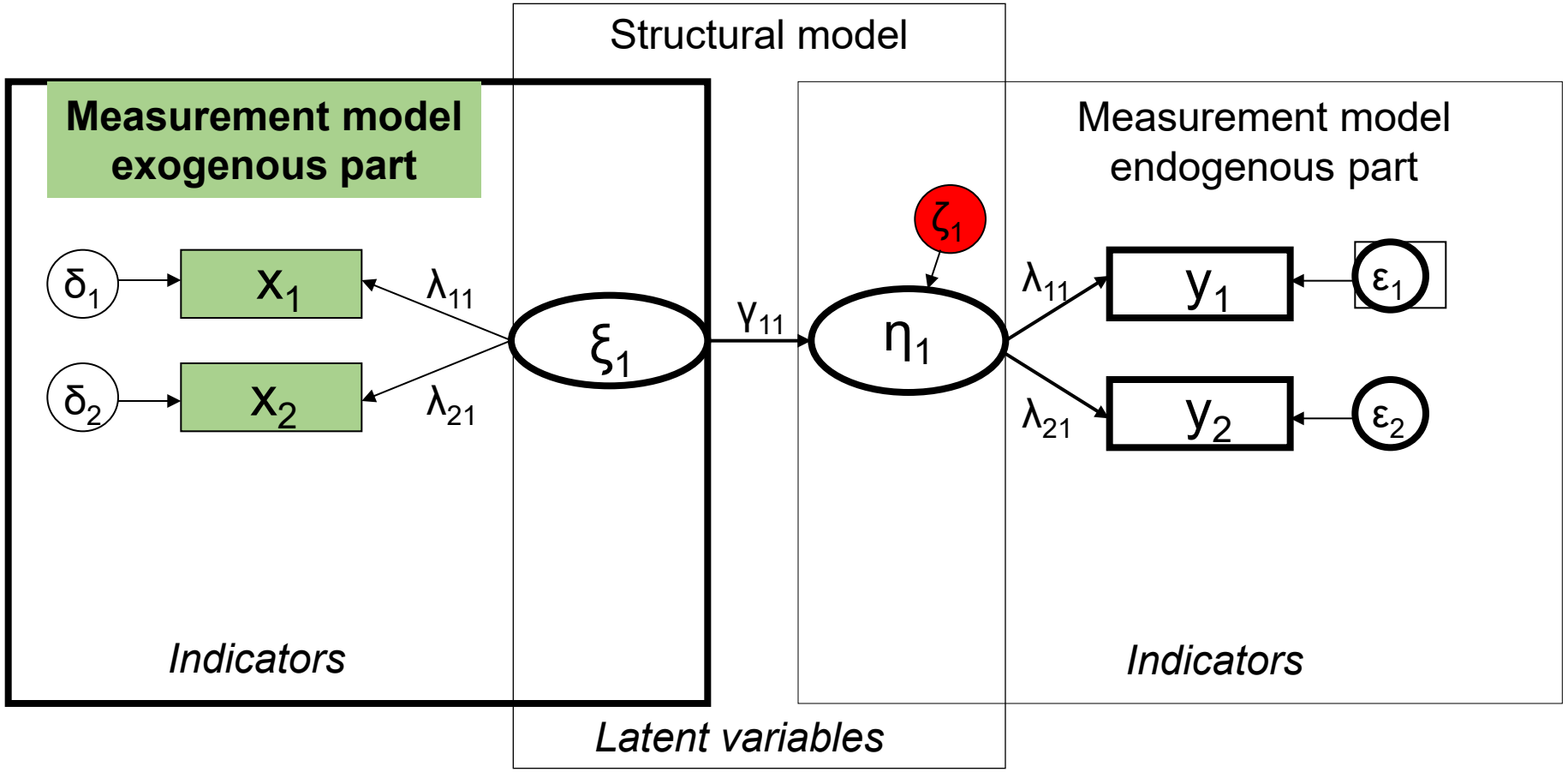
> Switch to the formal (mathematical) model

Equation of structural model:

$$\eta = \Gamma \times \xi + \zeta$$

η	Γ	ξ	ζ
Vector of *endogenous* latent variables η_i (m x 1)	Gamma coefficients of ξ_i and η_j variables (m x n)	Vector of *exogenous* latent ξ_i variables (n x 1)	Vector of residual variables of *latent endogenous* variables η_i (m x 1)

> Switch to the formal (mathematical) model



> Switch to the formal (mathematical) model

- Equation of measurement model of latent *exogenous* variables:

$$x_1 = \lambda_{11} \times \xi_1 + \delta_1$$

Generalization

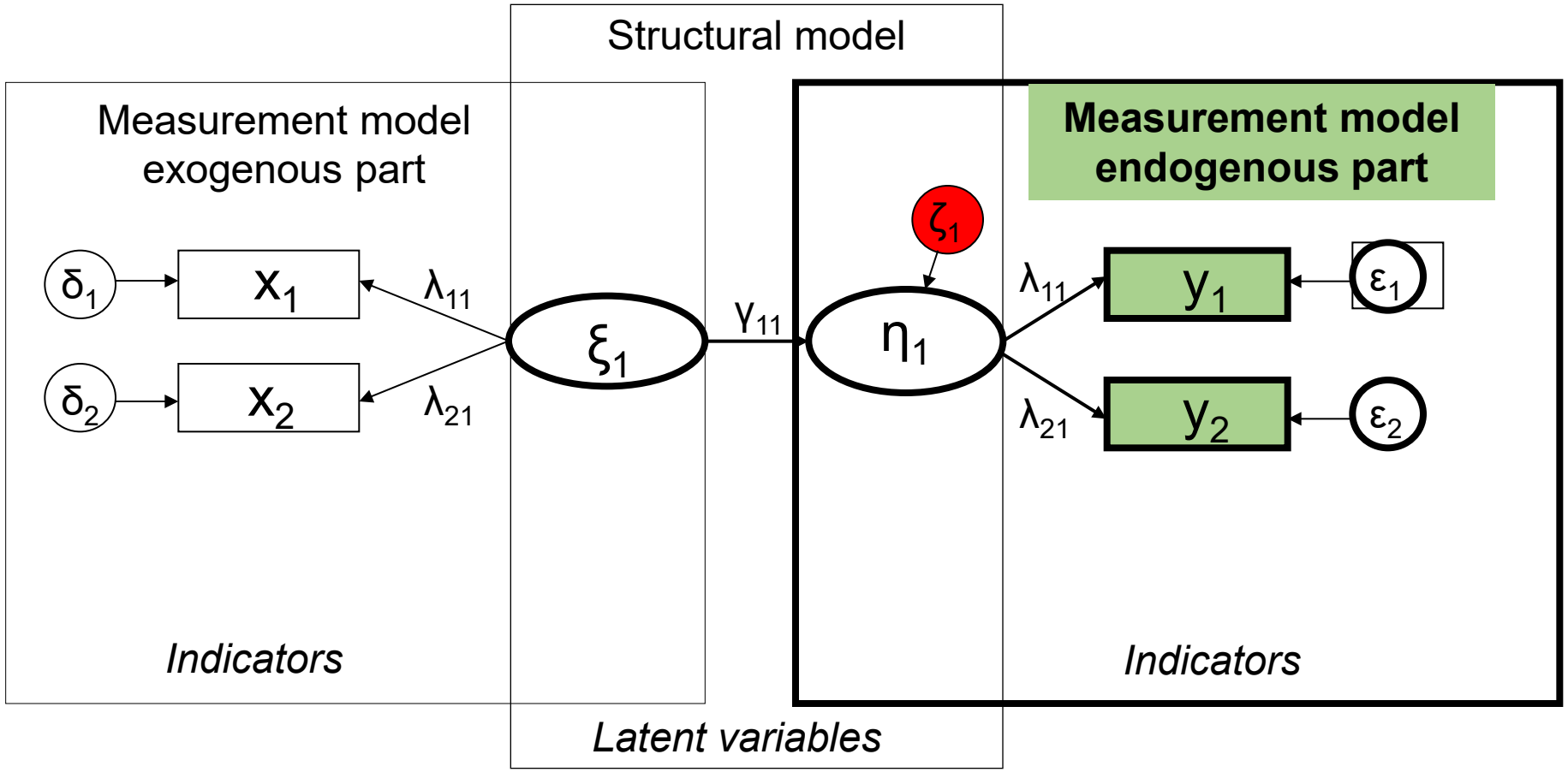
> Switch to the formal (mathematical) model

- Equation of measurement model of latent *exogenous* variables:

$$x = \Lambda\xi + \delta \qquad (\text{new} \quad X = \mu + \Lambda\xi + \delta)$$

$\mathbf{x}$	=	Λ	×	ξ	+	δ
Vector of *exogenous* indicators (p x 1)		Matrix of (path) coefficients (factor loadings) of the model of measurement of the *exogenous* variables (p x n)		Vector of *exogenous* latent variables (n x 1)		Vector of residuals of *exogenous* indicators (p x 1)

> Switch to the formal (mathematical) model



> Switch to the formal (mathematical) model

- Equation of measurement model of latent *endogenous* variables:

$$y = \Lambda\eta + \varepsilon \qquad (\text{new } Y = \mu + \Lambda\eta + \varepsilon)$$

$$\mathbf{y} \quad = \quad \Lambda \quad \times \quad \eta \quad + \quad \varepsilon$$

Vector of *endogenous* indicators

(manifest variables)

(q x 1)

Matrix of (path) coefficients

(factor loadings)

of the model of measurement of the *endogenous* variables

(q x m)

Vector of *endogenous* latent variables

(m x 1)

Vector of residuals of *endogenous* indicators

(q x 1)

> Assumptions of structural equation models

Basic assumptions:

- latent and residual variables do ***not*** correlate with each other
- different residual variables do ***not*** correlate with each other

> Assumptions of structural equation models

Further, basic assumtions in detail:

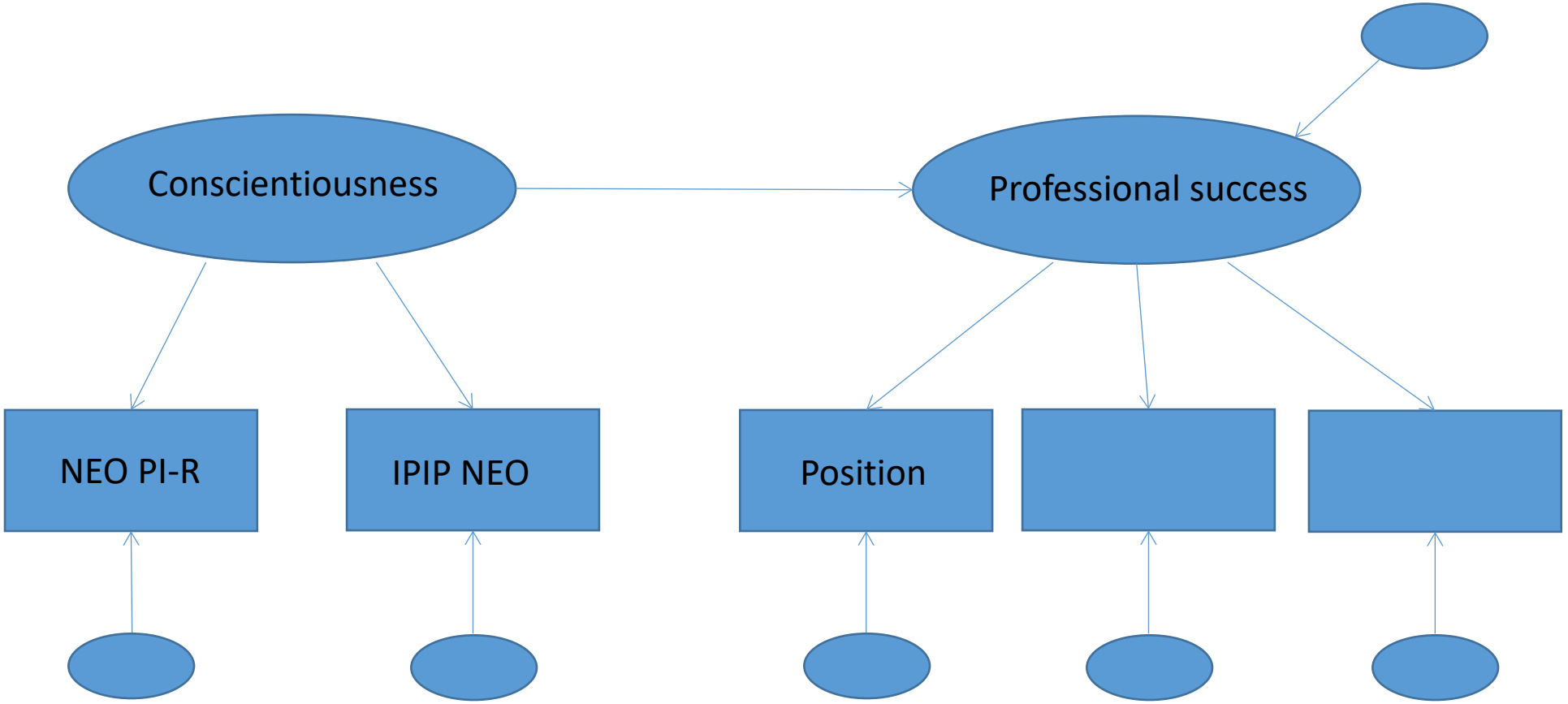
- ζ does not correlate with ξ
- ε does not correlate with η
- δ does not correlate with ξ
- δ, ε and ζ do not correlate with each other

Note.

- there are two types of residuals:
  - residuals as characteristics of individual manifest variables
  - residuals as random error (= remainders)

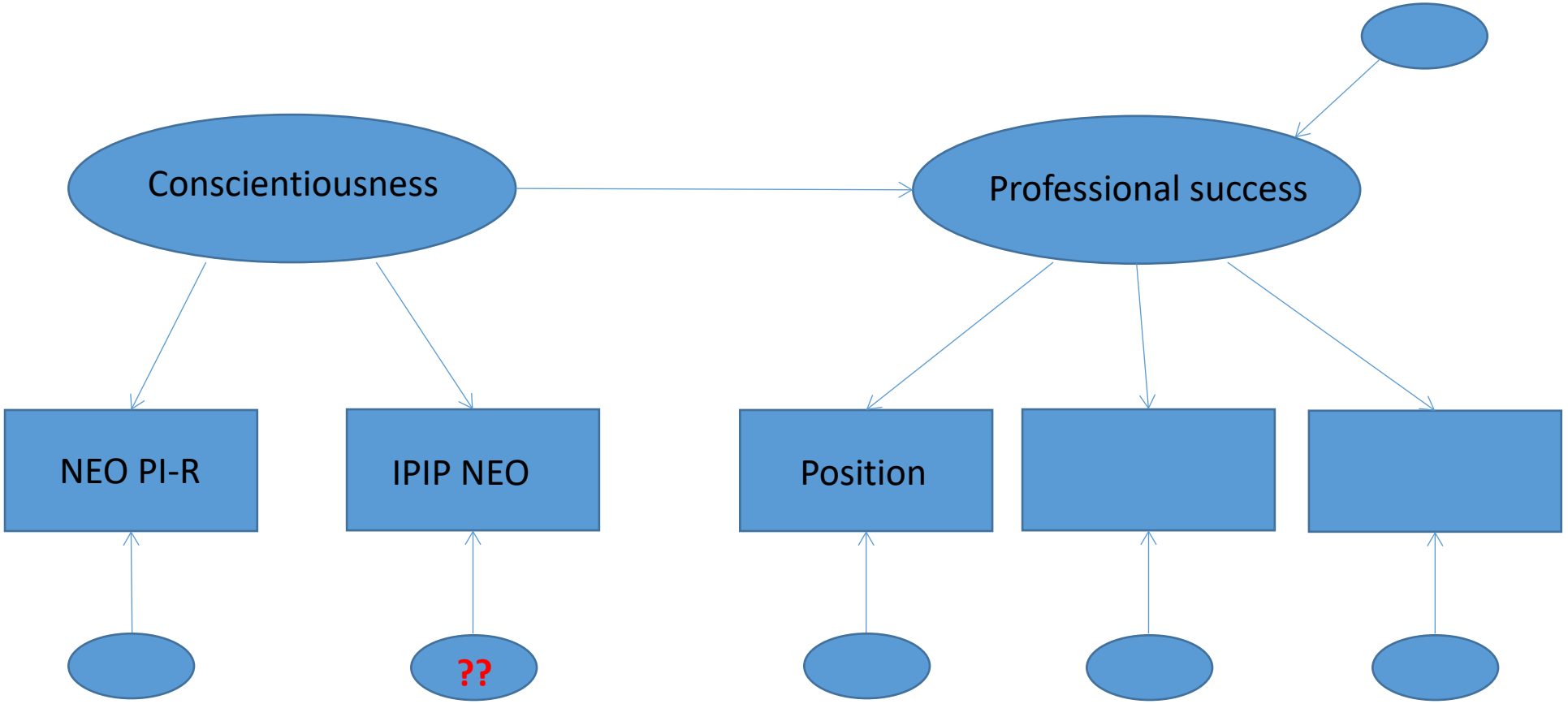
A path diagram for H1

H1: The more conscientious a person is, the larger the professional success of this person.



Practice B

Which symbol has to replace ?? in the diagram?



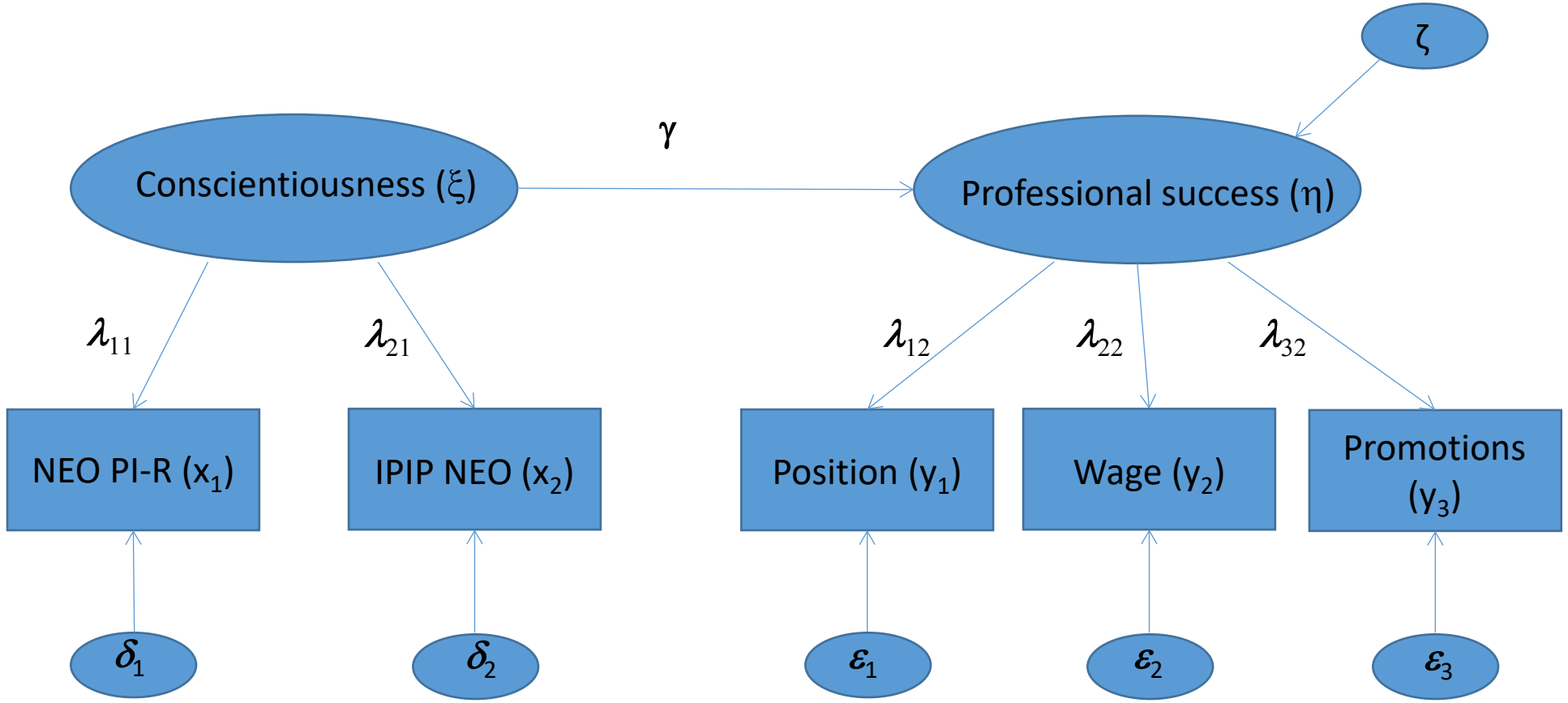
Practice B

Which symbol has to replace ?? in the diagram?

- ξ
- ε
- η
- δ
- π
- ϕ

A path diagram for H1

H1: The more conscientious a person is, the larger the professional success of this person is.



> Hypotheses for a complex structural model: *Examples*

In the following three other hypotheses are combined with the first one to achieve a *complex* model.

> Hypotheses for a complex structural model: *Examples*

- **H1:** The more conscientious a person is, the larger the professional success of this person (original H1).
- **H2:** The larger the work motivation of a person is, the larger the professional sucess of this person.
- **H3:** With more conscientiousness, the professional reputation is increasing.
- **H4:** Larger work motivation means an increasing professional reputation.

> Hypotheses for a complex structural model: *Examples*

- **M1:** Conscientiousness is indicated by scales of two personality inventories: NEO PI-R and IPIP NEO.
- **M2:** Work motivation is measured by means of a concentration test (C test) and self evaluation.
- **M3:** Professional success is reflected by the professional position, wage and number of promotions.
- **M4:** Professional reputation is operationalized by the result of questioning colleagues.

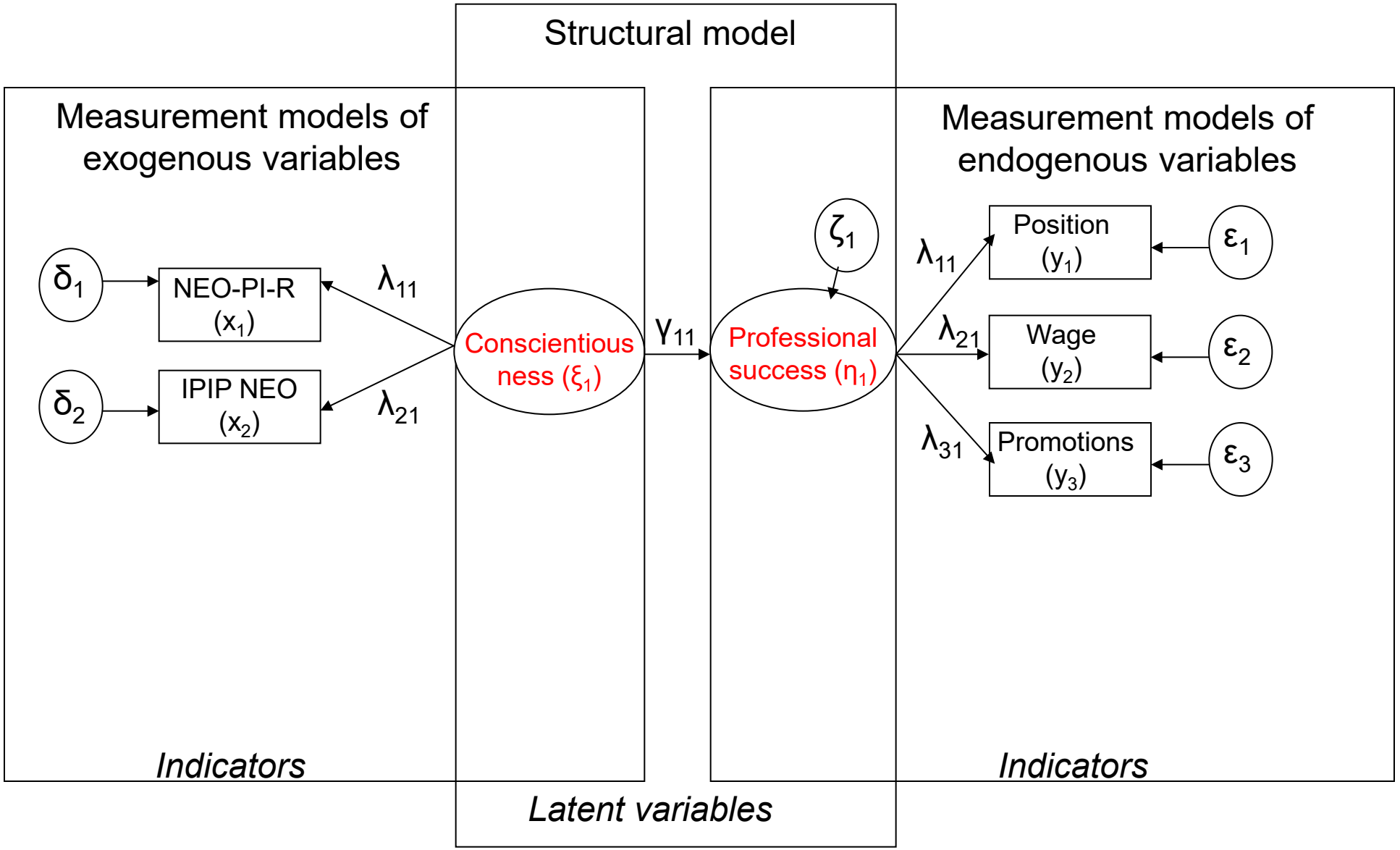
> Hypotheses for a complex structural model: *Examples*

The outset:

- **H1:** The more conscientious a person is, the larger the professional success of this person is.
- **H2:** The larger the work motivation of a person is, the larger the professional sucess of this person.
- **H3:** With more conscientiousness the professional reputation is increasing.
- **H4:** Larger work motivation means an increasing professional reputation.

- **M1:** Conscientiousness is indicated by scales of two personality inventories: NEO PI-R and IPIP NEO.
- **M2:** Work motivation is measured by means of a concentration test (C test) and self evaluation.
- **M3:** Professional success is reflected by the professional position, wage and number of promotions.
- **M4:** Professional reputation is operationalized by the result of questioning colleagues.

> Complex structural equation model



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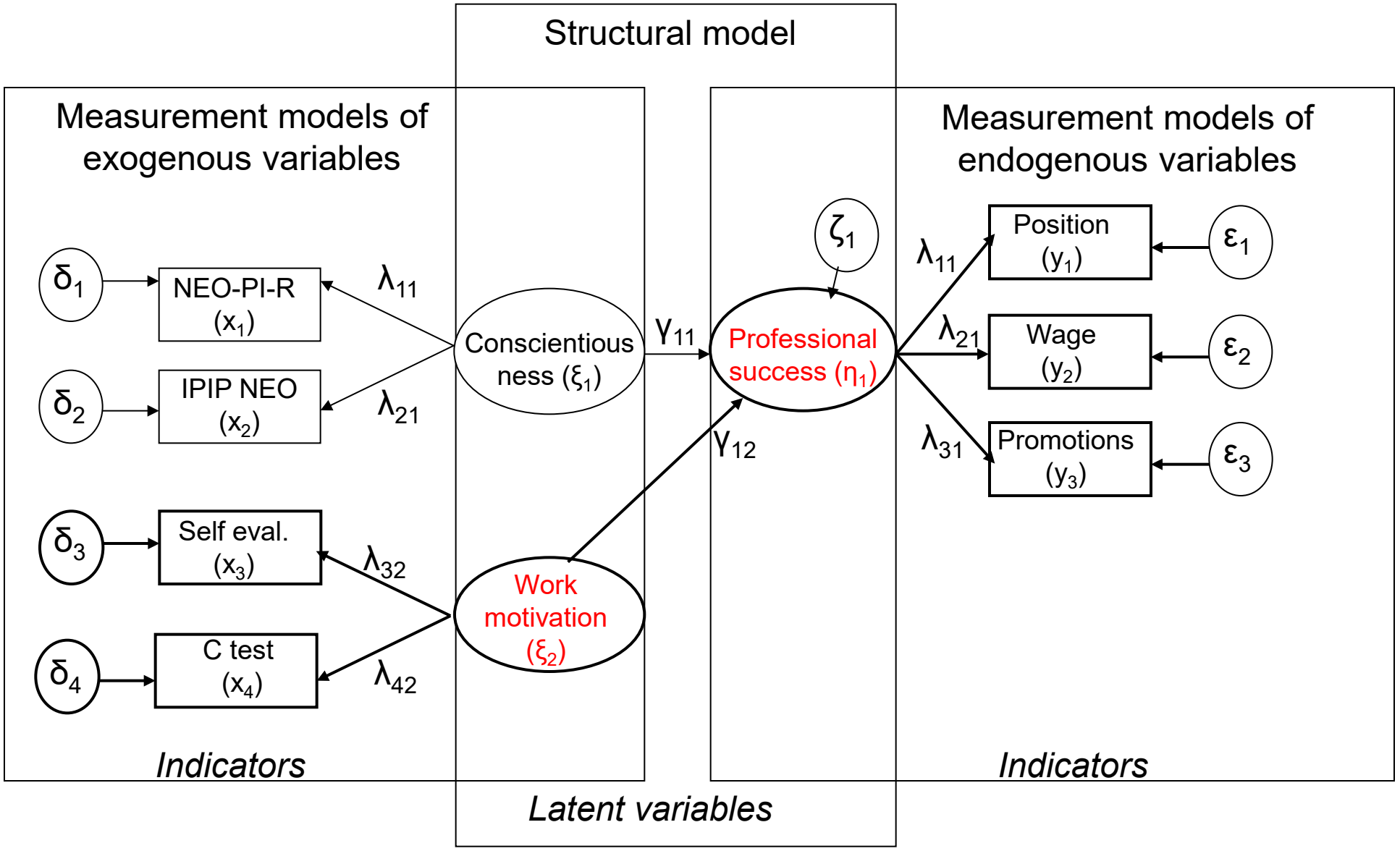

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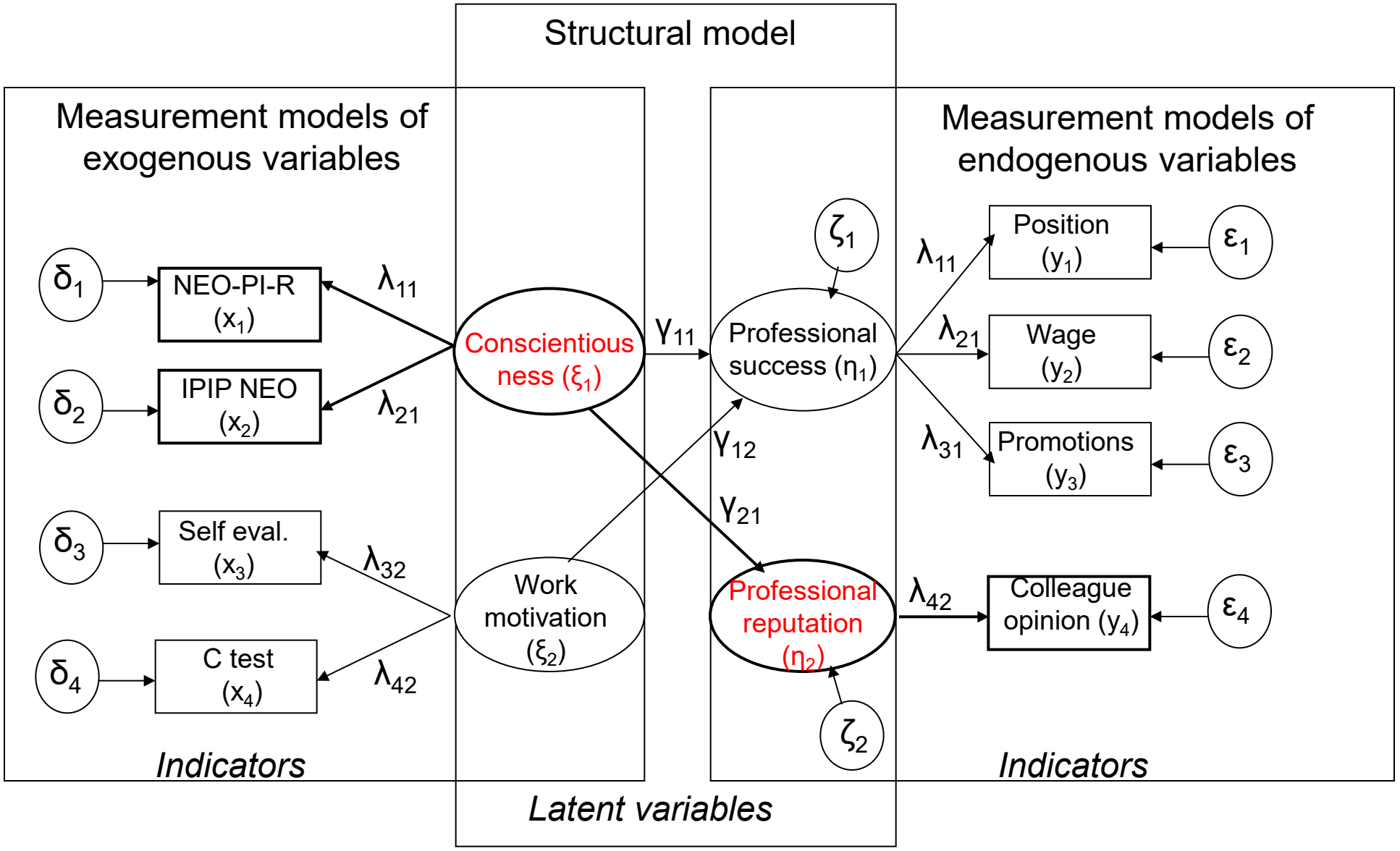
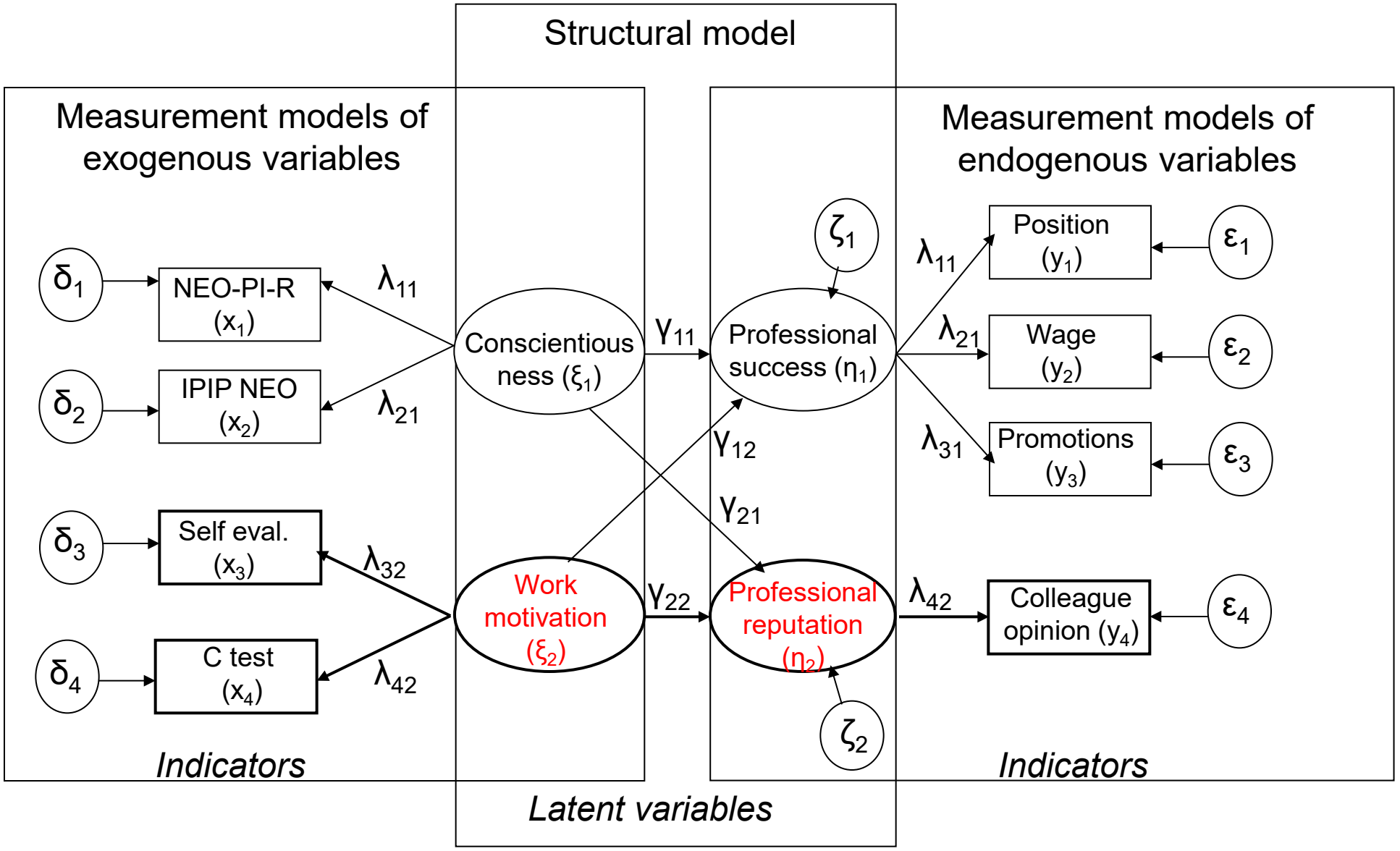


> Complex structural equation model



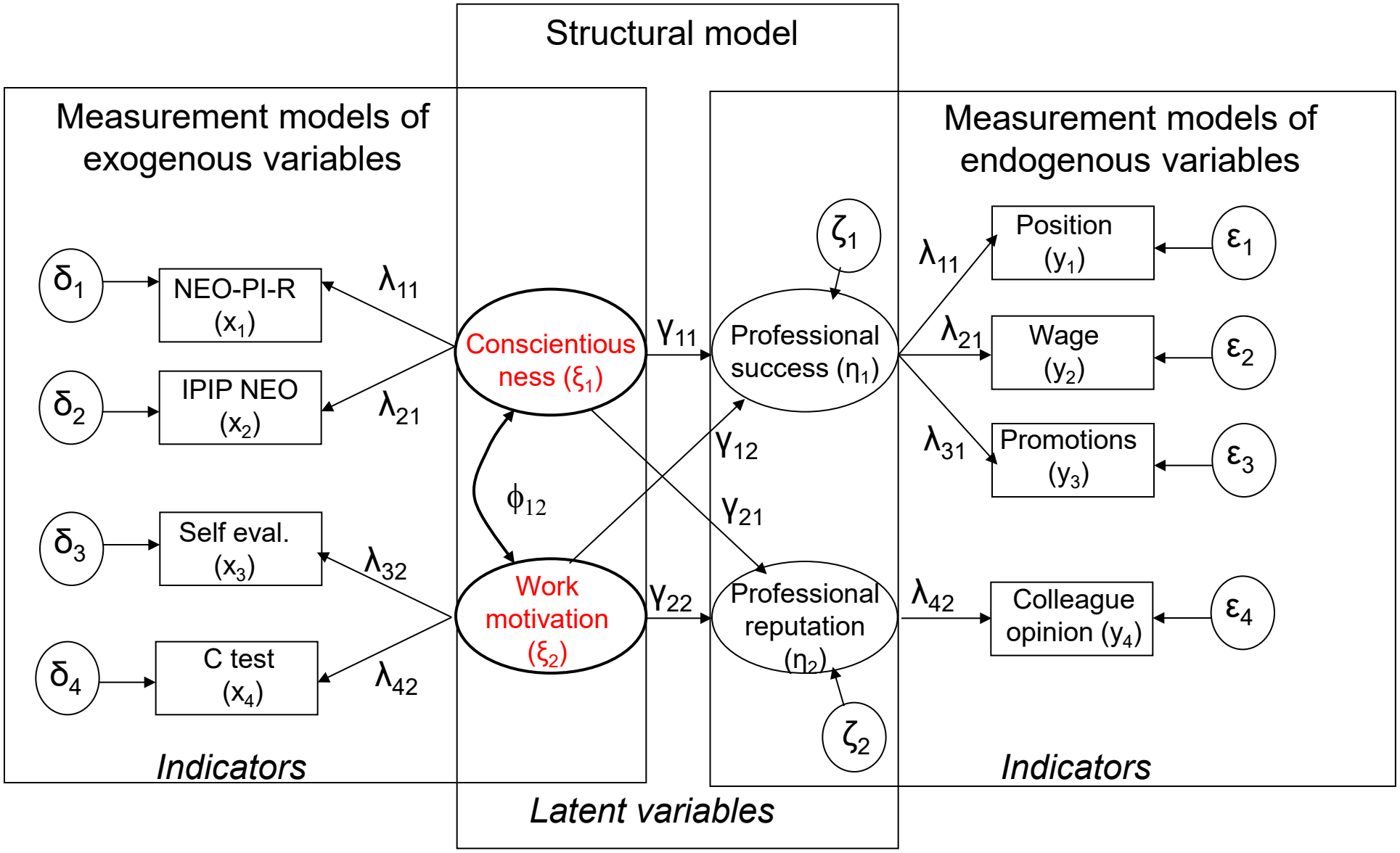
> Hypotheses for a complex structural model: *Examples*

Additional structural hypotheses:

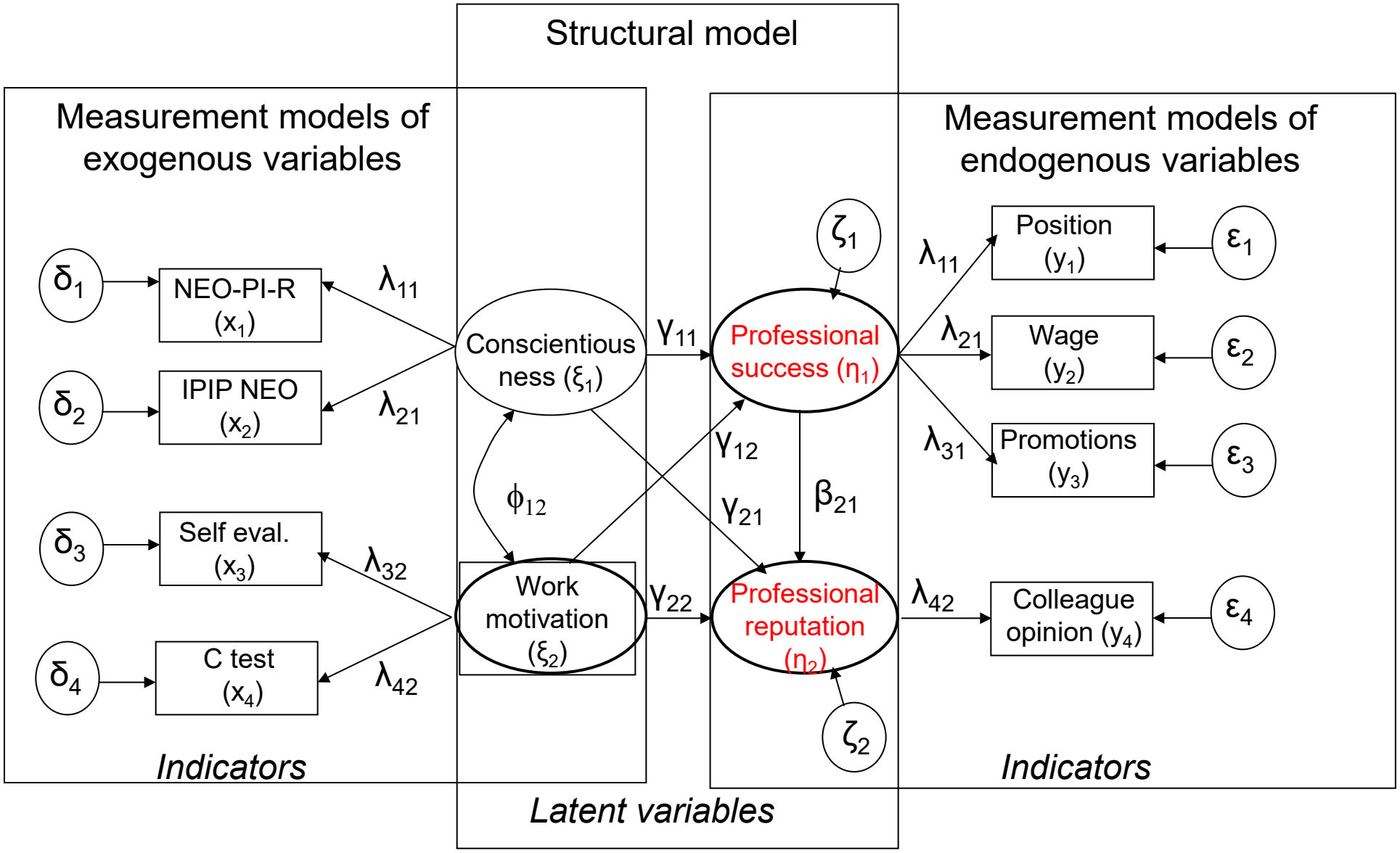
(Remember: the need to be complete)

- **H5:** Conscientiousness and work motivation are not independent of each other (= they are correlated).
- **H6:** Professinal success exerts an influence on professional reputation.

> Complex structural equation model



> Complex structural equation model



> the path diagram

- It includes …
  - all manifest variables
  - all latent variables
  - all links representing structure
  - all parameters associated with the major links

Steps in preparing data analysis

1. Formation of hypothesis
2. Path diagram and specification of model
3. **Identification of the structure of the model**
4. Estimation of parameters
5. Evaluation of the results
6. (modification of the structure of the model)

3. Identification of the structure of models

Check whether enough empirical information is available for estimating the parameters of the model!

… without such information the results may not be valid!

(this check is based on the assumption that either a covariance matrix or a correlation matrix provides the input to SEM)

3. Identification of the structure of models

A note.

(… remember your high school education in mathematics)

A system of linear equations with unknowns can only be solved if there are *as many* equations *as* there are unknowns!

3. Identification of the structure of models

Check whether enough empirical information is available for estimating the parameters of the model!

It is done by computing the degree of freedom (df):

The degree of freedom „*df*“ = s - t

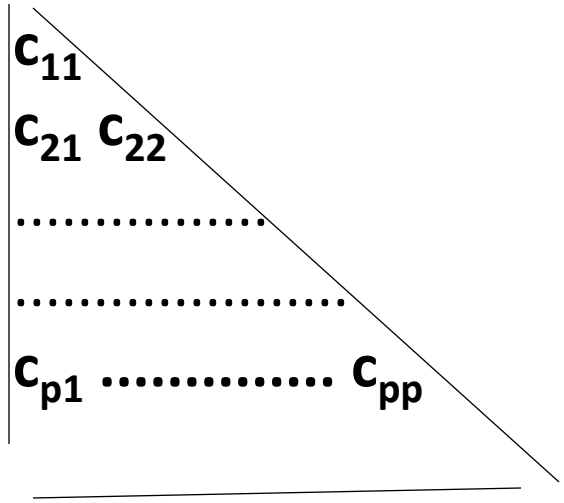
„… indication of whether parameter estimation is possible“

3. Identification of the structure of models

- ***The available information „s“ (items of information)***:

  there are *n* indicator variables (all manifest variables):

$$s = \frac{n(n+1)}{2}$$ = number of unique variances and covariances of the covariance matrix



3. Identification of the structure of models

- ***The available information „s“***:

  there are *n* indicator variables (all manifest variables):

  $s = \frac{n(n+1)}{2}$ = number of unique variances and covariances of the covariance matrix

- ***The needed information „t“:***

  t = number of parameters to be estimated

3. Identification of the structure of models

- **The meanings** of the degree of freedom (df):

The need for *identification* means ... df >= 0

The need for *evaluating* the model means ...

df > 0

3. Identification of the structure of models

- **The meaning** of the degree of freedom (df) = s – t

df = 0 ... is characterized as ... „just identified“

df > 0 ... is characterized as ... „identified“ (*desirable option*)

df < 0 ... is characterized as ... „not identified“

3. Identification of the structure of models

- **The meaning** of the degree of freedom (df) = s – t

… be aware if the degree of freedom is negative, the program is likely to run into problems and does not provide a result.

… otherwise, it is likely to be incorrect!

3. Identification of the structure of models

- **Cautionary note:**

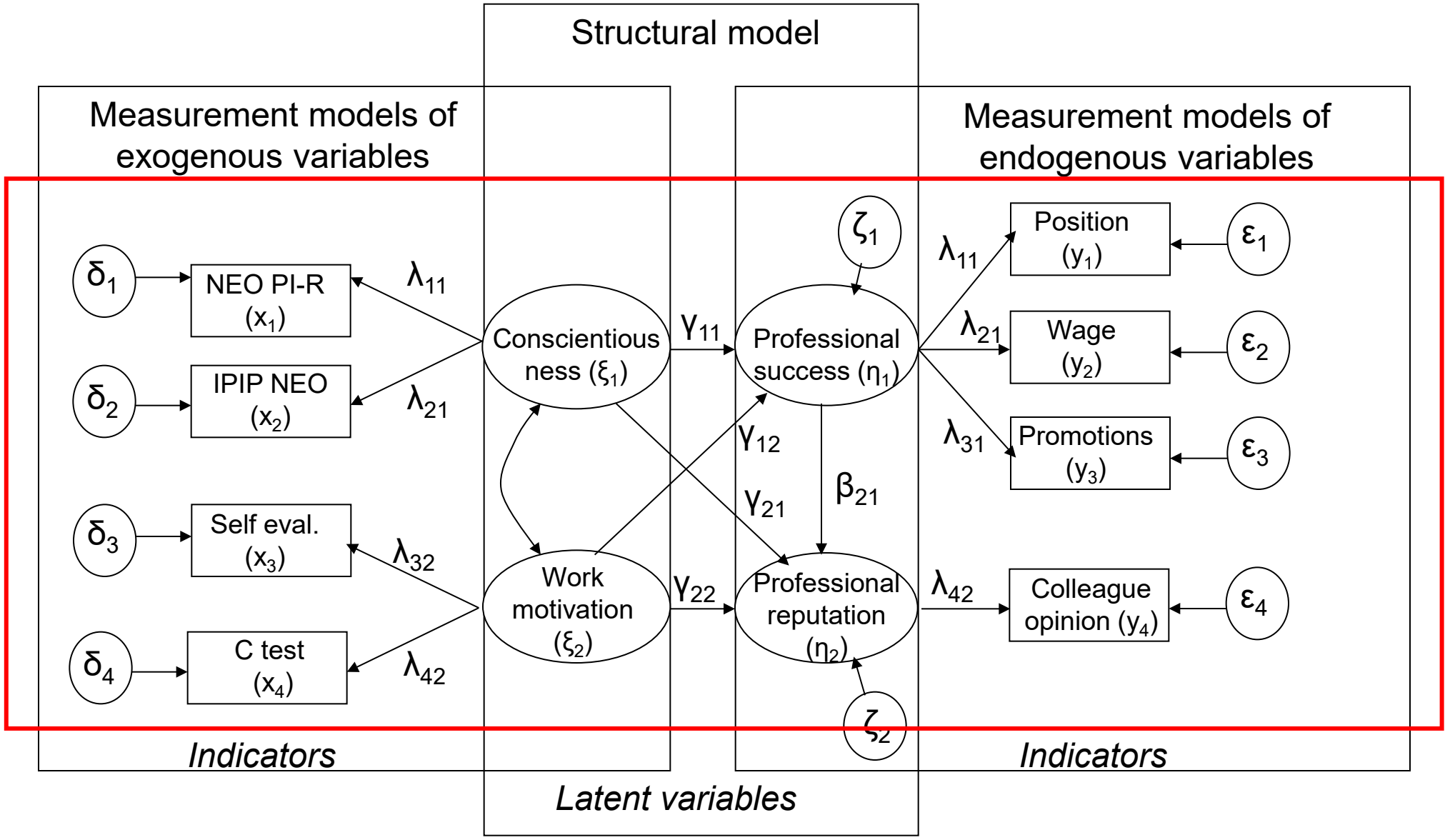
… if the model is complex, the degree of freedom of the .....

complete model and also of .....

each measurement model

needs to be checked (sometimes measurment models are not good although the complete model is good).

Parts to be checked:



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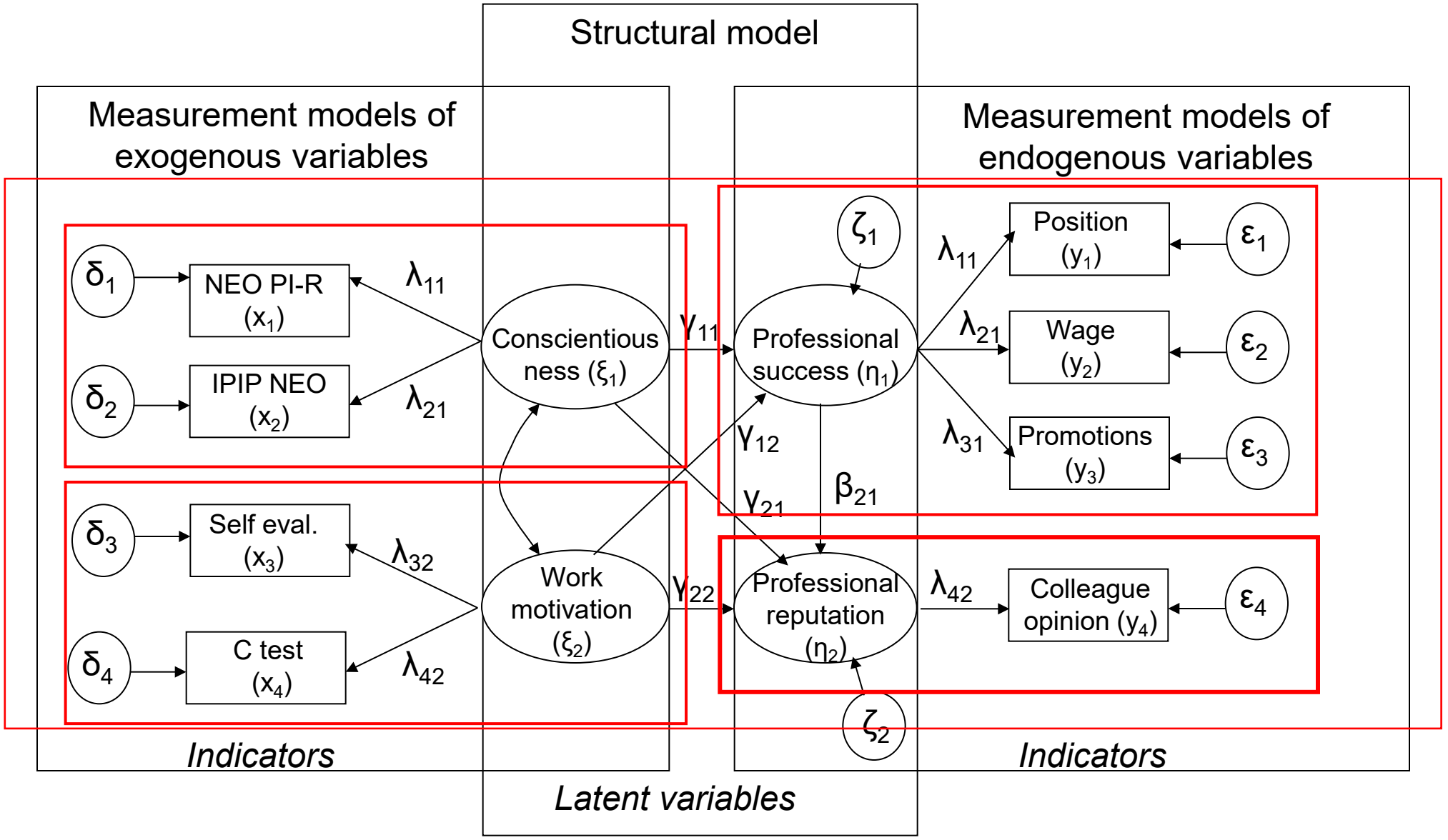
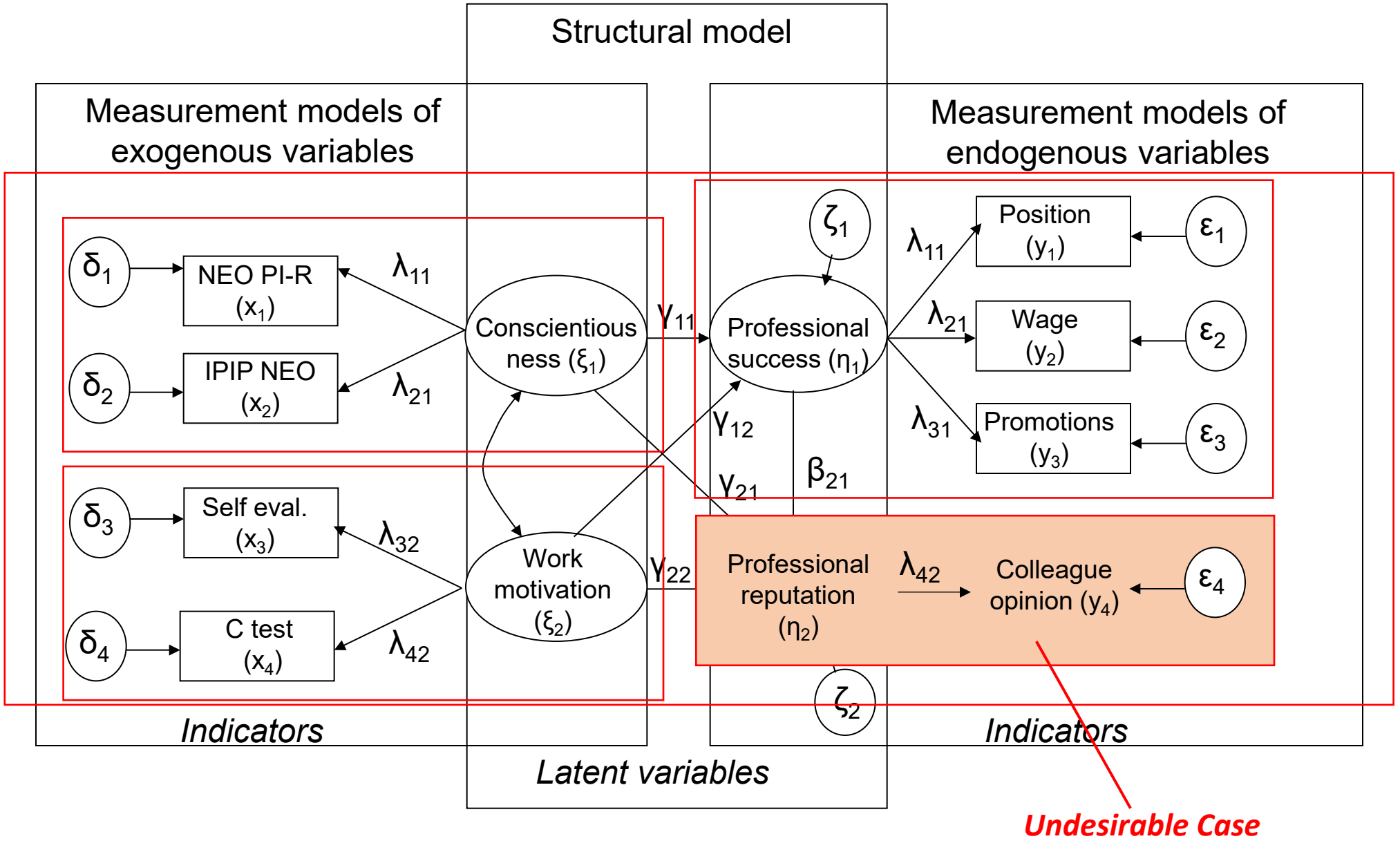


Parts to be checked:



3. Identification of the structure of models

- **There are combinations of manifest and latent variables that need *special treatment* for achieving correct results …**

Be aware that additional parameters need to be considered that are usually not included in the model of measurement:

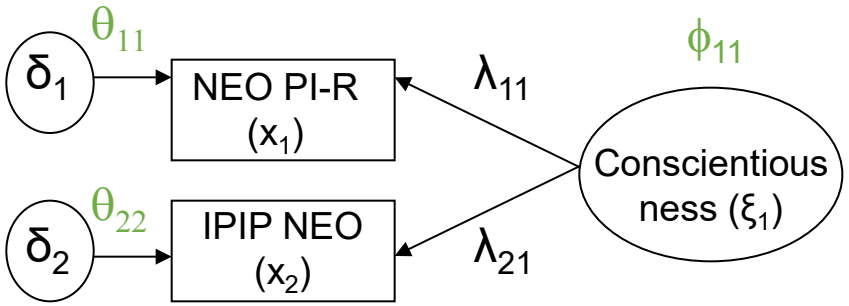
- the residual variance (θ)

- the variance of an exogeneous latent variable (ϕ)

- the of ζ (ψ)

3. Identification of the structure of models

A two-indicator example:



This model of measurement includes five parameters (ϕ_{11}, λ_{11}, λ_{12}, θ_{11}, θ_{22}) that need to be estimated,
t = 5.

Data:

$var_{NEO\ PI\text{-}R}$

$cov_{NEO\ PI\text{-}R,\ IPIP\ NEO}$ $var_{IPIP\ NEO}$

N = 2:

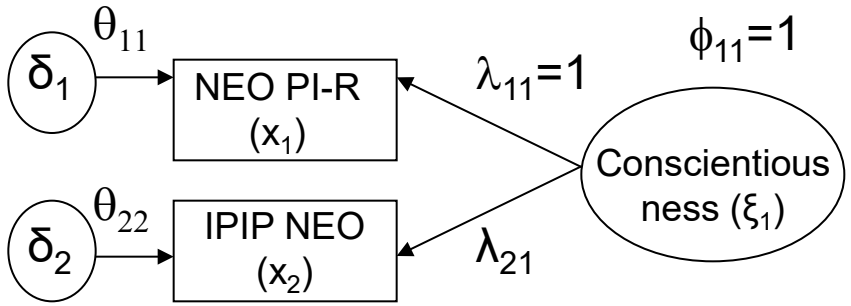
$$S = \frac{2\,(2+1)}{2} = 3$$

ϕ_{11}, θ_{11}, θ_{22} are part of the model of the covariance matrix (will be introduced in another section).

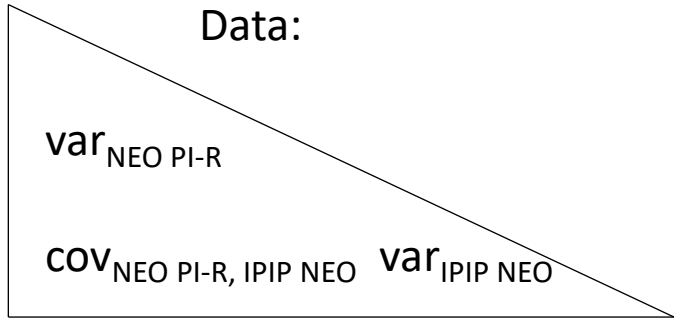
df = s – t = 3 – 5 = -2 < 0 (means … is *not identified*)

3. Identification of the structure of models

A two-indicator example: What to do?



This model of measurement includes three parameters (λ_{21}, θ_{11}, θ_{22}) that need to be estimated,
t = 3.



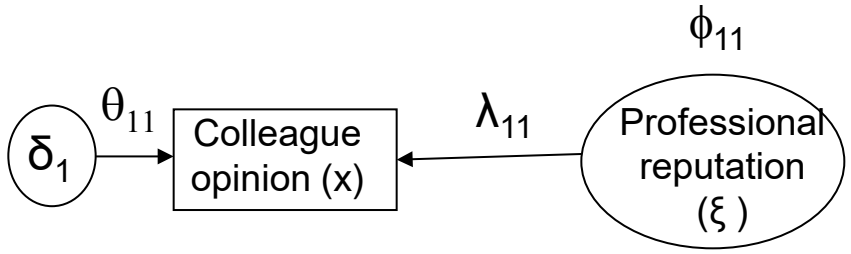
N = 2:

$$S = \frac{2\,(2+1)}{2} = 3$$

df = s – t = 3 – 3 = 0 (means … is *just identified*)

3. Identification of the structure of models

A one-indicator example*:*



This model of measurement includes three parameters (λ_{11}, θ_{11} , ϕ_{11}) that need to be estimated,
t = 3.

Data:

Variance (Colleague opinion)

N = 1:

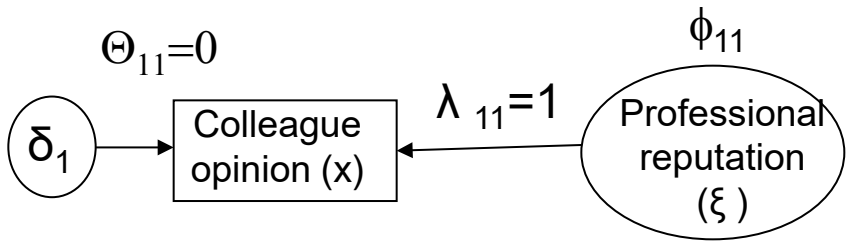
$$S = \frac{1\,(1+1)}{2} = 1$$

θ_{11} and ϕ_{11} are part of the model of the covariance matrix (will be introduced in another section).

df = s – t = 1 – 3 = -2 < 0 (means … is *not identified*)

3. Identification of the structure of models

A one-indicator example: What to do?



This model of measurement includes one parameter that need to be estimated, t = 1.

Data:

Variance (Colleague opinion)

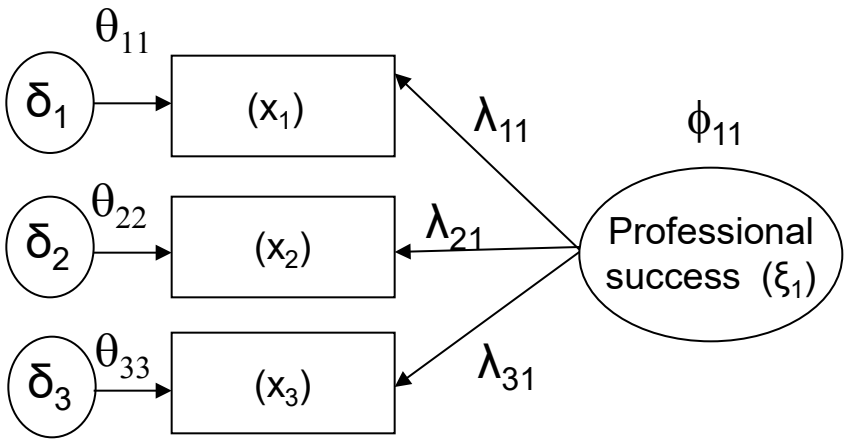
N = 1:

$$S = \frac{1\,(1+1)}{2} = 1$$

df = s – t = 1 – 1 = 0 (means … is *just identified*)

3. Identification of the structure of models

A three indicator example:



This model of measurement includes seven parameters (ϕ_{11}, λ_{11}, λ_{21}, λ_{31}, θ_{11}, θ_{22} , θ_{33}) that need to be estimated,
t = 7.

N = 3:

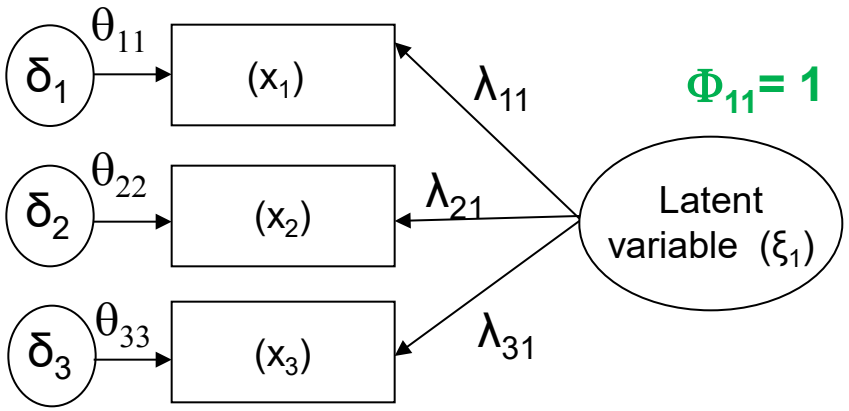
$$S = \frac{3(3+1)}{2} = 6$$

ϕ_{11}, θ_{11}, θ_{22} and θ_{33} are part of the model of the covariance matrix (will be introduced in another section).

df = s – t = 6 – 7 = -1 < 0 (means … is *not identified*)

3. Identification of the structure of models

A three indicator example: What to do?



This model of measurement includes six parameters (λ_{11}, λ_{21}, λ_{31}, θ_{11}, θ_{22} , θ_{33}) that need to be estimated,
t = 6.

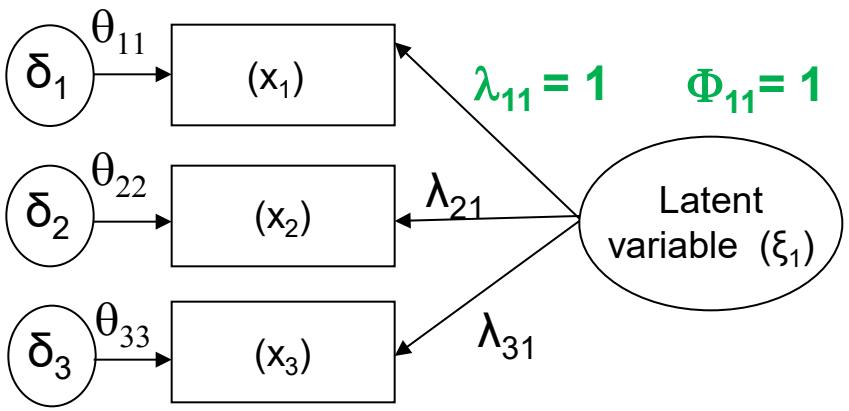
N = 3:

$$S = \frac{3(3+1)}{2} = 6$$

df = s – t = 6 – 6 = 0 (means … is *just identified*)

3. Identification of the structure of models

A three indicator example: *Better*!



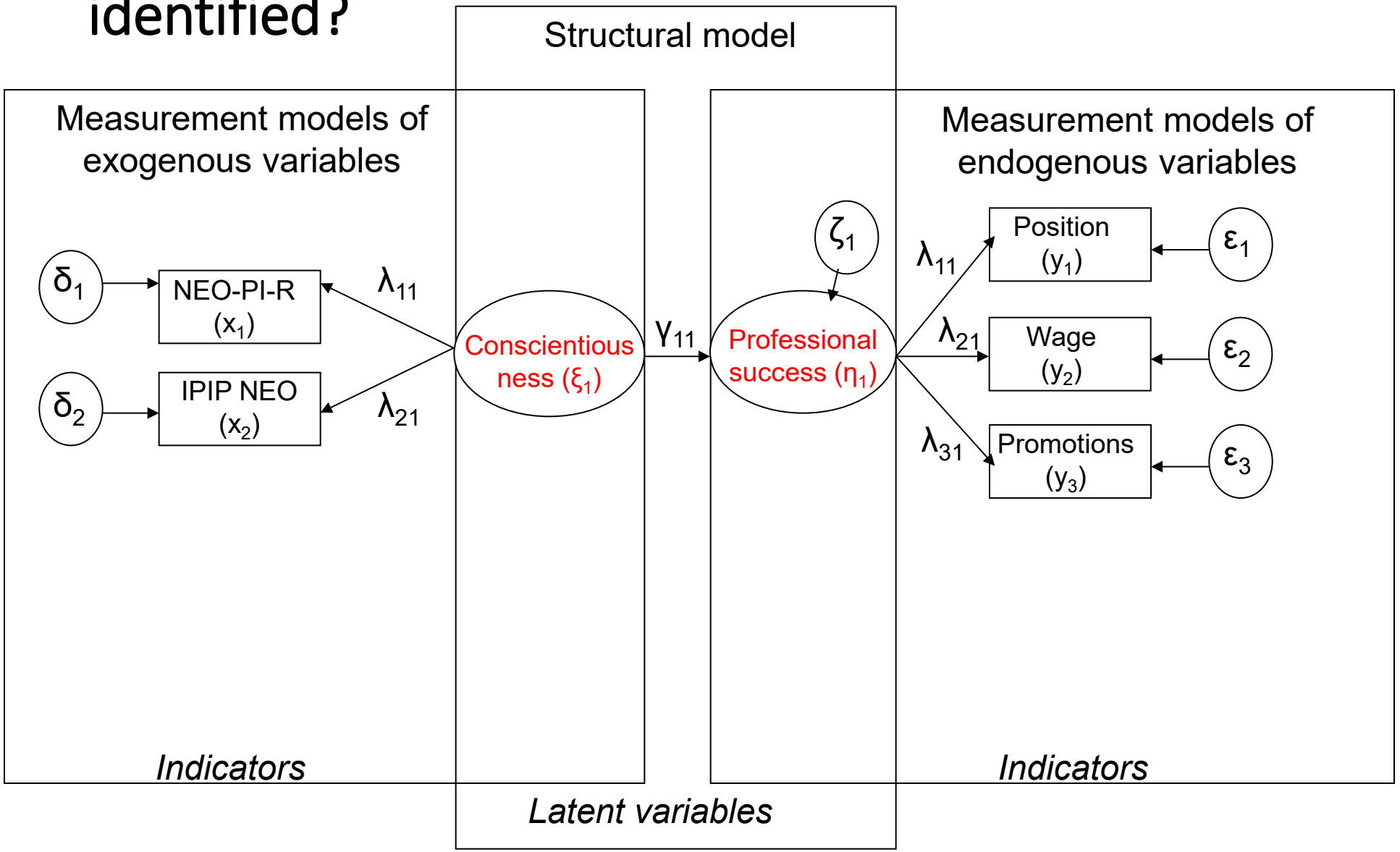
This model of measurement includes five parameters (λ_{21}, λ_{31}, θ_{11}, θ_{22} , θ_{33}) that need to be estimated,
t = 5.

N = 3:

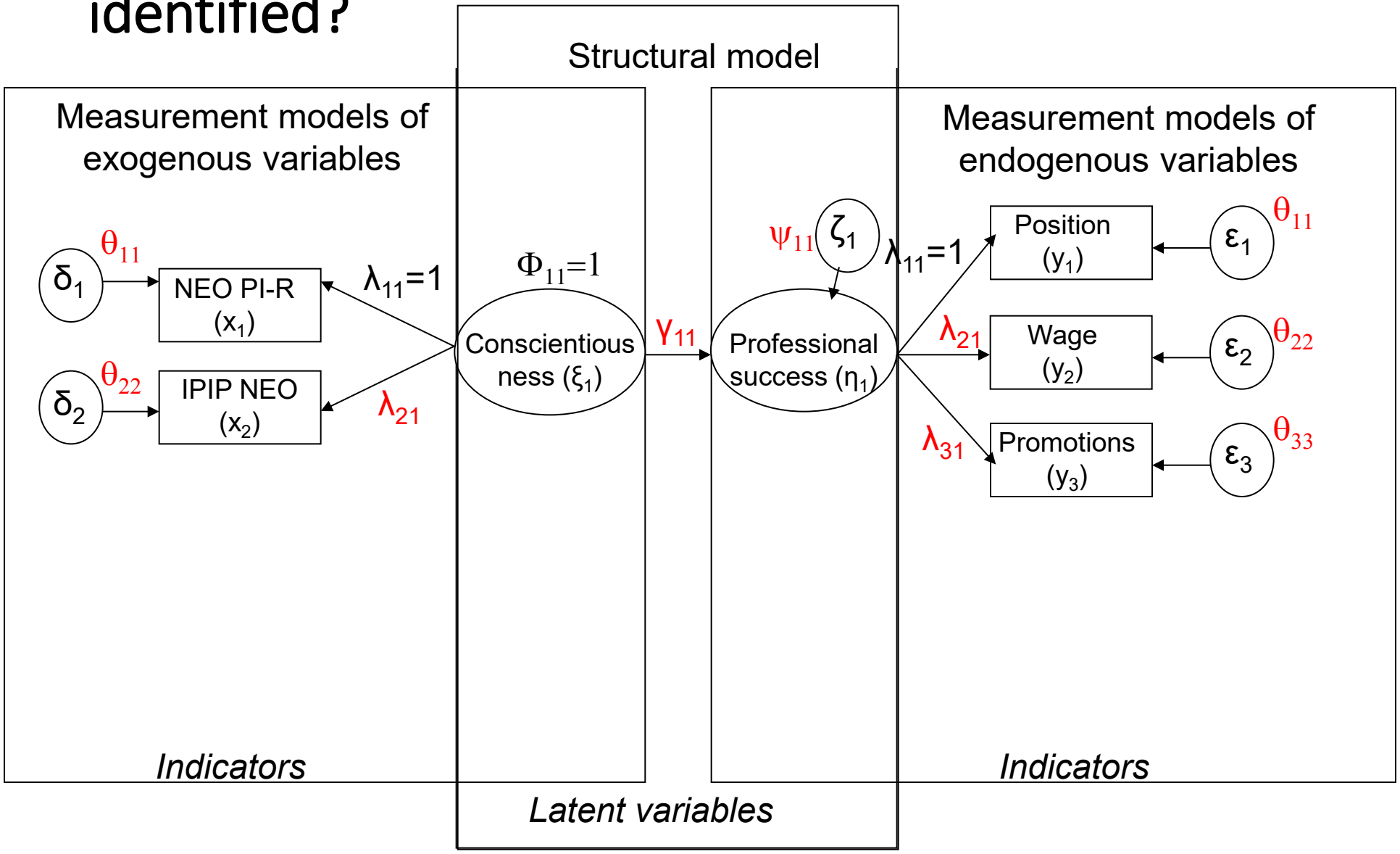
$$S = \frac{3(3+1)}{2} = 6$$

df = s – t = 6 – 5 = 1 (means … is *identified*)

> Is this simple structural equation model identified?



> Is this simple structural equation model identified?

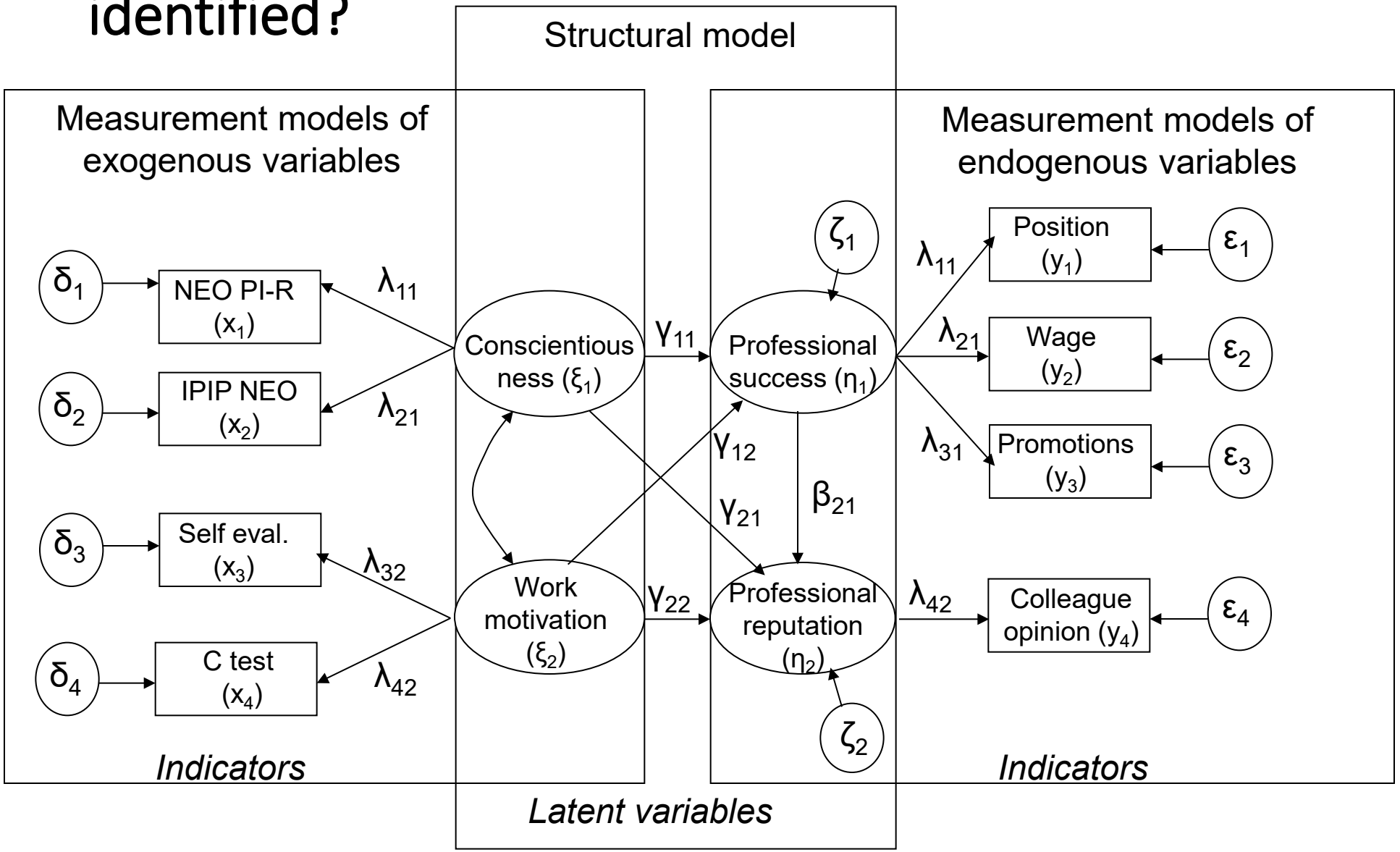


> Is this simple structural equation model identified?

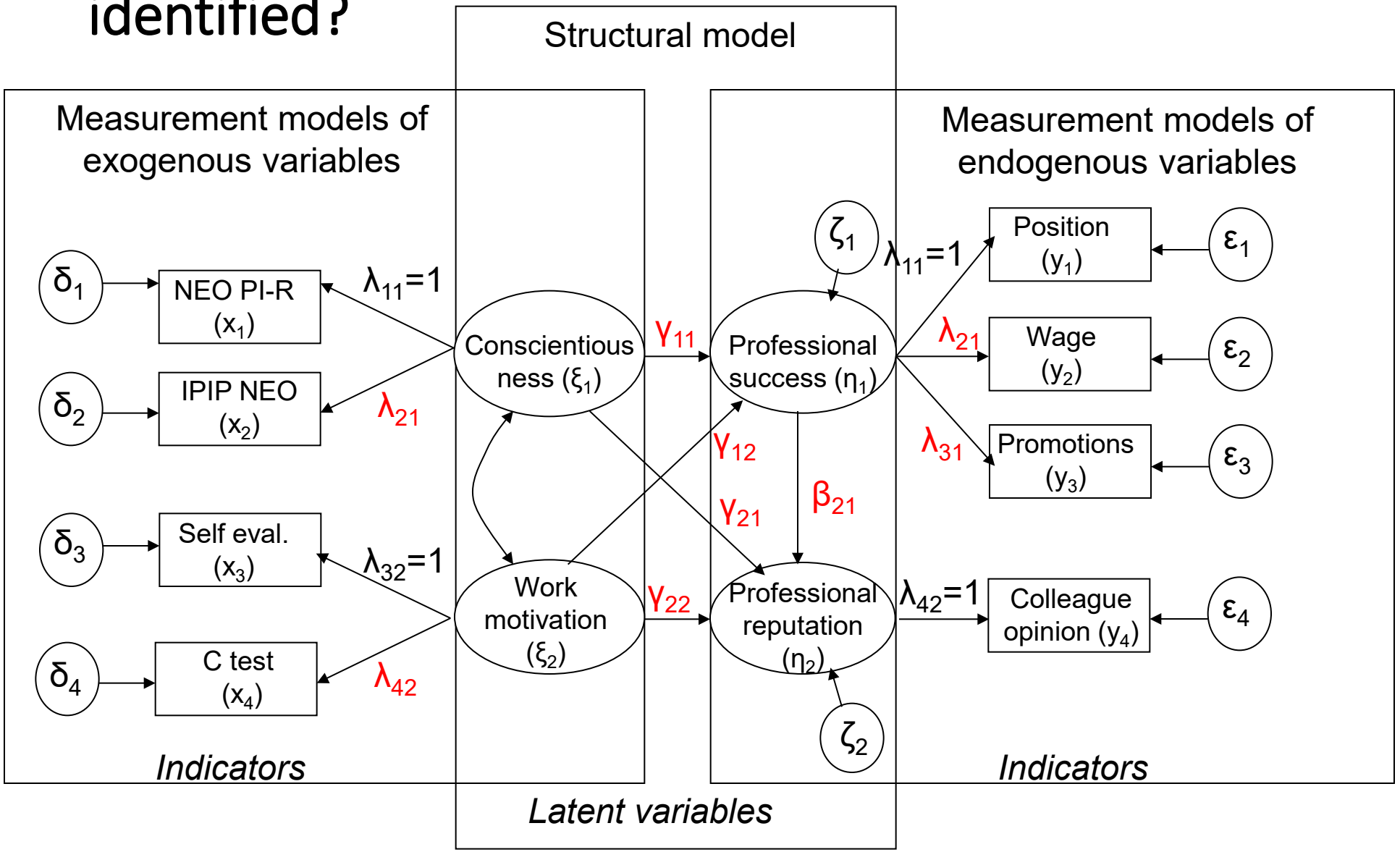
- Number of parameter (according to counting): 10
- Number of items of information: 5 x (5+1) / 2 = 15

- (s – t) <u>df = 5</u>

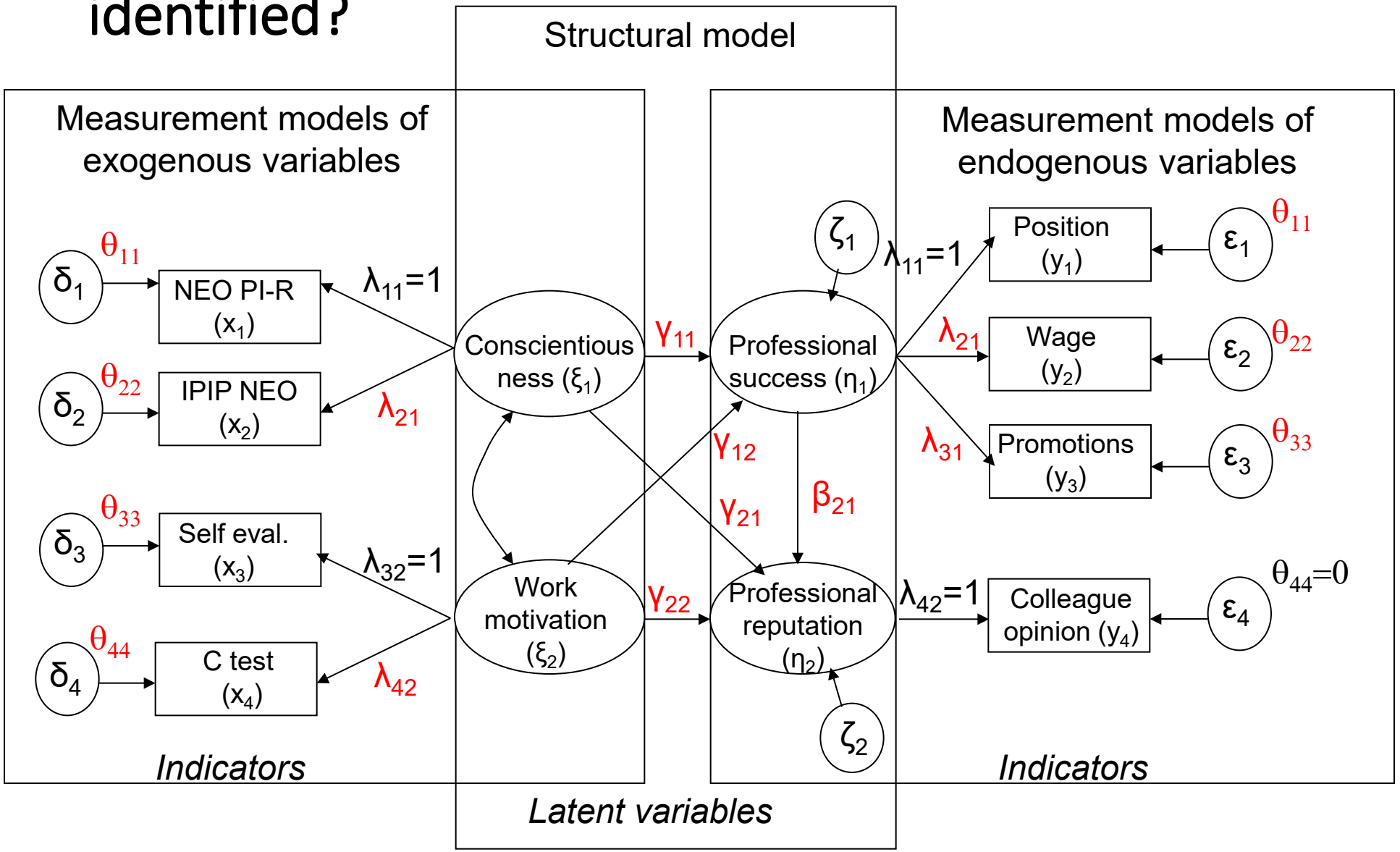
> Is this <u>complex</u> structural equation model identified?



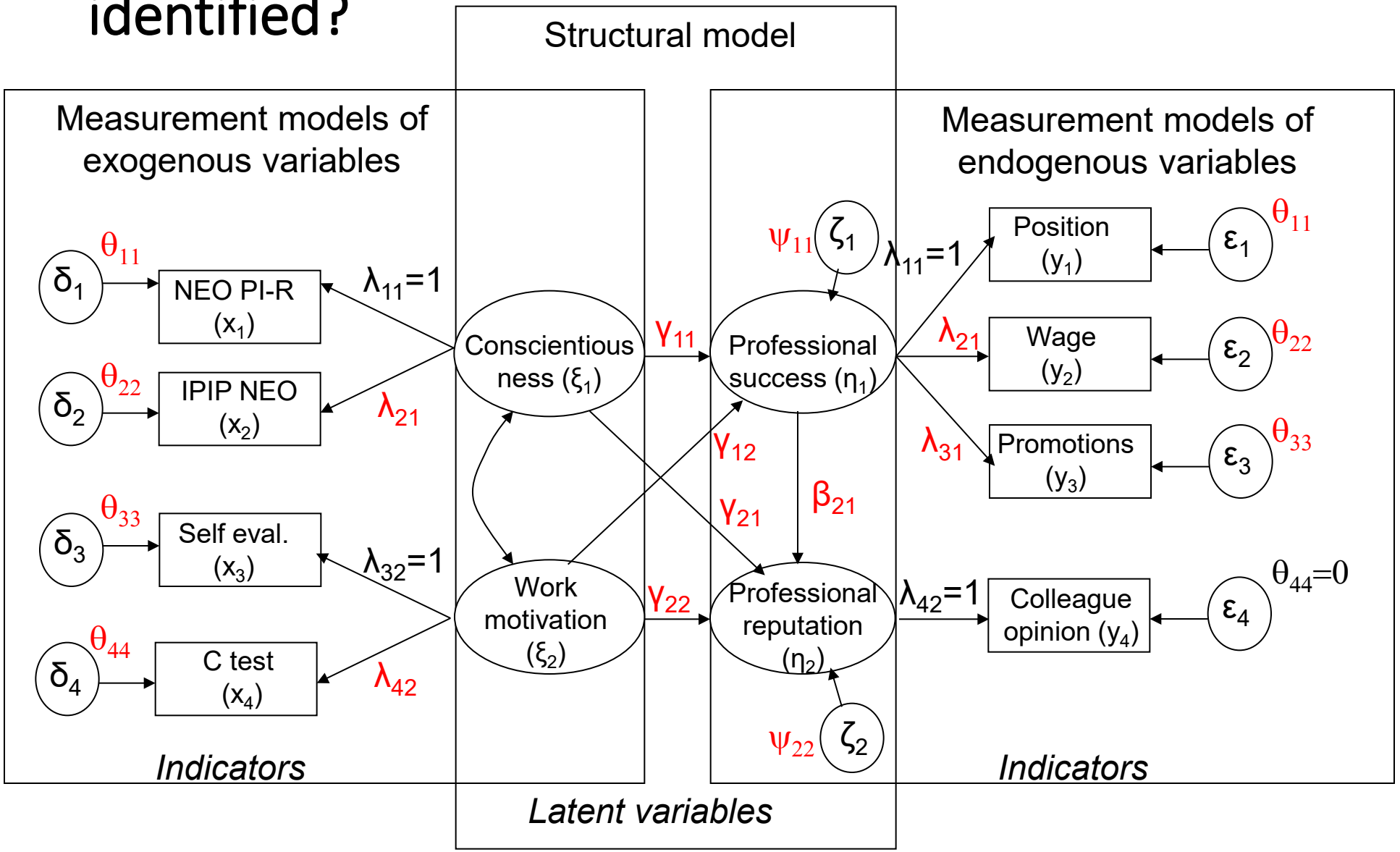
> Is this complex structural equation model identified?



> Is this complex structural equation model identified?



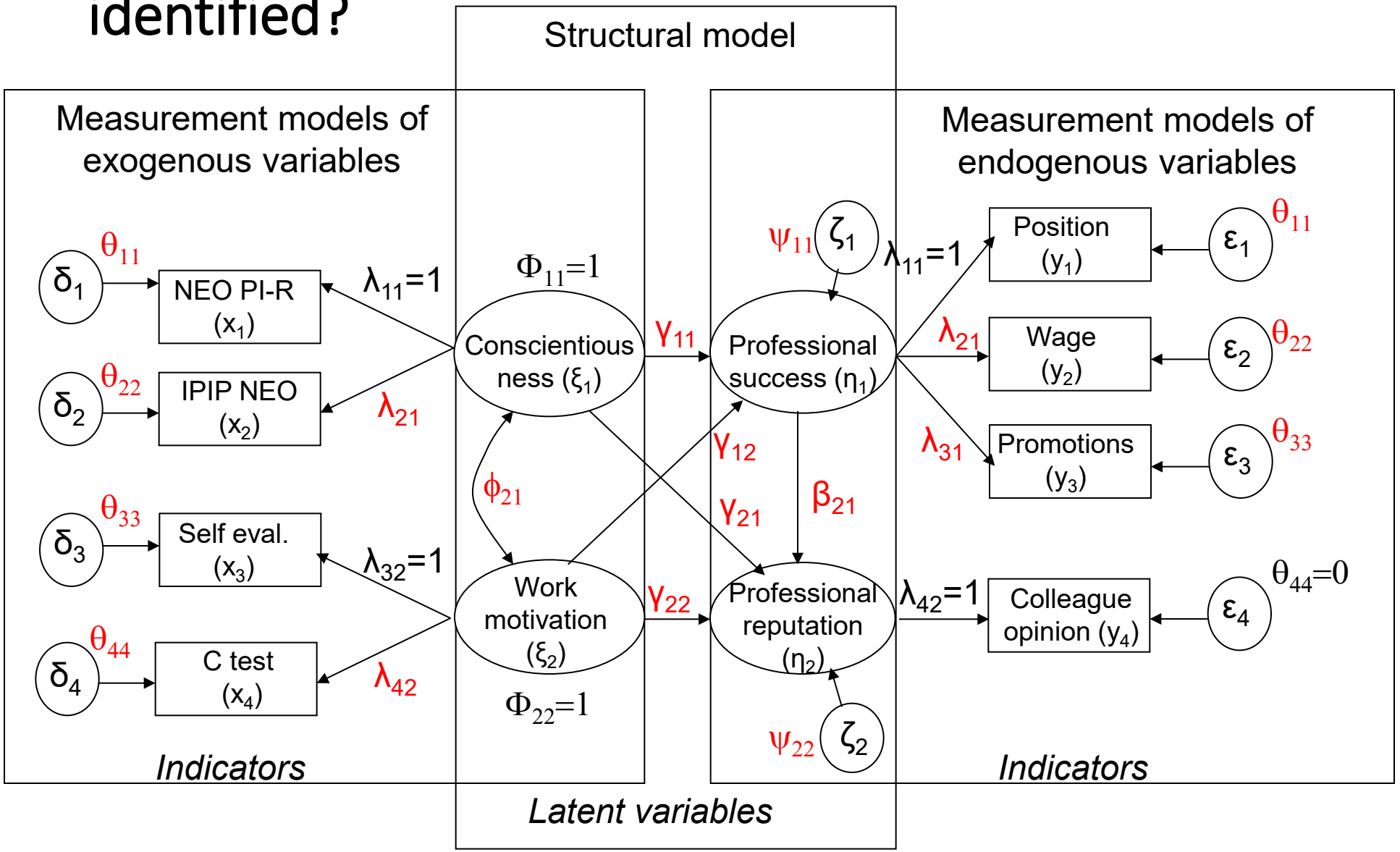
> Is this complex structural equation model identified?



Practice C

- Determine: What is the number of to-be-estimated parameters?

> Is this complex structural equation model identified?



Practice C

- What is the number of to-be-estimated parameters?

- 13
- 15
- 17
- 19

Practice C

- What is the degree of freedom for the complete complex model?

  n = 8

$$s = \frac{n(n+1)}{2}$$

  df = s - t

Practice C

- What are the degrees of freedom for the complete model?

- 13
- 14
- 15
- 16
- 17
- 19

3. Identification of the structure of models

- **Supplement**

- there are additional matrices including parameters

- **these matrices are of importance for the *estimation* of parameters and the evaluation of model fit**

> Vectors and matrices (4)

Further matrices of importance:

• **ψ**	Psi	Matrix of variances of the residuals of the *endogenous* latent variables (ζ)
• **Φ**	Phi	Matrix of variances and covariances of the *exogenous* latent variables
• $\boldsymbol{\Theta}_{\varepsilon}$	Theta-Epsilon	Diagonal matrix of variances of the residual variables of the model of measurement of the *endogenous* part
• $\boldsymbol{\Theta}_{\delta}$	Theta-Delta	Diagonal matrix of variances of the residual variables of the model of measurement of the *exogenous* part

> Vectors and matrices (4)

Further matrices …..

- what these matrices are useful for ?

  … they constitute the **model** of the covariance matrix

  (also referred to as *model-implied covariance matrix*)

  …. in addition to the <u>exogenous</u> measurement model

$$\boldsymbol{\Sigma} = \boldsymbol{\Lambda}\boldsymbol{\Phi}\boldsymbol{\Lambda}' + \boldsymbol{\Theta}_{\delta}$$

„sigma“

> Vectors and matrices (4)

Further matrices …..

… in addition to the <u>exogenous</u> measurement model

$$\boldsymbol{\Sigma} = \boldsymbol{\Lambda}\boldsymbol{\Phi}_{\xi}\boldsymbol{\Lambda}'+\boldsymbol{\Theta}_{\delta} \qquad \left\{= \left[\Lambda\boldsymbol{\xi} + \boldsymbol{\delta}\right]^2\right\}$$

A note.

- The **model of the covariance matrix** is another important model that plays a keyrole in CFA and SEM

$$\Sigma = \Lambda\Phi\Lambda' + \Theta$$

- **Sigma** (Σ) is a p x p matrix that is used for parameter estimation and the investigation of model fit.

A note.

- The model of the covariance matrix is another important model that plays a keyrole in CFA and SEM

$$\Sigma = \Lambda\Phi\Lambda' + \Theta$$

- Σ is designed in such a way that it potentially *corresponds to* the empirical p x p covariance matrix **S** **(S ~ Σ)**
- Parameter estimation is expected to lead to the *best possible correspondence* with the empirical p x p covariance matrix **S**

Summary and brush up:

0. Introductory remarks
1. Formation of hypotheses
2. Path diagram and specification of model
3. Identification of the structure of models

What are exogeneous / endogeneous latent variables?

… independent / dependent latent variables

Summary and brush up:

0. Introductory remarks

What are exogeneous / endogeneous latent variables?

… independent / dependent latent variables

1. Formation of hypotheses

… being able to state research questions / hypotheses

…. being able to identify the constructs and find indicators

2. Path diagram and specification of model

… draw a path diagram and add parameters

… transform into the formal model

3. Identification of the structure of models

… being able to compute degrees of freedom for substructures

Questions regarding course unit 2

- What are the components of a complete structural equation model?
- What is the basic assumption regarding the relationship of the true part (=systematic part) and the residual part of measurement?
- What means that „the model is identified“?
- What is the meaning of degree of freedom?

Literature

- **Kline, R. B. (2011). *Principles and practices of structural equation modeling* (3rd edition) (Chapter 1: Introduction). New York, NY: The Guilford Press.**