A guide to the concepts of structural equation modelling

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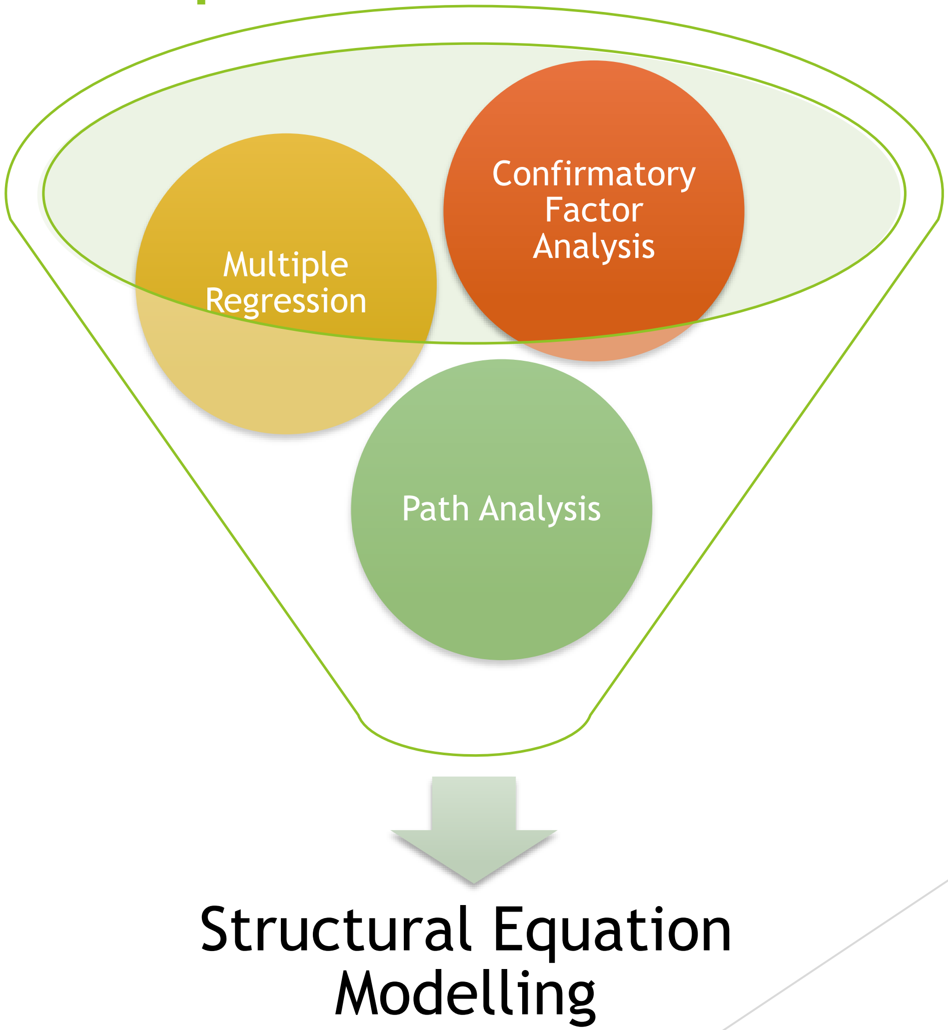
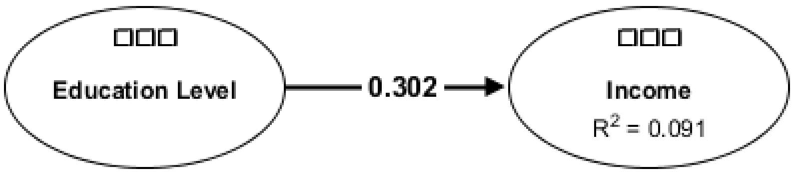
DARE

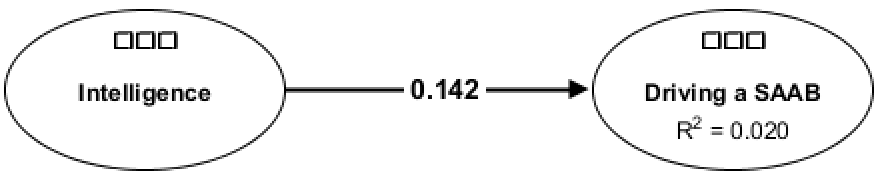
Structural Relationships and Latent Concepts



Structural Relationships

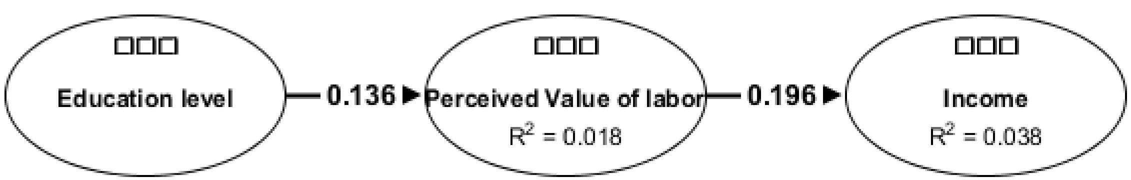
Research starts with an conscious or unconscious hypothesis:





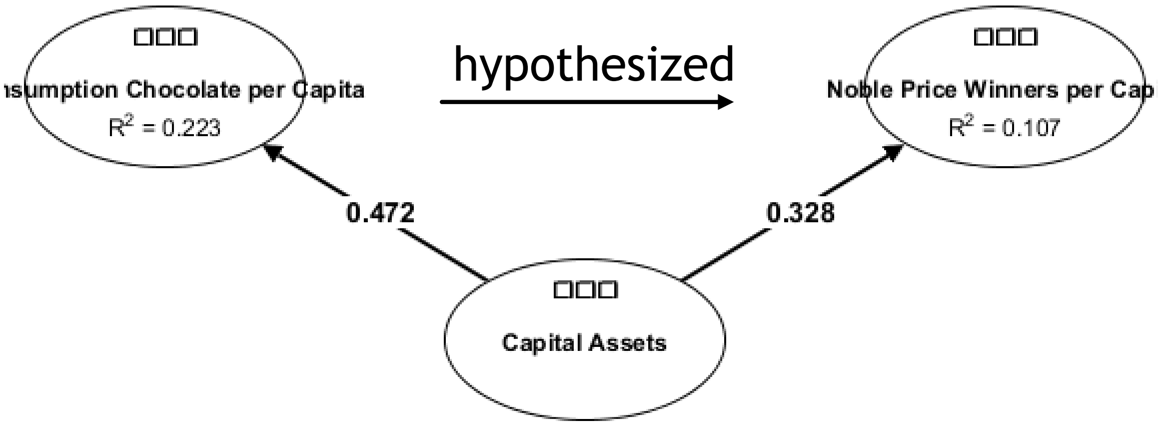
Causality?

The effect mechanism

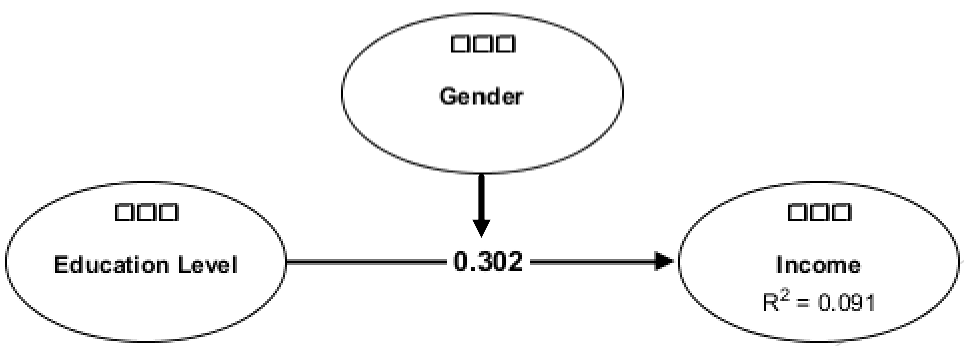


Structural Relationships

Phantom Relationship: Revealing the need for a theoretical foundation

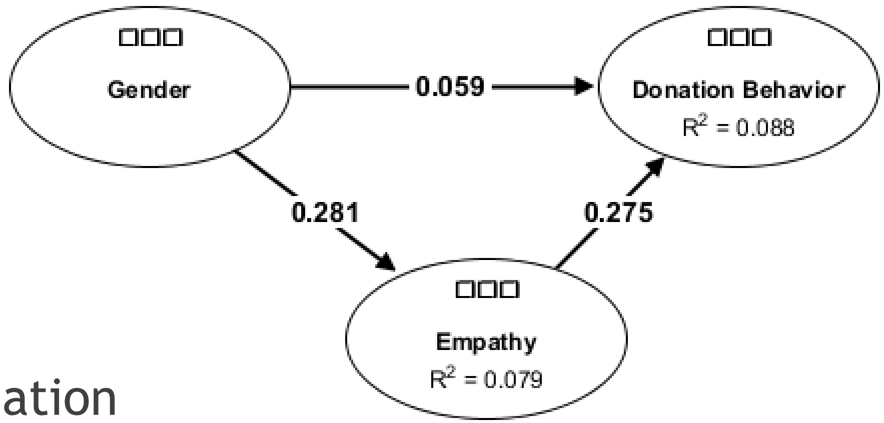


Moderated Relationship: Interaction Effects



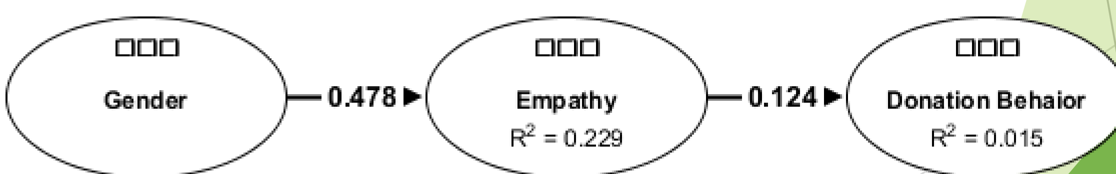
Indirect effect: Triangle of Mediation

Direct and Indirect Relationship: Indirect Relationships, the backbone of theories



- Partial Mediation
  - Complementary
  - Competitive
- Full mediation
- No mediation

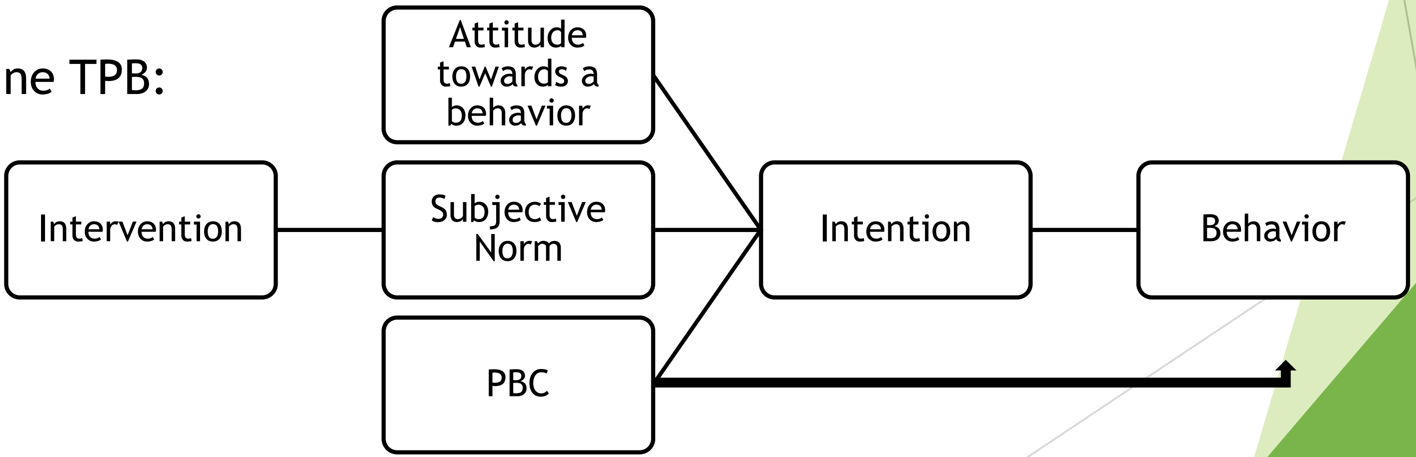
Willer, R. et al. (2015): What drives the gender gap in charitable giving? Lower empathy leads men to give less to poverty relief. In: *Social Science Research* 52, S. 83–98. DOI: 10.1016/j.ssresearch.2014.12.014



Advantages of Path analysis

- Identify initial effects, even though final outcome may not be significantly affected
- Understand effect mechanism
- Understand parallel relationships
- Understand mediator and moderator
- Testing entire theories

Imagine TPB:



The concept of **latent variables** (LV)

Confirmatory Factor Analysis

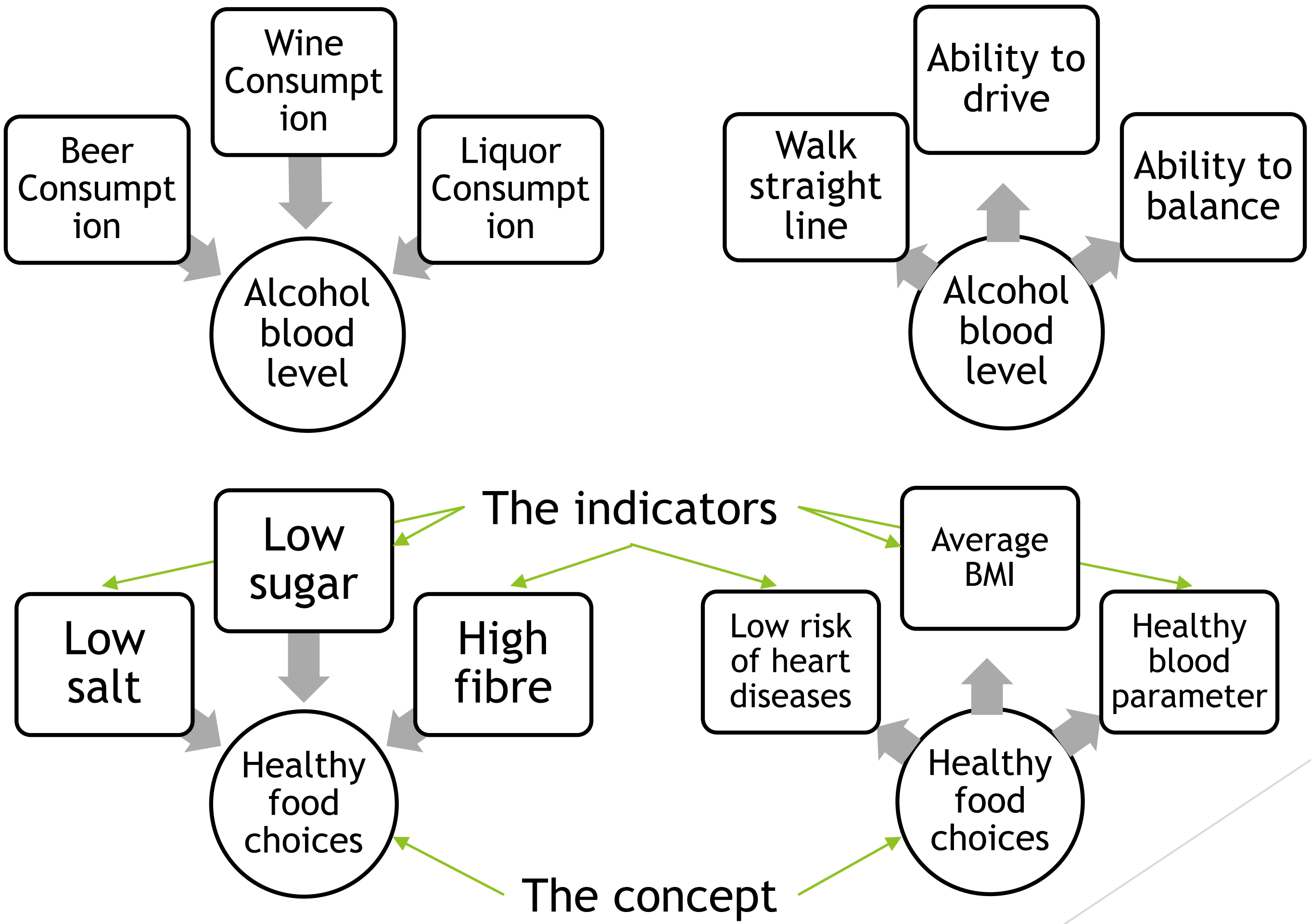
- A variable is not directly observable:
  - Hidden variables, e.g. Racism, quality of life, intelligence,
  - Abstract concepts or mental states, e.g. confidence, extraversion, wisdom, Sustainable behavior in the food domain, welfare

  ⇒ LV reduces dimensionality

  ⇒ LV lead to improved concept measurements, i.e. less measurement error

  ⇒ LV leads to inter-individual, i.e. generalizable concepts

Latent Variables: formative vs. reflective



Latent Variables: formative vs. reflective

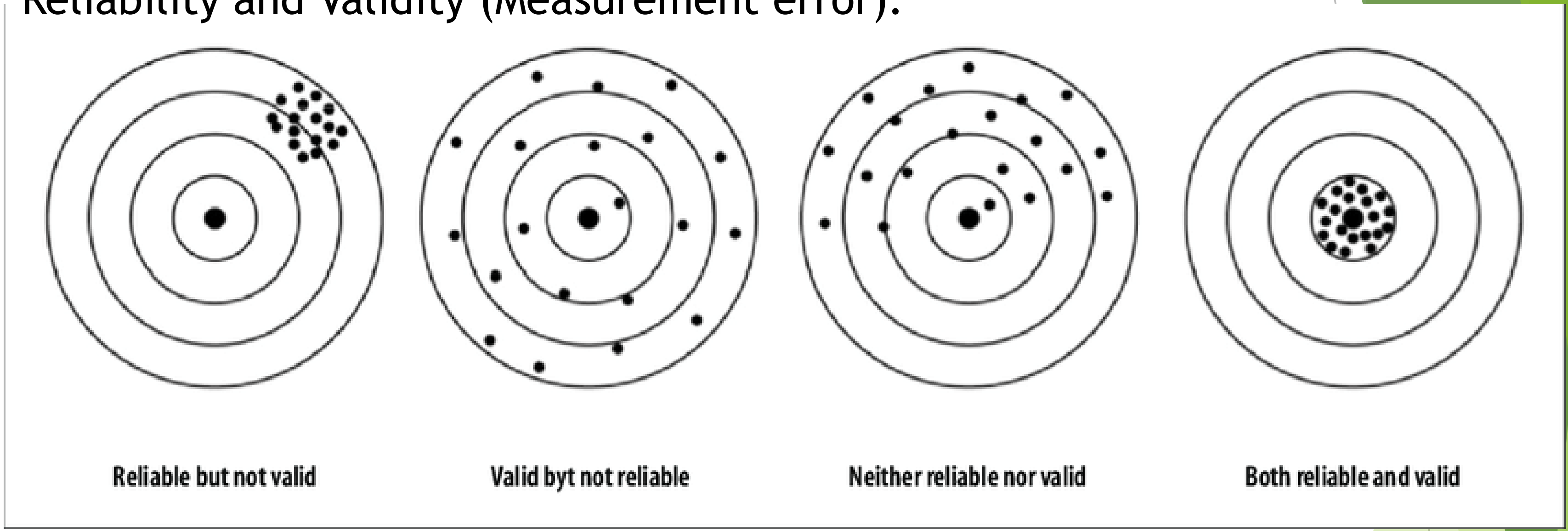
Confirmatory Factor Analysis

Formative	Reflective
Direction of causality is from indicator to LV	Direction of causality is from LV to indicator
No reason to expect indicators to be correlated	Indicators should be correlated
Dropping an indicator from the measurement model increases error of LV measurement	Dropping an indicator may not induce error

Assessing **Reflective Measurement** Models

Confirmatory Factor Analysis

Reliability and Validity (Measurement error):



- Estimate Reliability and Validity

Assessing **Reflective** **Measurement** Models

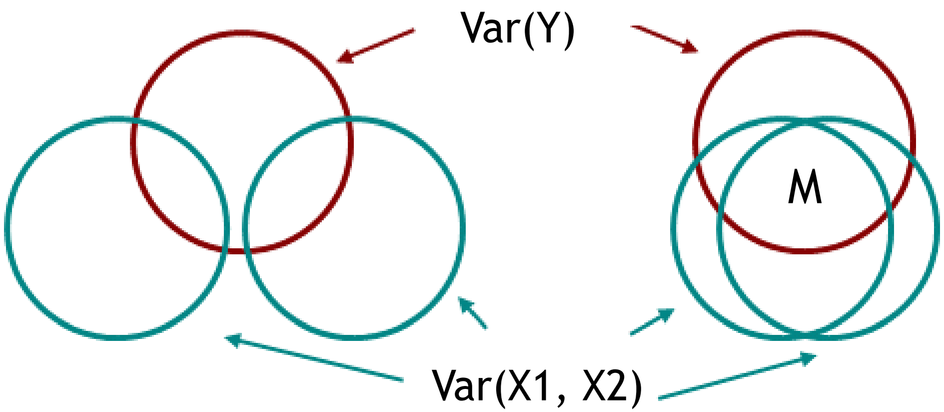
Confirmatory Factor Analysis

Reliability and Validity – capture measurement error:

1. **Concept Reliability**: **Cronbach's alpha**, **Dijkstra-Henseler's rho**
2. Concept Validity
   - **Convergence Validity:** Average Variance extracted, i.e. **AVE** (similar to explained variance concepts or LV explanatory power for indicator variance)
   - **Discriminant Validity** (Heterotrait-monotrait ratio of correlations, i.e. **HTMT or** Fornell-Larcker criterion: An LV should explain variance of its own indicators (AVE) better than indicators of other LVs
3. **Indicator Reliability** (squared factor loadings): an indicator's explainatory power for an LV

Assessing Formative Measurement Models

1. Indicator Relevance: factor loadings
2. Multicollinearity: Variance Inflation factor (VIF)



3. External validity: empirical confirmation

Empirical Data: Value Belief Norm Theory (VBN)

- VBN-theory is hypothesized to explain the generation of ecological norms

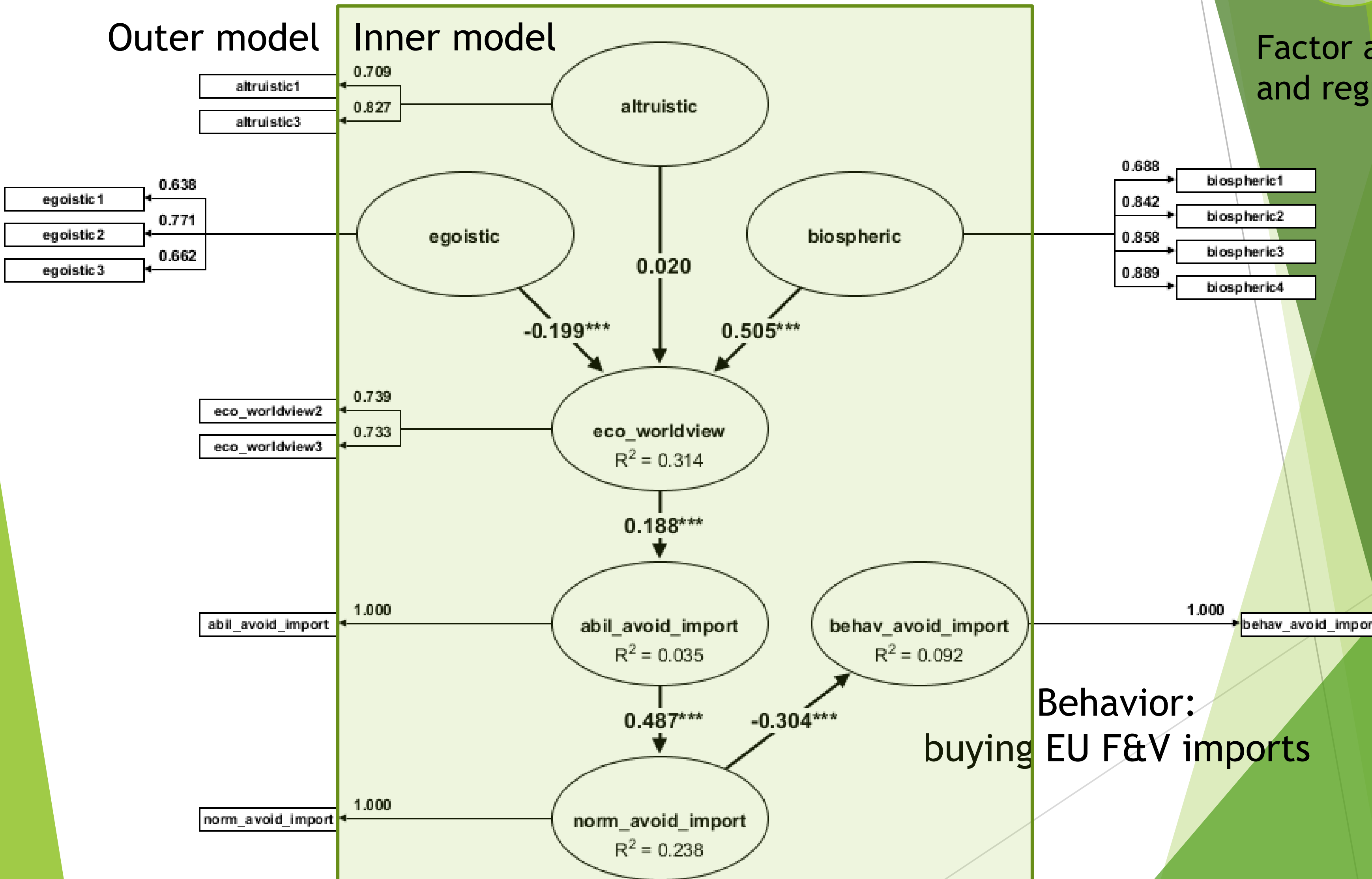
Values:
Altruistic, Egoistic, Biospheric, *Schwartz values*

Belief 1:
Ecological worldview (NEP-scale)

Belief 3:
Perceived ability to reduce threat

Norm:
Sense of obligation to take action

Empricial Data: VBN-Theory (M1)



Factor analysis and regressions!

Behavior:
buying EU F&V imports

Assessing Reflective Measurement Models: Construct Reliability

Confirmatory Factor Analysis

Construct	Dijkstra-Henseler's rho (ρ_A)	Jöreskog's rho (ρ_c)	Cronbach's alpha(α)
egoistic	0,7397	0,7330	0,7390
altruistic	0,7512	0,7435	0,7391
biospheric	0,8999	0,8926	0,8926
eco_worldview	0,7027	0,7027	0,7027
abil_avoid_import	1,0000	1,0000	
behav_avoid_import	1,0000	1,0000	
norm_avoid_import	1,0000	1,0000	

DHR> 0.7, Cα>0.7 is advised

Assessing Reflective Measurement Models: Convergence Validity

Confirmatory Factor Analysis

Construct	Average variance extracted (AVE)
egoistic	0,4796
altruistic	0,5932
biospheric	0,6770
eco_worldview	0,5417
abil_avoid_import	1,0000
behav_avoid_import	1,0000
norm_avoid_import	1,0000

Egoistic 4 dropped

AVE > 0.5 advised

Assessing Reflective Measurement Models: Discriminant Validity

Confirmatory Factor Analysis

Construct	egoistic	altruistic	biospheric	eco_worldview	abil_avoid_import	behav_avoid_import	norm_avoid_import
egoistic	0,4796						
altruistic	0,0005	0,5932					
biospheric	0,0010	0,3599	0,6770				
eco_worldview	0,0463	0,1072	0,2738	0,5417			
abil_avoid_import	0,0151	0,0000	0,0055	0,0354	1,0000		
behav_avoid_import	0,0197	0,0029	0,0001	0,0049	0,0789	1,0000	
norm_avoid_import	0,0309	0,0104	0,0497	0,0714	0,2376	0,0924	1,0000

Forner Larcker Criterion or HTMT: An LV should explain variance of its own indicators better than indicators of other LVs

Solution: Merging or Dropping of concepts or indicators

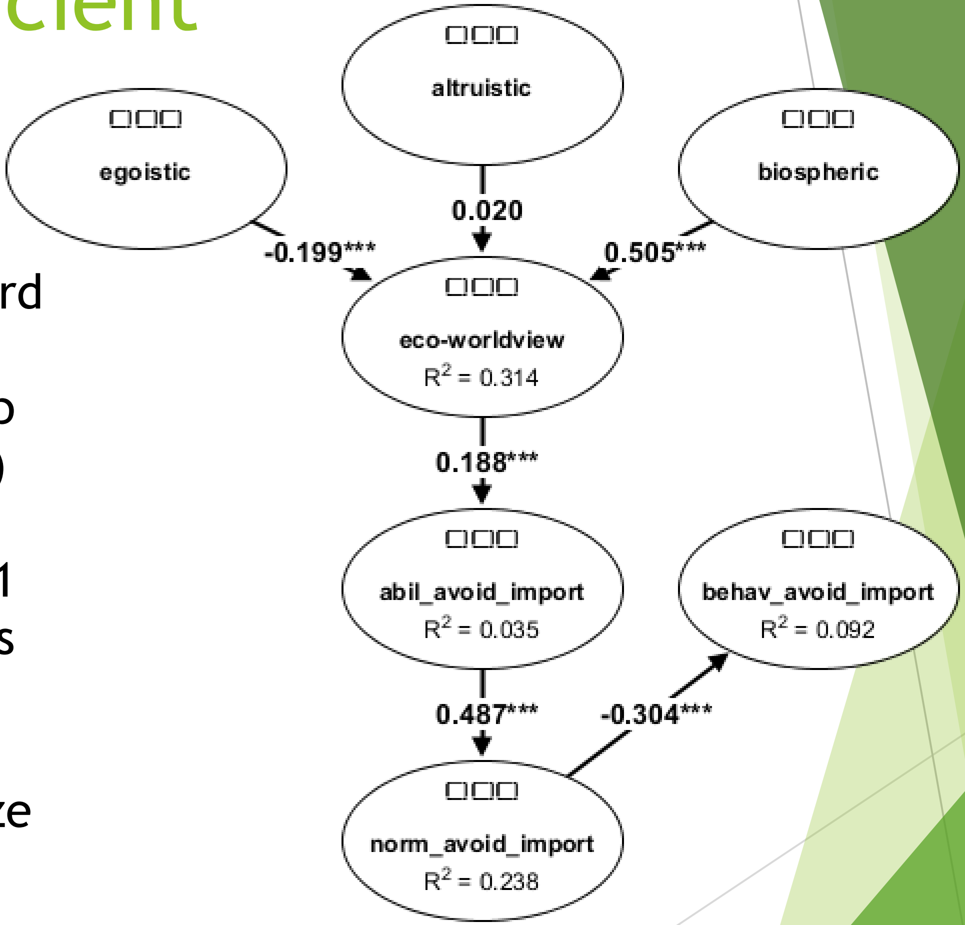
Assessing the Structural models: The path coefficient

How to interpret the path coefficient?

1. PLS standardizes each var
2. If X changes by one standard deviation Y changes by b standard deviations (with b being the path coefficient)
3. Perfection correlation results in b=1, reverse b=-1
4. b holds if everything else is constant

⇒ Interpret sign

⇒ Interpret relative effect size

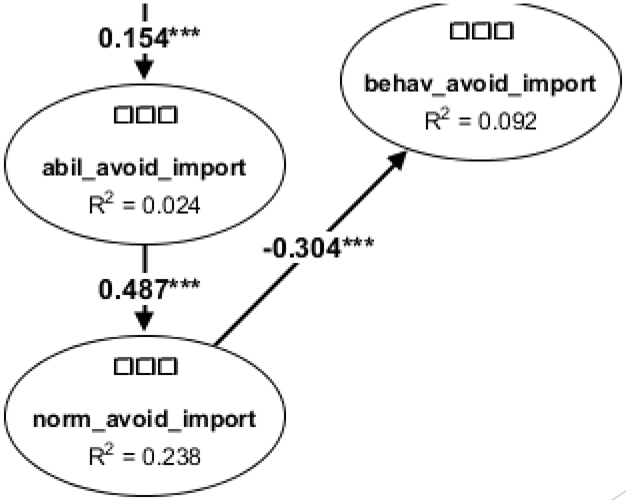


Assessing the Structural models: the “objective” effect size (f^2)

f^2-statistic:

Effect	Beta	Indirect effects	Total effect	Cohen's f^2
abil_avoid_import -> norm_avoid_import	0,4875		0,4875	0,3117
abil_avoid_import -> behav_avoid_import		-0,1482	-0,1482	
norm_avoid_import -> behav_avoid_import	-0,3039		-0,3039	0,1018

- Effect size based on f^2 (threshold may depend on discipline):
  - f^2>0,35 strong effect
  - f^2>0,15 moderate effect
  - f^2>0,02 weak effect



Assessing the Structural models: Significance and Bootstrapping

Can we assume our data to be normally distributed?

- Resampling method with replacement

⇒ draw multiple samples to create a population

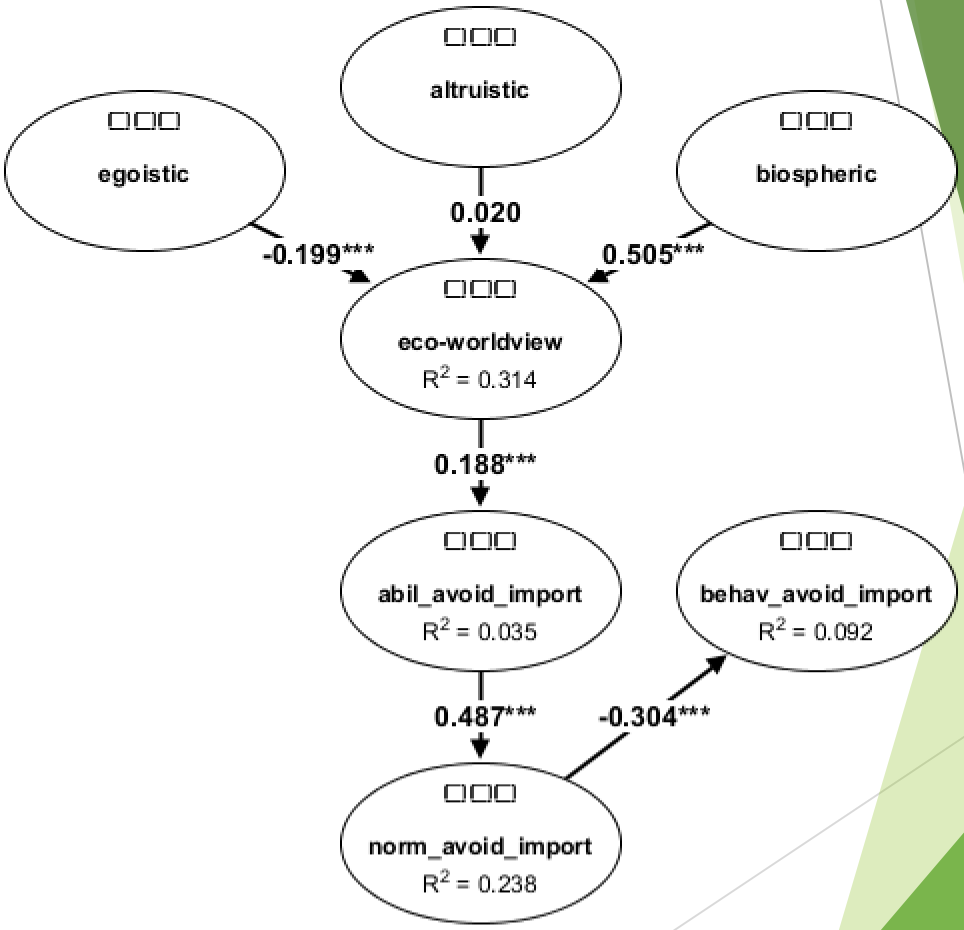
- Bootstrapping estimates a sampling distribution => standard errors =>
  - Confidence intervals, variance, prediction error and so on
  - No parametric tests, no normality assumptions
- Most recommend a bootstrap with repetitions >= 999 OR >N

Sample	N	X -> Y
1	1000	0.51
2	1000	0.46
3	1000	0.43
4	1000	0.47
5	1000	0.3
6	1000	0.62
7	1000	0.5
8	1000	0.55
9	1000	0.38
10	1000	0.44
11	1000	0.46
12	1000	0.44
…	…	…
k	1000	0.52

Assessing the Structural models: R^2

(Adj.) R^2: measures within sample prediction

⇒ Here R^2 is not global model fit criteria



Assessing the Structural models: Overall model fit and prediction power

Compare different models

	Value	HI95	HI99
SRMR	0,0575	0,0328	0,0402

- SRMR = standardized root mean square residual, the lower better, SRMR<0.08 is considered a good model fit
- Q^2-predictive relevance
  - Blindfolding procedure: Blindfolding is a sample re-use technique, which systematically deletes data points and provides a prognosis of their original values

Reason for SEM

- Identify initial effects
- Understand effect mechanism
- Understand parallel relationships
- Understand mediator and moderator
- Testing entire theories
- Measure structural relationships of latent variables
- Report on multiple hypothesis in 1 model
- Robust to non-normal data

Conclusions

- Understand the structural relationships you hypothesize
- Measure your concepts as good as possible
- Provide evidence for both with SEM

About Us

- **Researchgate**: https://www.researchgate.net/profile/Dominic_Lemken
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