

**Issues in assessing
measurement invariance in
cross-national research**

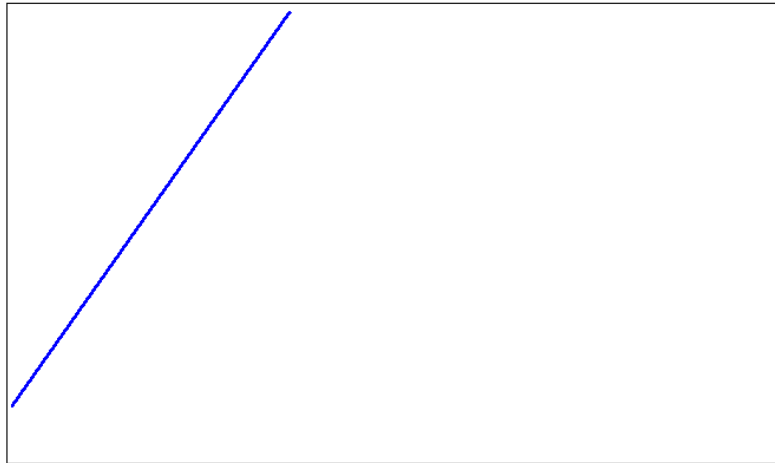
Hans Baumgartner

Penn State University

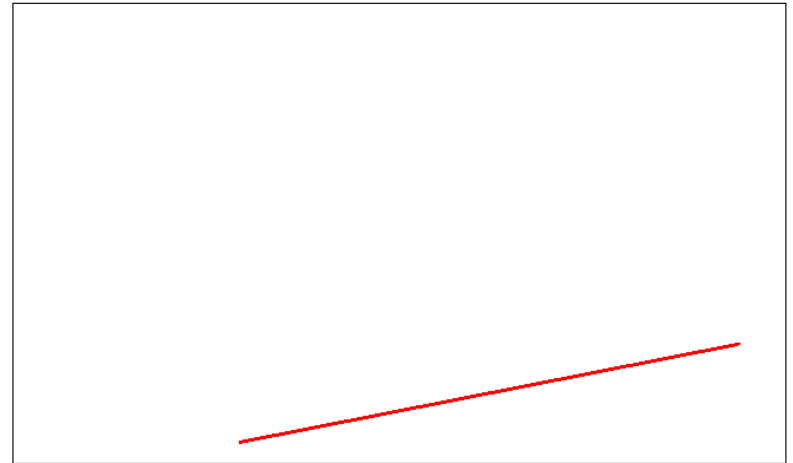
Jan-Benedict Steenkamp

Tilburg University

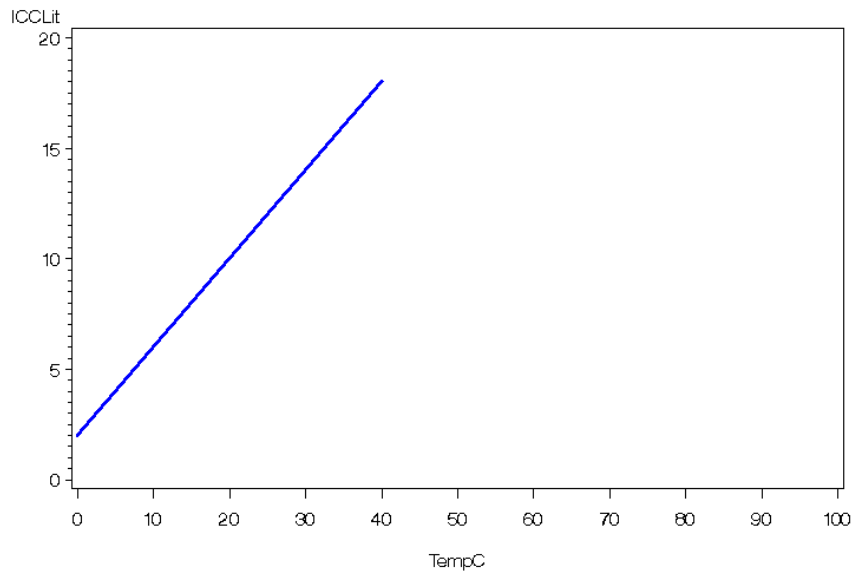
Ice cream consumption for Austria



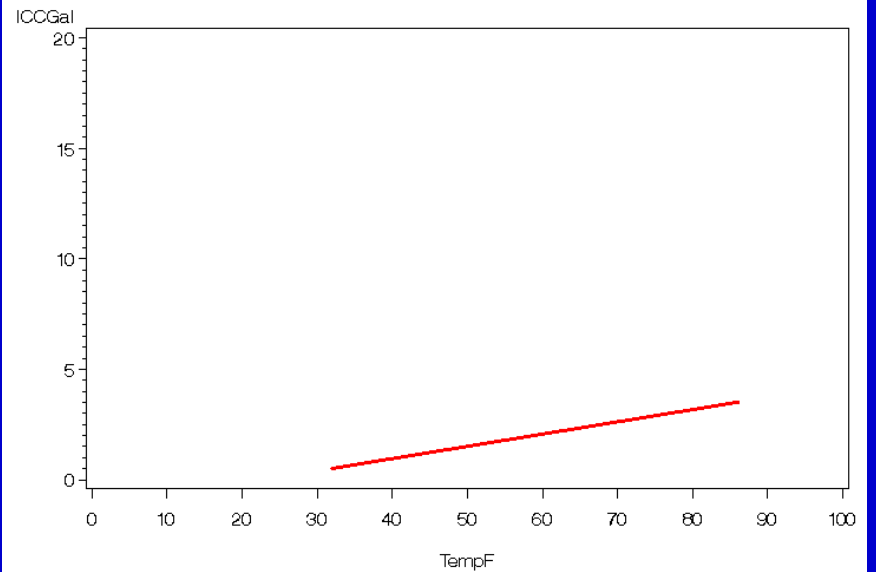
Ice cream consumption for USA



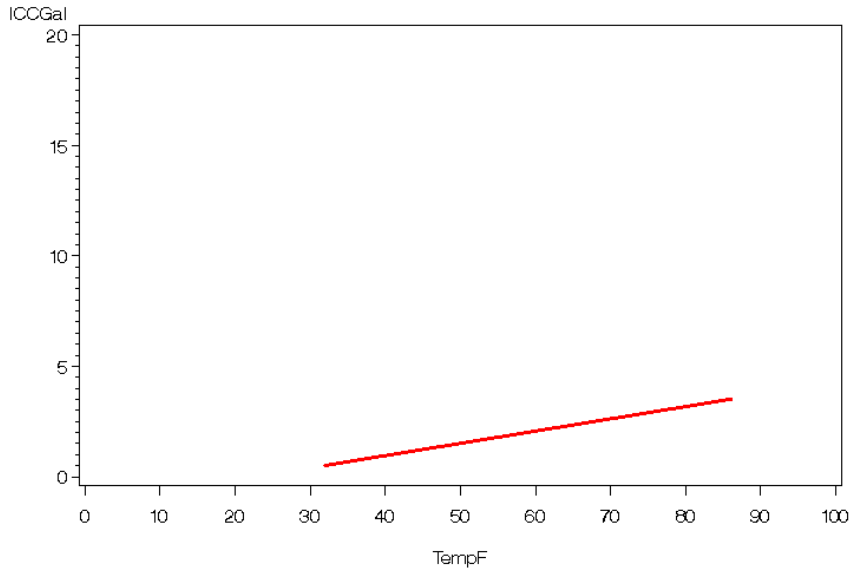
Ice cream consumption for Austria



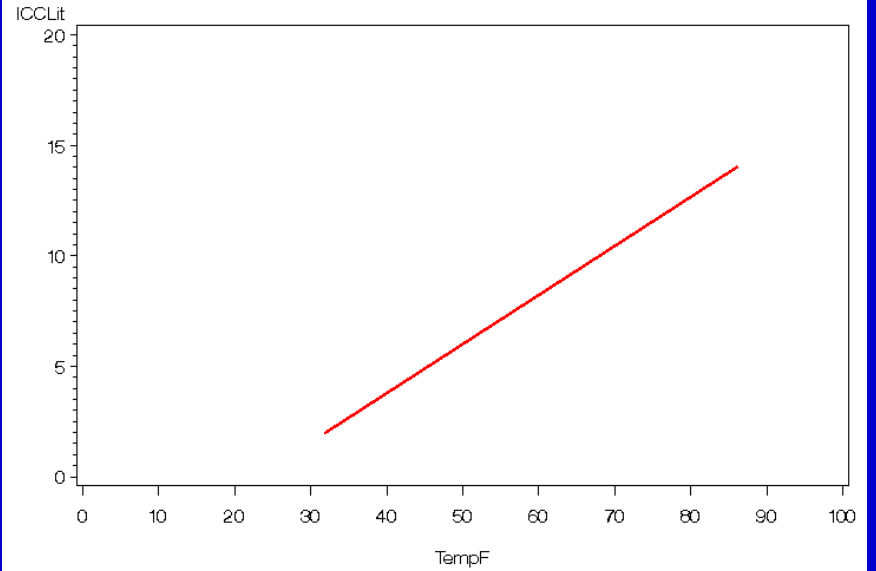
Ice cream consumption for USA



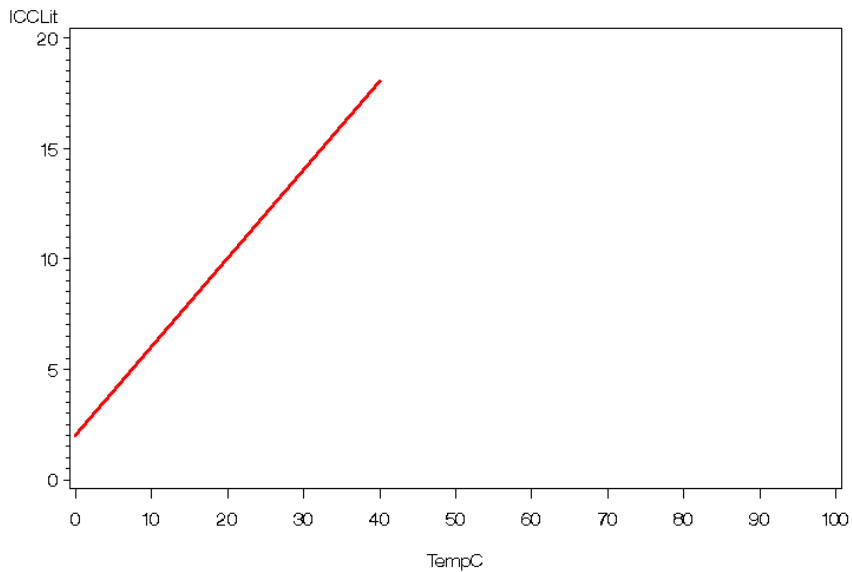
Ice cream consumption for USA



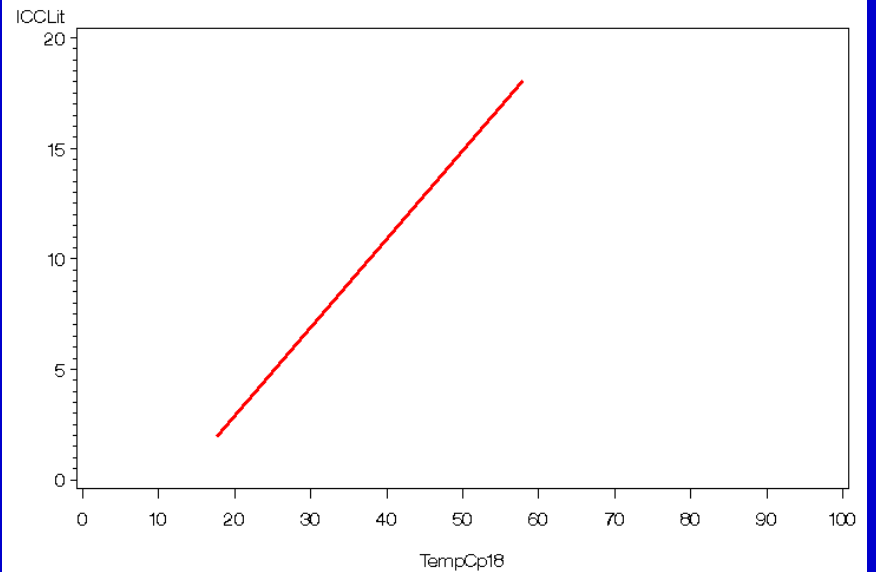
Ice cream consumption for USA



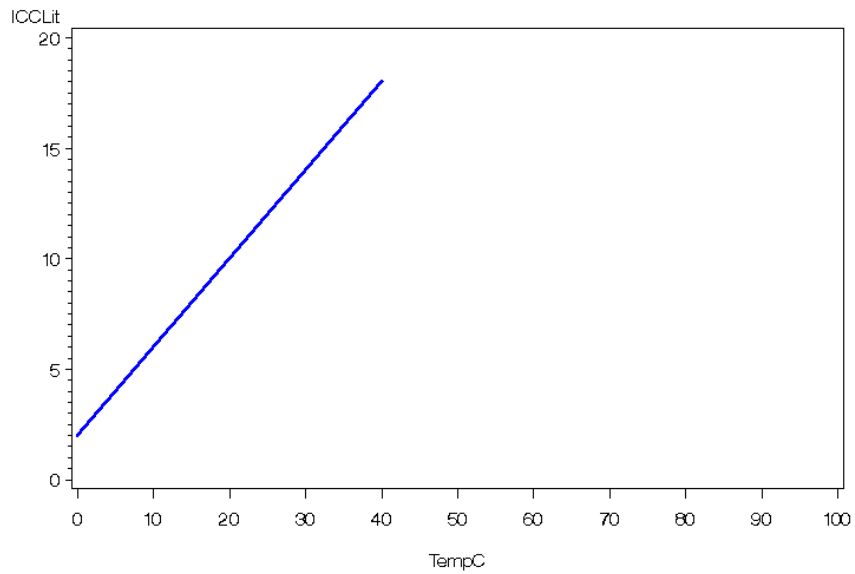
Ice cream consumption for USA



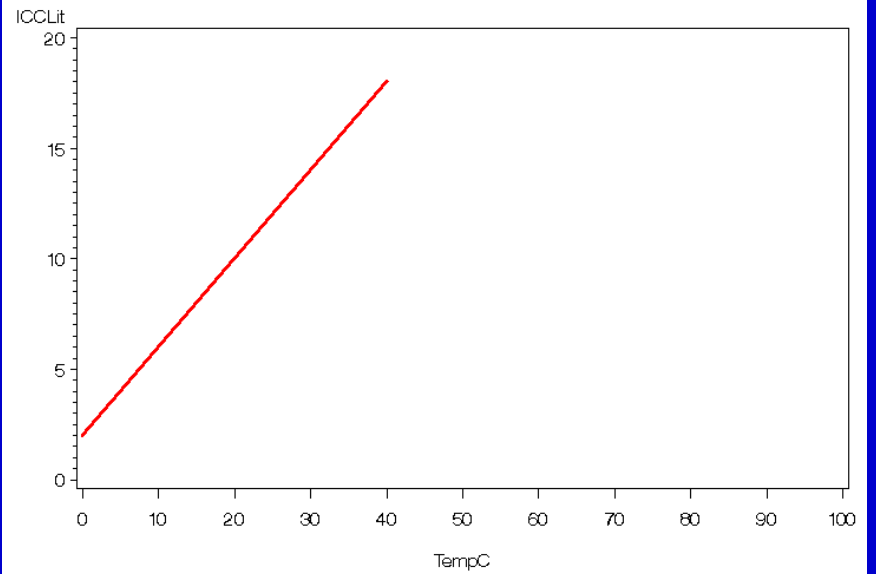
Ice cream consumption for USA



Ice cream consumption for Austria



Ice cream consumption for USA



Measurement invariance in actual research practice

- often lack of concern for measurement invariance in cross-national research;
- “without evidence of measurement invariance, the conclusions of a study must be weak” (Horn 1991, p. 119);
- discussion of a variety of important issues that arise when measurement invariance is assessed, with special consideration for situations in which comparisons are conducted across many different groups;

Data

ARG	Argentina	397	JPN	Japan	449
AUT	Austria	393	NED	Netherlands	504
BEL	Belgium	508	NOR	Norway	549
BRA	Brazil	398	POL	Poland	391
CHN	China	419	POR	Portugal	439
CZE	Czech Republic	493	ROM	Romania	431
DEN	Denmark	519	RUS	Russia	396
ESP	Spain	546	SUI	Switzerland	393
FRA	France	402	SVK	Slovakia	379
GBR	Great Britain	355	SWE	Sweden	419
GER	Germany	640	THA	Thailand	402
HUN	Hungary	577	TRE	Taiwan	396
IRL	Ireland	552	UKR	Ukraine	396
ITA	Italy	397	USA	United States	1181

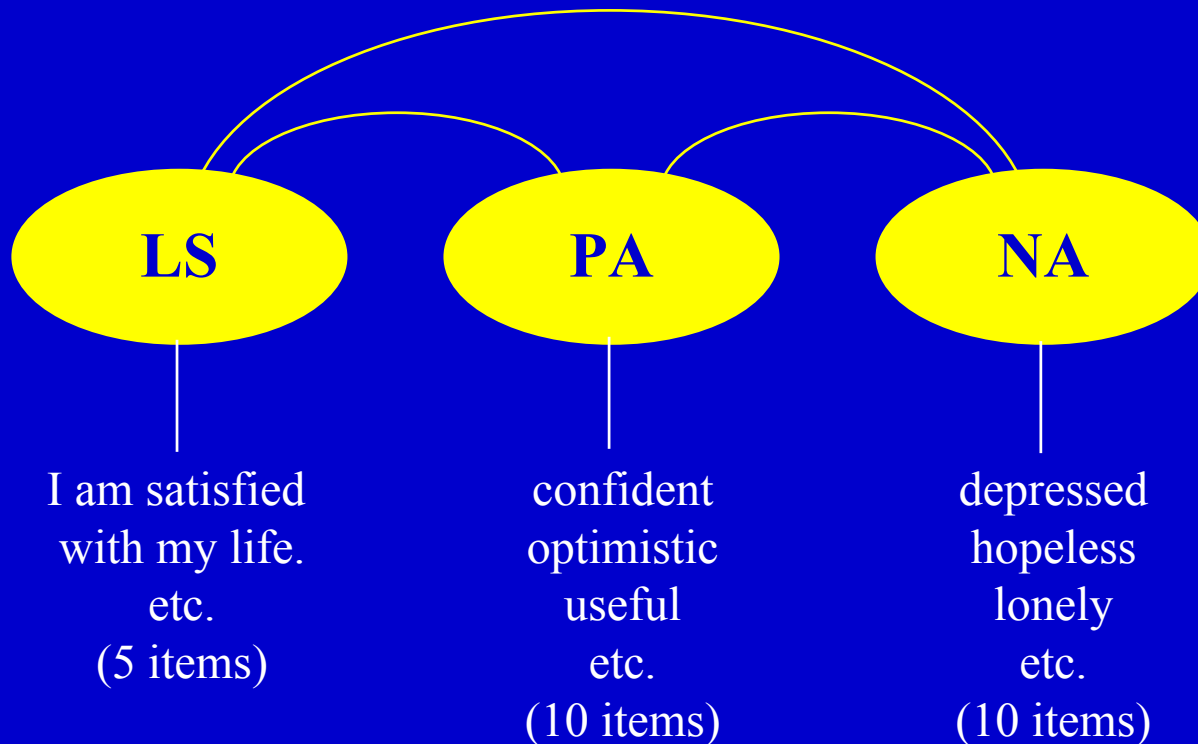
Satisfaction With Life Scale (Diener et al. 1985)

- scale to measure global life satisfaction as a cognitive-judgmental process;
- five items rated on 5-point agree/disagree scales:
 - In most ways my life is close to my ideal.
 - The conditions of my life are excellent.
 - I am satisfied with my life.
 - So far I have gotten the important things I want in life.
 - If I could live my life over, I would change almost nothing.

Affectometer 2 **(Kammann and Flett 1983)**

- scale to measure a person's general happiness or sense of well-being based on the balance of positive and negative feelings in recent experience;
- Below are various feelings that you might use to describe how happy or unhappy you are in your life. Please indicate how often you have felt each of the following feelings over the past month (5-point scale from none of the time to all the time):
 - Positive Affect (confident, optimistic, satisfied, useful, etc.)
 - Negative Affect (depressed, hopeless, lonely, discontented, etc.)

Measurement model for SWB



Measurement model

Let x^g be a $p \times 1$ vector of observed variables in country g , ξ^g an $m \times 1$ vector of latent variables, δ^g a $p \times 1$ vector of errors of measurement, τ^g a $p \times 1$ vector of item intercepts, and Λ^g a $p \times m$ matrix of factor loadings. Then

$$x^g = \tau^g + \Lambda^g \xi^g + \delta^g$$

The means part of the model is given by

$$\mu^g = \tau^g + \Lambda^g \kappa^g$$

and the covariance part is given by

$$\Sigma^g = \Lambda^g \Phi^g \Lambda^{g'} + \Theta^g$$

Model identification

- to identify the covariance part, the latent constructs have to be assigned a scale in which they are measured; this is done by choosing a marker item and setting its loading to one;
- to identify the means part, the intercepts of the marker items are fixed to zero (which equates the means of the latent constructs to the means of their marker variables, $\mu_m^g = \kappa_m^g$);
- although these constraints help with identifying the model, they are not sufficient for meaningful cross-national comparisons;

Forms of measurement invariance

- levels of invariance:
 - imposition of increasingly stringent forms of invariance on the measurement model;
- full vs. partial invariance:
 - extent to which measurement invariance of a given kind is satisfied,

Levels of invariance

- **configural invariance:** the pattern of salient and nonsalient loadings is the same across different countries;
- **metric invariance:** the scale metrics are the same across countries;

$$\Lambda^1 = \Lambda^2 = \dots = \Lambda^G$$

- **scalar invariance:** in addition to the scale metrics the item intercepts are the same across countries;

$$\tau^1 = \tau^2 = \dots = \tau^G$$

Linking the level of invariance required to the research objective

	Configural invariance	Metric invariance	Scalar invariance
Exploring the basic structure of the construct cross-nationally	✓		
Examining structural relationships with other constructs cross-nationally	✓	✓	
Conducting cross-national comparisons of means	✓	✓	✓

Full vs. partial invariance

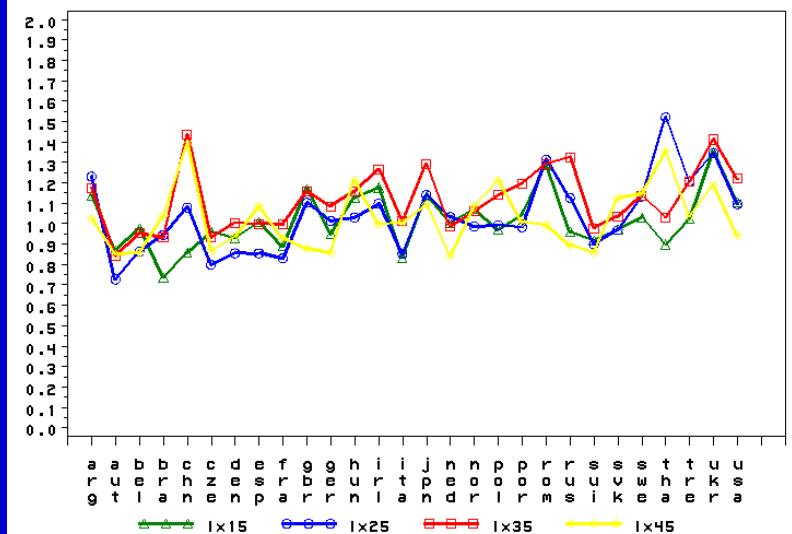
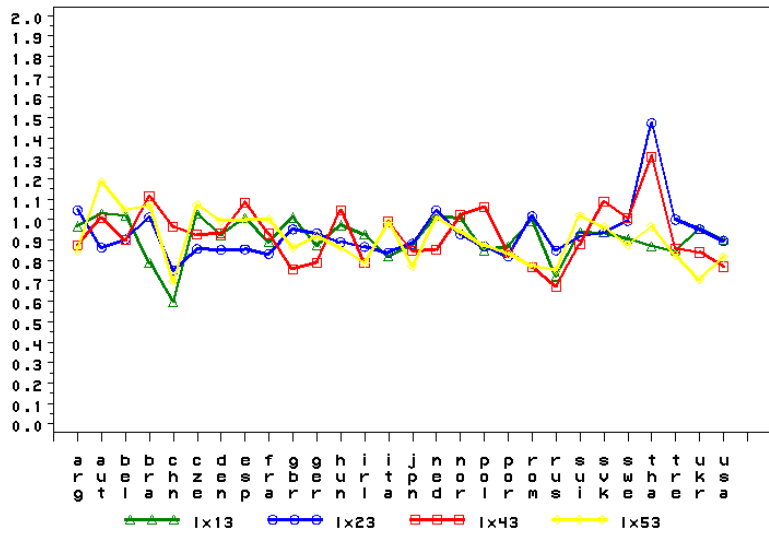
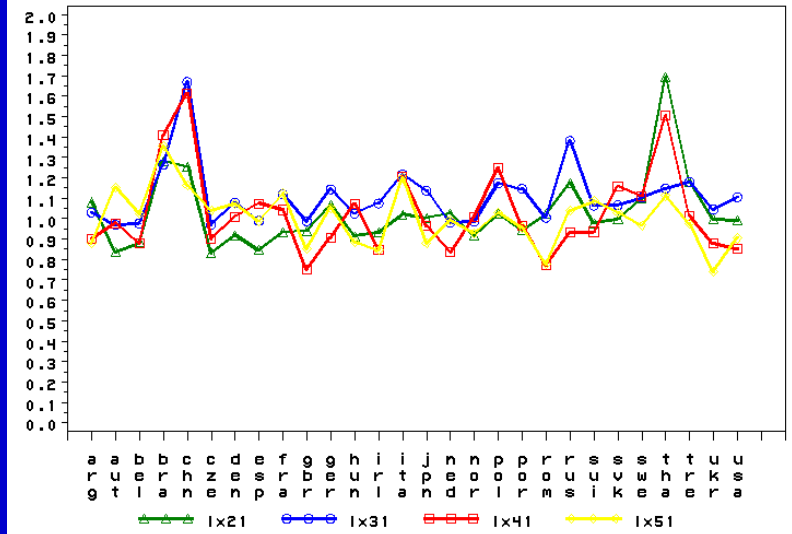
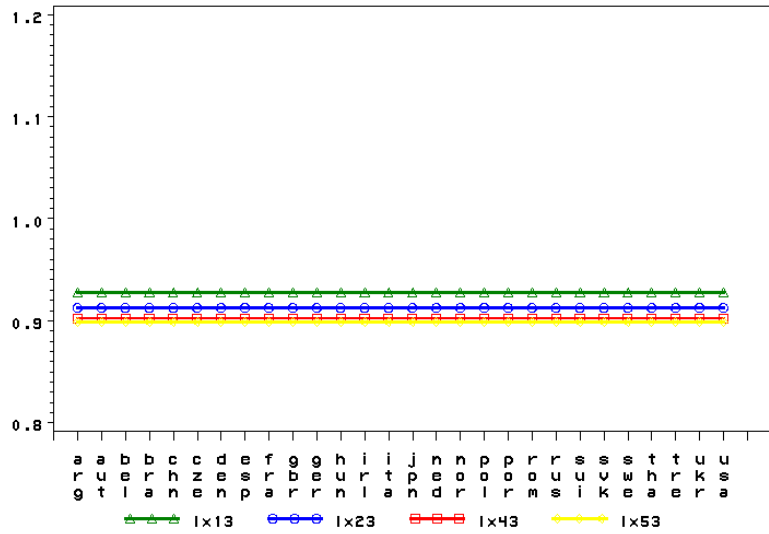
- full measurement invariance of a given type (e.g., metric, scalar) is frequently not satisfied in practice;
- partial measurement invariance as a “compromise” between full measurement invariance and complete lack of invariance (Byrne et al. 1989);
- issue of the minimal degree of partial measurement invariance necessary for comparisons of cross-national differences in factor means to be meaningful (Steenkamp and Baumgartner 1998);

Partial measurement invariance

- for identification purposes, one item per factor has to have invariant loadings and intercepts (marker item); the marker item has to be chosen carefully;
- at least one other invariance constraint on the loadings/intercepts is necessary to ascertain whether the marker item satisfies metric/scalar invariance;
- Cheung and Rensvold (1999) proposed the factor-ratio test in which all possible pairs of items are tested for metric invariance and sets of invariant items are identified;
- an alternative is to start with the fully invariant model of a given kind and relax invariance constraints based on significant modification indices, changes in alternative fit indices, and expected parameter changes;

Assessing metric invariance across many different countries

- choose a marker item for each factor
 - graph the factor loadings
 - compute variance components
 - calculate individual item reliabilities
- compare the configural with the full metric invariance model;
- use Bonferroni-adjusted modification indices (or other fit indices) and expected parameter changes to free loadings that are not invariant;



Variance components for loadings

Life satisfaction			Positive affect			Negative affect		
Item 1	.015	.013	Item 1	.123	.052	Item 1	.032	.034
Item 2	.011	.010	Item 2	.020	.030	Item 2	.009	.017
Item 3	.004	.011	Item 3	.046	.033	Item 3	.053	.026
Item 4	.016	.009	Item 4	.352	.050	Item 4	.010	.021
Item 5	.011	.013	Item 5	.063	.026	Item 5	.004	.017
			Item 6	1.148	.074	Item 6	.308	.060
			Item 7	.003	.017	Item 7	.031	.027
			Item 8	.002	.022	Item 8	.006	.020
			Item 9	.018	.039	Item 9	.150	.037
			Item 10	.017	.035	Item 10	.162	.037

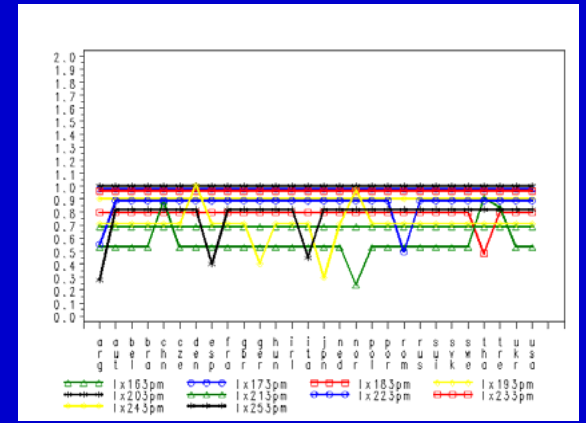
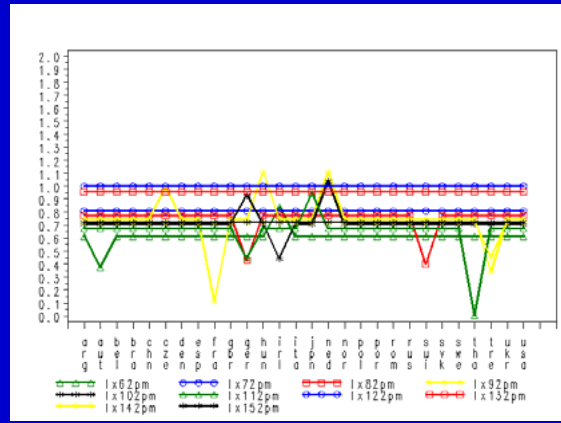
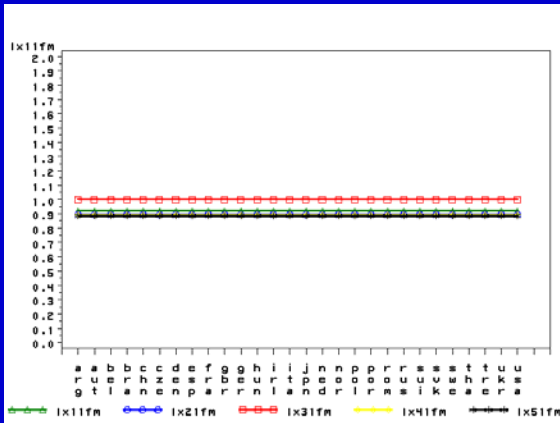
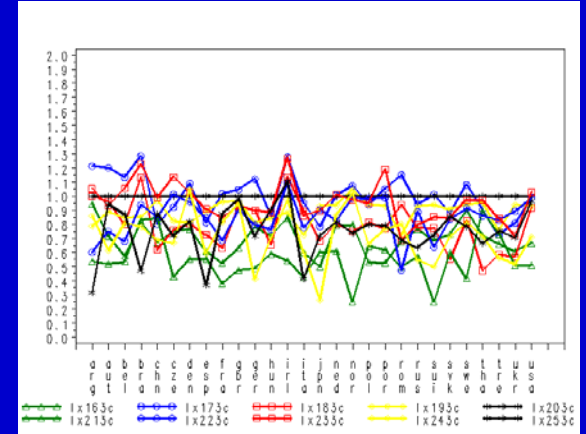
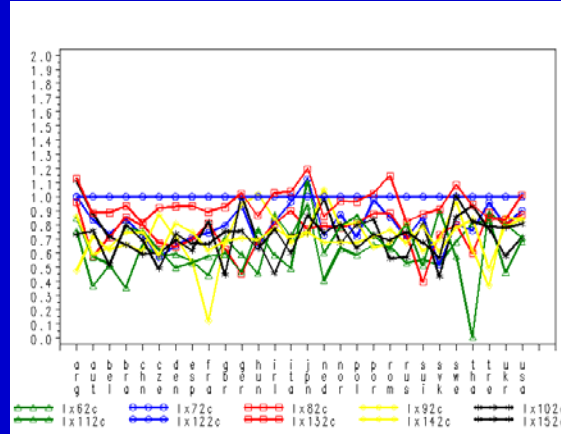
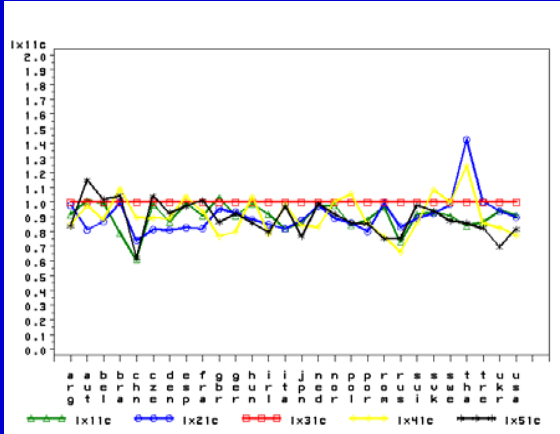
Individual-item reliabilities

Life satisfaction			Positive affect			Negative affect		
Item 1	.53	(.20-.71)	Item 1	.23	(.05-.46)	Item 1	.33	(.21-.44)
Item 2	.54	(.42-.69)	Item 2	.36	(.19-.53)	Item 2	.52	(.38-.65)
Item 3	.64	(.32-.79)	Item 3	.36	(.08-.54)	Item 3	.38	(.15-.50)
Item 4	.47	(.31-.68)	Item 4	.25	(.01-.56)	Item 4	.46	(.23-.60)
Item 5	.38	(.16-.50)	Item 5	.35	(.17-.56)	Item 5	.53	(.30-.66)
			Item 6	.25	(.00-.49)	Item 6	.18	(.03-.18)
			Item 7	.51	(.35-.67)	Item 7	.39	(.11-.60)
			Item 8	.44	(.28-.59)	Item 8	.35	(.13-.52)
			Item 9	.27	(.15-.34)	Item 9	.29	(.08-.49)
			Item 10	.31	(.20-.45)	Item 10	.27	(.04-.45)

Model comparison tests

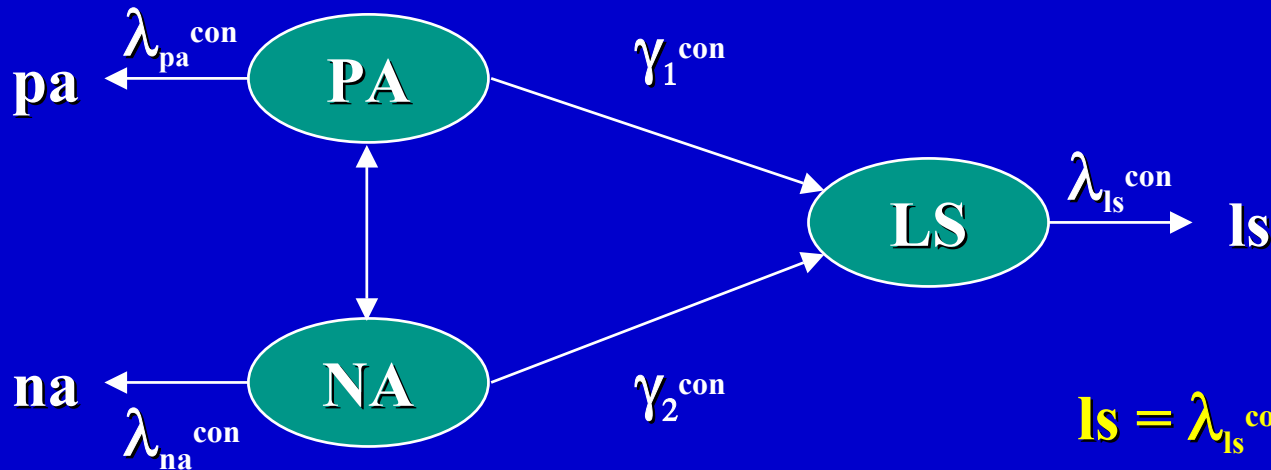
	χ^2	df	RMSEA	CFI	TLI
Configural invariance	24,888	7,616	.073 (.060-.092)	.950	.945
Full metric invariance	27,462	8,210	.074	.944	.943
Partial metric invariance	26,590	8,180	.072	.946	.945
Initial scalar invariance	38,987	8,744	.094	.912	.915
Final scalar invariance	28,242	8,556	.073	.943	.944

Factor loadings

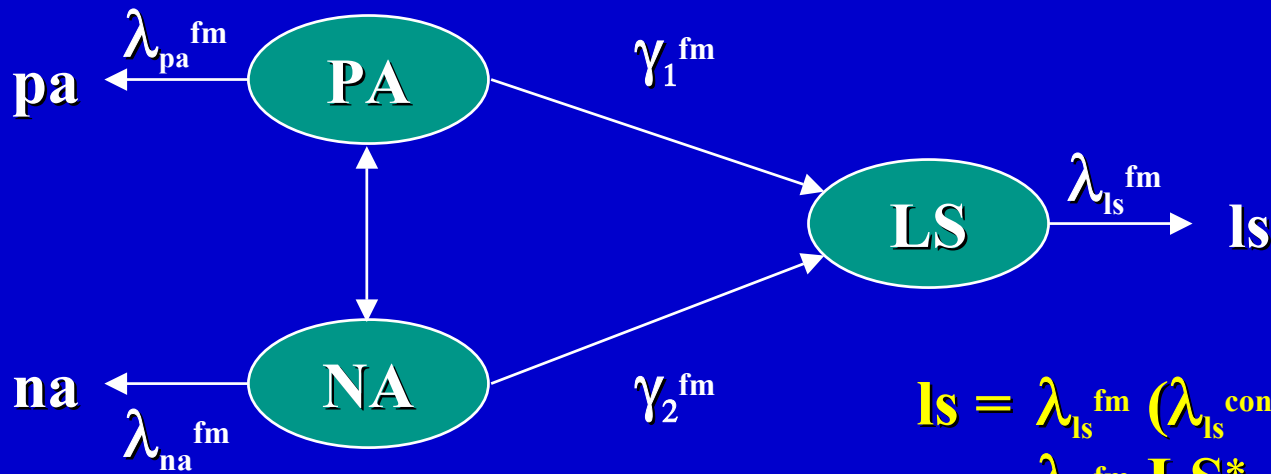


Metric invariance: Life satisfaction

	1	2	3	4	5		1	2	3	4	5
ARG						JPN					
AUT						NED					
BEL						NOR					
BRA						POL					
CHN						POR					
CZE						ROM					
DEN						RUS					
ESP						SUI					
FRA						SVK					
GBR						SWE					
GER						THA					
HUN						TRE					
IRL						UKR					
ITA						USA					



$$ls = \lambda_{ls}^{con} LS + \varepsilon$$



$$ls = \lambda_{ls}^{fm} (\lambda_{ls}^{con} / \lambda_{ls}^{fm}) LS + \varepsilon$$

$$= \lambda_{ls}^{fm} LS^* + \varepsilon$$

Comparison of the path coefficients in the configural and full metric invariance solutions

$$\gamma_1^{\text{fm}} = (\lambda_{\text{ls}}^{\text{con}} / \lambda_{\text{ls}}^{\text{fm}}) / (\lambda_{\text{pa}}^{\text{con}} / \lambda_{\text{pa}}^{\text{fm}}) (\gamma_1^{\text{con}})$$

$$\begin{array}{ccc} & \lambda_{\text{pa}}^{\text{con}} / \lambda_{\text{pa}}^{\text{fm}} & \\ & < 1 & > 1 \end{array}$$

		< 1	> 1
< 1	$\lambda_{\text{ls}}^{\text{con}} / \lambda_{\text{ls}}^{\text{fm}}$?	$ \gamma_1^{\text{fm}} < \gamma_1^{\text{con}} $
> 1	$\lambda_{\text{ls}}^{\text{con}} / \lambda_{\text{ls}}^{\text{fm}}$	$ \gamma_1^{\text{fm}} > \gamma_1^{\text{con}} $?

Some illustrative examples

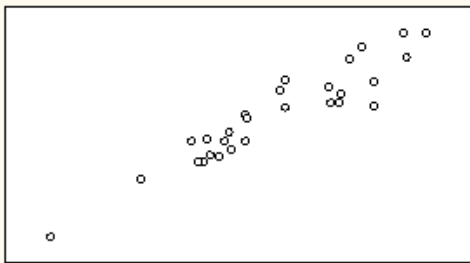
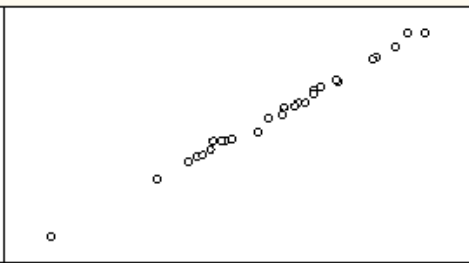
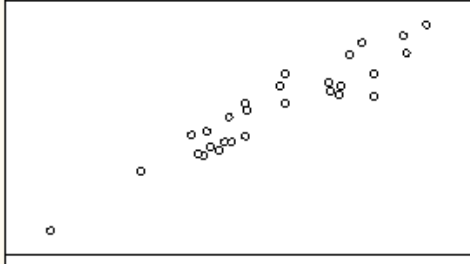
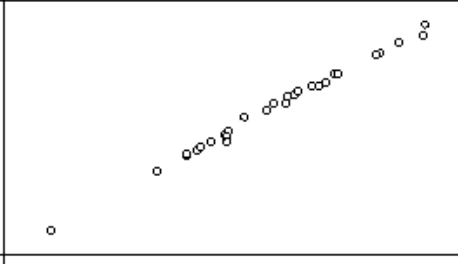


	SWE	SVK	JPN	GBR
$\lambda_{ls}^{con} / \lambda_{ls}^{fm}$	1.04	1.06	.94	1.00
$\lambda_{pa}^{con} / \lambda_{pa}^{fm}$	1.09	.85	1.17	.91
γ_1^{con}	.88	.62	.81	.76
γ_1^{fm}	.82	.73	.63	.81

Evaluating the difference between the path coefficients in the configural and full metric invariance solutions

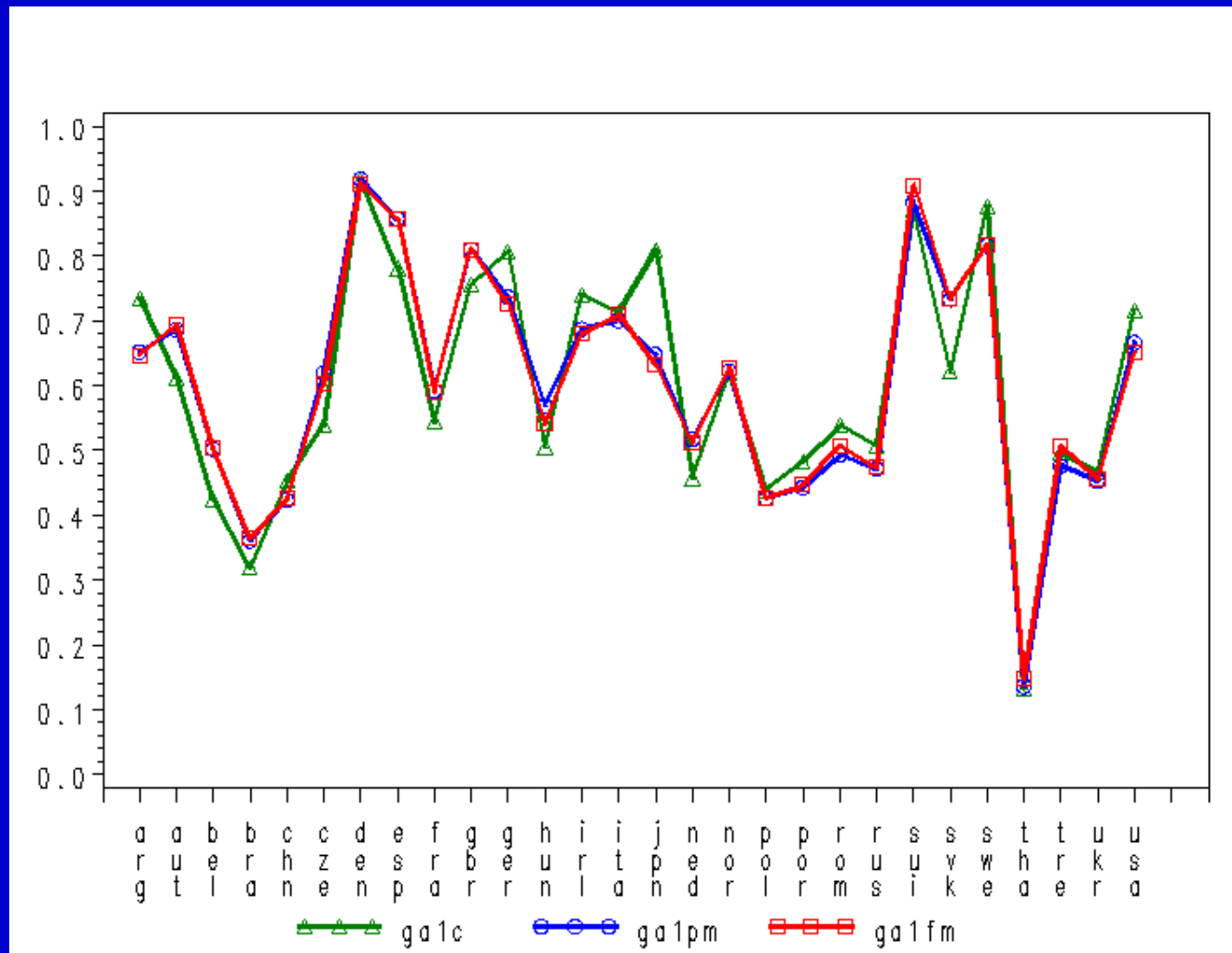


- best estimate of the structural coefficient in each group;
- however, since the scale metrics may differ, it's dangerous to compare the effects across groups;
- the scale metrics are specified to be the same and thus the effects are in principle comparable;
- however, the invariance constraints on the scale metrics may not be justified and the estimated effects may be distorted;

Comparison of paths from PA to LS in configural, full metric and partial metric invariance solutions

		0.912 galfm 0.148
	0.919 galpm 0.136	
0.917 galcon 0.133		

Comparison of paths from PA to LS in configural, full metric and partial metric invariance solutions



Assessing scalar invariance across many different countries

- compare the final metric invariance model with the full (or initial) scalar invariance model;
- use Bonferroni-adjusted modification indices (or other fit indices) and expected parameter changes to free item intercepts that are not invariant;

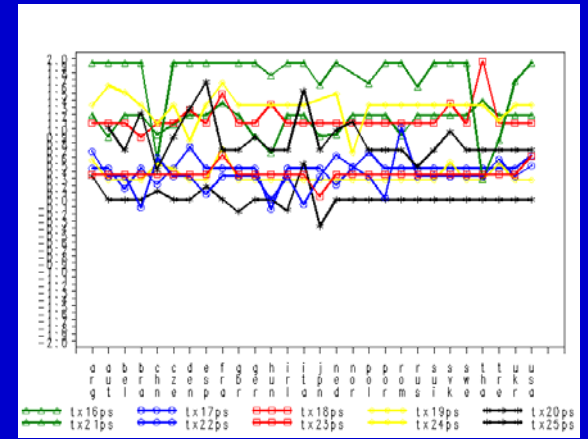
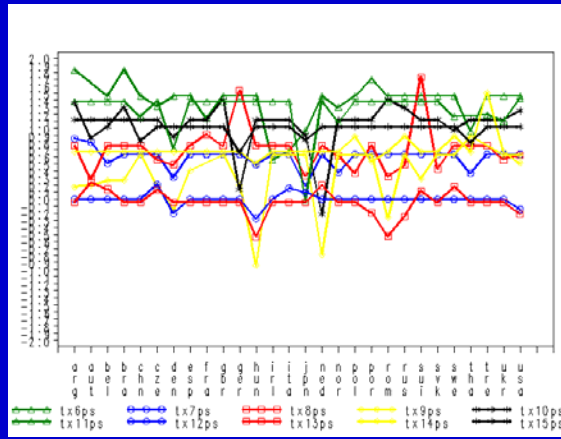
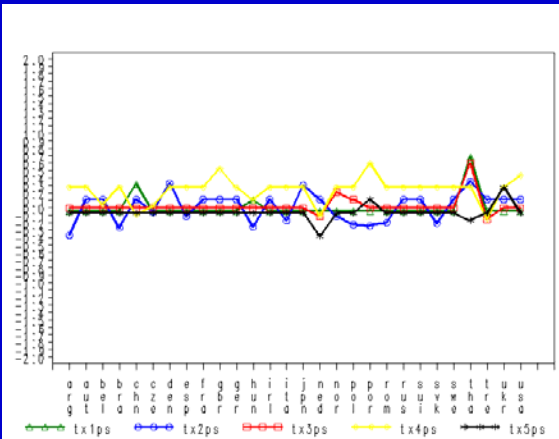
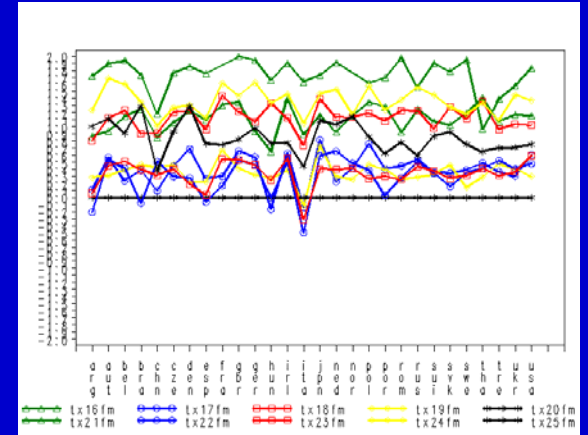
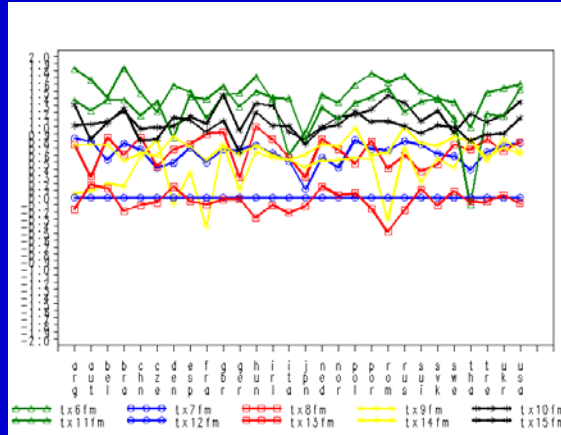
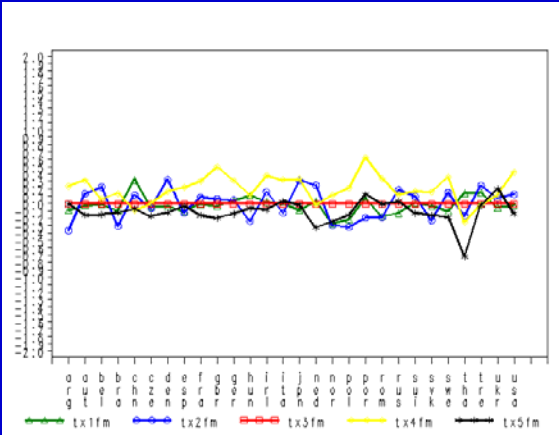
Model comparison tests

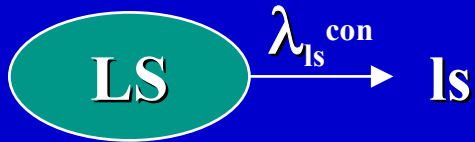
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Scalar invariance: Life satisfaction

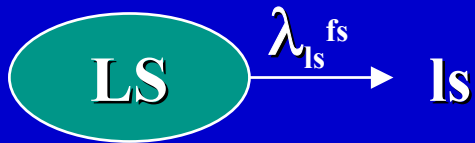
	1	2	3	4	5		1	2	3	4	5
ARG	Green	Red	Green	Green	Green	JPN	Green	Red	Green	Green	Green
AUT	Green	Green	Green	Green	Green	NED	Green	Green	Red	Red	Red
BEL	Green	Green	Green	Red	Green	NOR	Green	Red	Red	Green	Green
BRA	Green	Red	Green	Green	Green	POL	Green	Red	Red	Green	Green
CHN	Red	Green	Green	Red	Green	POR	Green	Red	Green	Red	Red
CZE	Green	Red	Green	Red	Green	ROM	Green	Red	Green	Green	Green
DEN	Green	Red	Green	Green	Green	RUS	Green	Green	Green	Green	Green
ESP	Green	Red	Green	Green	Green	SUI	Green	Green	Green	Green	Green
FRA	Green	Green	Green	Green	Green	SVK	Green	Red	Green	Green	Green
GBR	Green	Green	Green	Red	Green	SWE	Green	Green	Green	Green	Green
GER	Green	Green	Green	Green	Green	THA	Red	Red	Red	Green	Red
HUN	Red	Red	Green	Red	Green	TRE	Green	Green	Red	Red	Green
IRL	Green	Green	Green	Green	Green	UKR	Green	Green	Green	Green	Red
ITA	Green	Red	Green	Green	Green	USA	Green	Green	Green	Red	Green

Item intercepts





$$ls = \tau_{ls}^{con} + \lambda_{ls}^{con} LS + \varepsilon$$



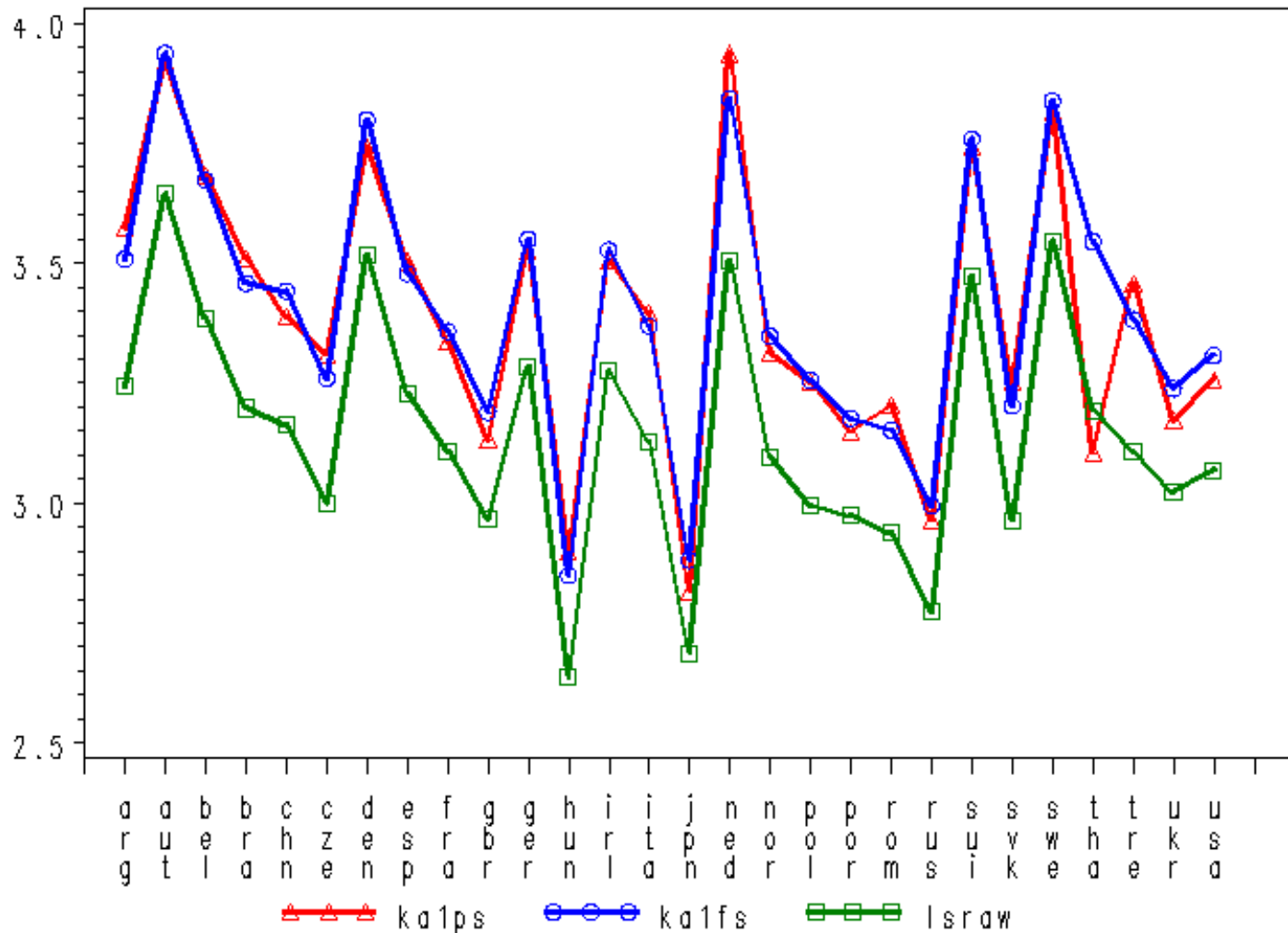
$$\begin{aligned} ls &= \tau_{ls}^{fs} + \lambda_{ls}^{fs} \left[(\tau_{ls}^{con} - \tau_{ls}^{fs}) / \lambda_{ls}^{fs} + (\lambda_{ls}^{con} / \lambda_{ls}^{fs}) LS \right] + \varepsilon \\ &= \tau_{ls}^{fs} + \lambda_{ls}^{fs} LS^* + \varepsilon \end{aligned}$$

Comparison of means in the configural and full scalar invariance solutions

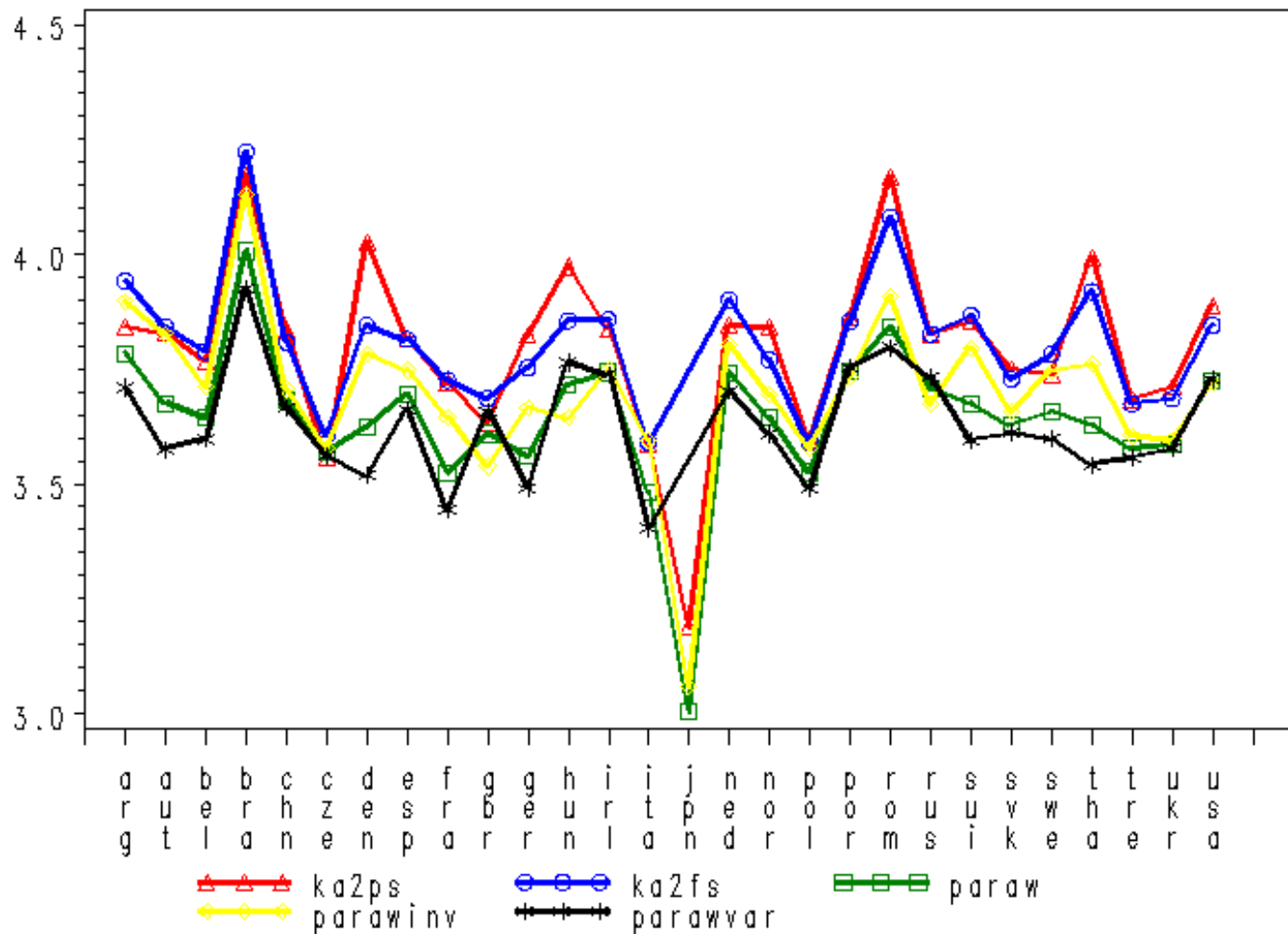
$$\mathbf{K}_{ls}^{fs} = \left(\tau_{ls}^{con} - \tau_{ls}^{fs} \right) / \lambda_{ls}^{fs} + \left(\lambda_{ls}^{con} / \lambda_{ls}^{fs} \right) (\mathbf{K}_{ls}^{con})$$

	$\lambda_{ls}^{con} / \lambda_{ls}^{fs}$	< 1	> 1
< 0	$\left(\tau_{ls}^{con} - \tau_{ls}^{fs} \right) / \lambda_{ls}^{fs}$	$ \mathbf{K}_{ls}^{fs} < \mathbf{K}_{ls}^{con} $?
> 0		?	$ \mathbf{K}_{ls}^{fs} > \mathbf{K}_{ls}^{con} $

Mean life satisfaction



Mean positive affect



Mean negative affect

