Random Item Effects Modeling (Part 2)

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Random Item Effects Modeling

International Comparisons of Student Achievement

Survey of Health, Ageing and Retirement in Europe

SHARE: Measurement Invariance

SHARE: Random Item Effects Approach

European Social Survey (ESS)

Invariance in Cross-National Consumer Research

International Comparisons of Student Achievement

- PISA 2003: Balanced incomplete test design, clusters, booklets, domains,...

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- Eight mathematic items (major domain) from booklet one

International Comparisons of Student Achievement

- PISA 2003: Balanced incomplete test design, clusters, booklets, domains,...
- Eight mathematic items (major domain) from booklet one
- 9796 respondents from 40 participating countries (excluding Liechtenstein with 28 students)

General Model $\mathcal{M}_4$: Level 1 and 2

$$
\begin{aligned}
P\left(Y_{ijk} \mid \theta_{ij}, \tilde{\boldsymbol{\xi}}_k\right) &= \Phi\left(\tilde{a}_{kj}\theta_{ij} - \tilde{b}_{kj}\right) \\
\left(\tilde{a}_{kj}, \tilde{b}_{kj}\right)^t &= (a_k, b_k)^t + \left(\epsilon_{a_{kj}}, \epsilon_{b_{kj}}\right)^t \\
\theta_{ij} &= \beta_{0j} + e_{ij}
\end{aligned}
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\end{aligned}
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Level 3

$$
\begin{aligned}
e_{ij} &\sim \mathcal{N}\left(0, \sigma^2_{\theta_j}\right) \\
\beta_{0j} &\sim \mathcal{N}\left(\gamma_{00}, \tau^2\right) \\
\left(\epsilon_{a_{kj}}, \epsilon_{b_{kj}}\right)^t &\sim \mathcal{N}\left(\mathbf{0}, \boldsymbol{\Sigma}_{\tilde{\xi}}\right)
\end{aligned}
$$

Model $\mathcal{M}_0$

MLIRT with nesting of students in countries and invariant items

International Comparisons of Student Achievement

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Model $\mathcal{M}_1$

Ignore nesting of students in countries and random items

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Model $\mathcal{M}_2$

MLIRT with nesting of students in countries and random items

PISA 2003: Exploring Cross-National Item Variation

Invariance			Non-Invariance						
	Model $\mathcal{M}_0$		Model $\mathcal{M}_1$			Model $\mathcal{M}_2$			
Item	Mean	SD	Mean	SD	σ_{a_k}	Mean	SD	σ_{a_k}	$p_0(a_k)$
Discrimination parameter									
1	.80	.02	.72	.03	.07	.81	.03	.08	.86
2	1.06	.03	1.07	.06	.28	1.09	.05	.23	.99
3	.72	.02	.61	.02	.06	.71	.02	.06	.56
4	.68	.02	.61	.02	.08	.69	.03	.11	.97
5	.55	.02	.53	.02	.09	.58	.02	.11	.99
6	.36	.02	.34	.03	.10	.40	.04	.16	.99
7	.69	.02	.60	.03	.07	.69	.03	.09	.92
8	.66	.02	.63	.03	.09	.68	.03	.11	.97

PISA 2003: Exploring Cross-National Item Variation

	Invariance		Non-Invariance						
	Model $\mathcal{M}_0$		Model $\mathcal{M}_1$			Model $\mathcal{M}_2$			
Item	Mean	SD	Mean	SD	σ_{b_k}	Mean	SD	σ_{b_k}	$p_0(b_k)$
Difficulty parameter									
1	-.58	.01	-.58	.06	.38	-.59	.03	.13	.99
2	.18	.01	.17	.07	.45	.19	.03	.11	.96
3	-.04	.01	-.04	.06	.37	-.03	.03	.10	.99
4	-.35	.01	-.37	.05	.34	-.35	.02	.10	.97
5	-.01	.01	-.02	.04	.24	-.02	.02	.08	.72
6	-1.51	.02	-1.54	.04	.24	-1.59	.02	.10	.90
7	-.78	.01	-.78	.05	.34	-.78	.02	.09	.95
8	-.94	.01	-.96	.04	.26	-.95	.02	.08	.76

PISA 2003: Exploring Cross-National Item Variation

	Invariance		Non-Invariance			
	Model $\mathcal{M}_0$		Model $\mathcal{M}_1$		Model $\mathcal{M}_2$	
Structural Part						
Fixed						
γ_{00}	.010	.083	.000	-	.734	.083
Random						
σ^2_θ	.791	.013	1.000	-	.791	.014
τ^2_{00}	.269	.063			.270	.063
Information Criteria						
-2log L	95727.5		102322.1		94681.0	
DIC (p_D)	100395.1(4667)				98960.2(4279)	

Model $\mathcal{M}_3$

MLIRT with nesting of students in countries, factor variance non-invariance, and invariant items

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Model $\mathcal{M}_4$

MLIRT with nesting of students in countries, factor variance non-invariance, and random items

PISA 2003: Exploring Cross-National Item Variation

	Invariance		Non-Invariance			
	Model $\mathcal{M}_3$		Model $\mathcal{M}_4$			
Item	Mean	SD	Mean	SD	σ_{a_k}	$p_0(a_k)$
Discrimination parameter						
1	.80	.02	.73	.04	.08	.43
2	1.06	.03	1.02	.12	.12	.82
3	.72	.02	.63	.03	.07	.17
4	.68	.02	.62	.03	.07	.29
5	.55	.02	.52	.03	.07	.39
6	.36	.02	.32	.06	.05	.09
7	.69	.02	.62	.03	.07	.21
8	.66	.02	.61	.04	.07	.25

PISA 2003: Exploring Cross-National Item Variation

	Invariance		Non-Invariance			
	Model $\mathcal{M}_3$		Model $\mathcal{M}_4$			
Item	Mean	SD	Mean	SD	σ_{b_k}	$p_0(b_k)$
Difficulty parameter						
1	-.58	.02	-.59	.03	.16	.99
2	.18	.02	.19	.09	.17	.99
3	-.04	.01	-.00	.04	.12	.99
4	-.35	.01	-.37	.03	.13	.99
5	-.01	.01	-.02	.03	.11	.98
6	-1.51	.02	-1.52	.09	.13	.99
7	-.78	.02	-.79	.03	.12	.99
8	-.94	.02	-.96	.04	.09	.93

PISA 2003: Exploring Cross-National Item Variation

	Invariance		Non-Invariance	
	Model $\mathcal{M}_3$		Model $\mathcal{M}_4$	
Structural Part				
Fixed				
γ_{00}	.010	.073	.496	.051
Random				
$\overline{\sigma}^2_\theta$	.797	.023	.370	.011
τ^2_{00}	.218	.056	.104	.025
Information Criteria				
-2log L	94331.2		87277.4	
DIC (p_D)	99984.3(5653.1)		91593.5(4316.1)	

SHARE: Survey of Health, Ageing and Retirement in Europe (2004)

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- 12 countries ranging from Scandinavia (Denmark and Sweden) through Central Europe (Austria, France, Germany, Switzerland, Belgium, and the Netherlands) to the Mediterranean (Spain, Italy and Greece). Further data were collected in 2005-2006 in Israel.
- SHARE contributes directly to inform public policies, both in substance and as a research tool

SHARE: Depression Inventory

- What are your hopes for the future? (any/no mentioned)
- In the last month, have you felt that you would rather be dead?
- Do you tend to blame yourself or feel guilty about anything?
- Have you had trouble sleeping recently?
- In the last month, what is your interest in things?
- Have you been irritable recently?
- What has your appetite been like?
- In the last month, have you had too little energy to do the things you wanted to do?
- How is your concentration? (television/radio)
- Can you concentrate on something you read?
- What have you enjoyed doing recently? (any/ no activity)
- In the last month, have you cried at all?

Observed Country Differences

	Austria	Sweden	Spain	France
Irritable recently	13 %	20 %	30 %	37%
Mentioned no hopes future	21 %	8 %	22 %	21%
Felt rather be dead	3 %	4 %	11 %	5%
Blame self or feel guilty	12 %	35 %	15 %	30%

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Differences in latent depression level and/item characteristics or both?

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Reasons for Non-Invariance

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- Familiarity with content/response format
- Response tendency

Types of measurement invariance

Steenkamp & Baumgartner, 1998

- Configural invariance
- Metric invariance (equal discrimination)
- Scalar invariance (equal difficulty/endorsement)
- Latent mean invariance
- Latent variance invariance

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When measurement invariance is not present or when the variance is not modeled, test scores cannot be compared across countries

Traditional Tests for Invariance

Widely Used

Likelihood ratio test (o.a. Thissen, Steinberg & Wainer, 1993):

- Baseline model: all parameters free
- Restrict parameters one by one and test for significant decrease in fit

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Problems

- Invariant anchor items needed to link the scales
- Invariant items hard to find with many groups and/or items
- Many analyses need to be done before the final set of invariant items is found

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National Item Parameters

$$\tilde{\boldsymbol{\xi}}_{kj} = \left(\tilde{a}_{kj}, \tilde{b}_{kj}\right)^t \quad \sim \quad \mathcal{N}\left((a_k, b_k)^t, \boldsymbol{\Sigma}_{\tilde{\xi}}\right)$$

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International Item Parameters:

$$(a_k, b_k)^t \sim \mathcal{N}\left(\boldsymbol{\mu}_{\xi}, \boldsymbol{\Sigma}_{\xi}\right)$$

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International Item Parameters:

$$(a_k, b_k)^t \sim \mathcal{N}\left(\boldsymbol{\mu}_\xi, \boldsymbol{\Sigma}_\xi\right)$$

Hyper priors:

$$\begin{aligned} \boldsymbol{\Sigma}_\xi &\sim \mathcal{IW}(\nu, \boldsymbol{\Sigma}_0) \\ \boldsymbol{\mu}_\xi \mid \boldsymbol{\Sigma}_\xi &\sim \mathcal{N}(\boldsymbol{\mu}_0, \boldsymbol{\Sigma}_\xi / K_0) \end{aligned}$$

SHARE example

Assume all subjects are independently sampled: $\theta \sim N(0, 1)$

Austria Sweden Spain France

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	Austria	Sweden	Spain	France
Irritable	13 %	20 %	30 %	37%
b_{kj}	1.312	1.012	0.768	0.482

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No hopes	21 %	8 %	22 %	21%
b_{kj}	0.808	1.622	0.918	0.951

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Suicidal	3 %	4 %	11 %	5%
b_{kj}	2.422	2.265	1.848	1.863

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Suicidal	3 %	4 %	11 %	5%
b_{kj}	2.422	2.265	1.848	1.863
Blame self	12 %	35 %	15 %	30%
b_{kj}	1.173	0.430	0.985	0.600

Testing Measurement Invariance

Hypotheses:

- For scalar and metric invariance:
  Ho: $\sigma^2_{a_k} = 0$ and $\sigma^2_{b_k} = 0$
- For latent mean and variance invariance:
  Ho: $\tau^2 = 0$ and $\sigma^2_{\theta_1} = \sigma^2_{\theta_2} = ... = \sigma^2_{\theta_J}$

Posterior Probability

- Compute probability of H0 under the estimated posterior density
- $\sigma^2 = 0$ has no probability under posterior density
- Define "about equality constraint" δ close to zero that represents "no relevant effect"

$$P(\sigma^2 < \delta | Y, M1)$$

Bayes factor

- Compares marginal likelihoods

$$\frac{P(Y|M0)}{P(Y|M1)} = \frac{\int P(Y|\boldsymbol{\theta}, M0)P(\boldsymbol{\theta}|M0)d\boldsymbol{\theta}}{\int P(Y|\boldsymbol{\theta}, M1)P(\boldsymbol{\theta}|M1)d\boldsymbol{\theta}}$$

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- Often hard to compute due to complex integrals
- Sensitive to specified prior

Bayes Factor and Posterior Probability Tests

		Bayes Factor		Prob.	
Discrimination	$\sigma^2_{a_k}$	$\delta < .01$	$\delta < .02$	$\delta < .01$	$\delta < .02$
irritability	0.026	4.97	4.92	0.033	0.404
fatigue	**0.040**	0.41	1.47	0.003	0.121
tearfulness	0.018	20.30	8.21	0.137	0.674
hopes	0.020	15.28	7.42	0.103	0.609
suicidal	**0.040**	2.07	2.35	0.014	0.193
sleeping problems	0.020	14.76	7.39	0.099	0.606
interest	**0.060**	0.24	0.72	0.002	0.059
appetite	0.029	5.46	4.42	0.037	0.362
concentration media	0.031	3.56	3.67	0.024	0.301
concentration	**0.038**	1.43	2.14	0.010	0.176
enjoyment	0.030	3.51	3.83	0.024	0.314
guilt	**0.042**	0.22	1.15	0.001	0.094

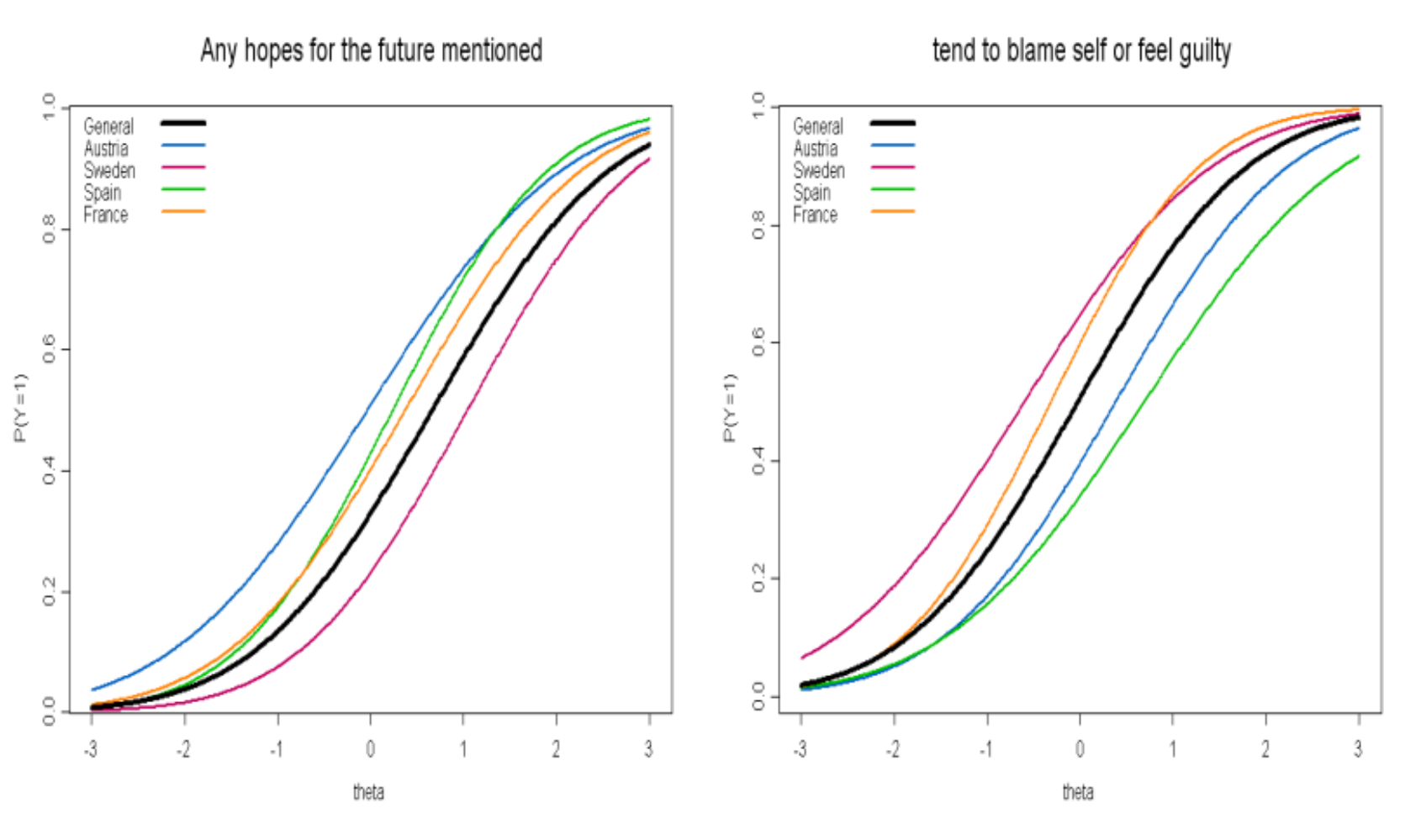
Bayes Factor and Posterior Probability Tests

		Bayes Factor	
Difficulty	$\sigma^2_{b_k}$	$\delta < .01$	$\delta < .02$
irritability	0.026	5.60	4.93
fatigue	0.022	12.66	6.71
tearfulness	0.022	9.06	6.18
hopes	**0.059**	0.04	0.29
suicidal	**0.050**	0.11	0.61
sleeping problems	0.031	2.27	3.3
interest	0.029	4.56	4.25
appetite	0.025	6.76	5.27
concentration media	**0.043**	0.20	1.07
concentration reading	**0.042**	0.34	1.36
enjoyment	**0.071**	0.00	0.06
guilt	**0.078**	0.00	0.02

Comparing Countries

	Austria	Sweden	Spain	France
means	-1.42	-1.27	-0.96	-1.00
Irritable	13 %	20 %	30 %	37%
b_{kj}	-0.019	-0.237	-0.219	-0.365
No hopes	21 %	8 %	22 %	21%
b_{kj}	0.138	0.613	0.264	0.209
Suicidal	3 %	4 %	11 %	5%
b_{kj}	0.678	0.550	0.509	0.284
Blame self	12 %	35 %	15 %	30%
b_{kj}	0.172	-0.261	0.454	-0.358

SHARE Depression Scale



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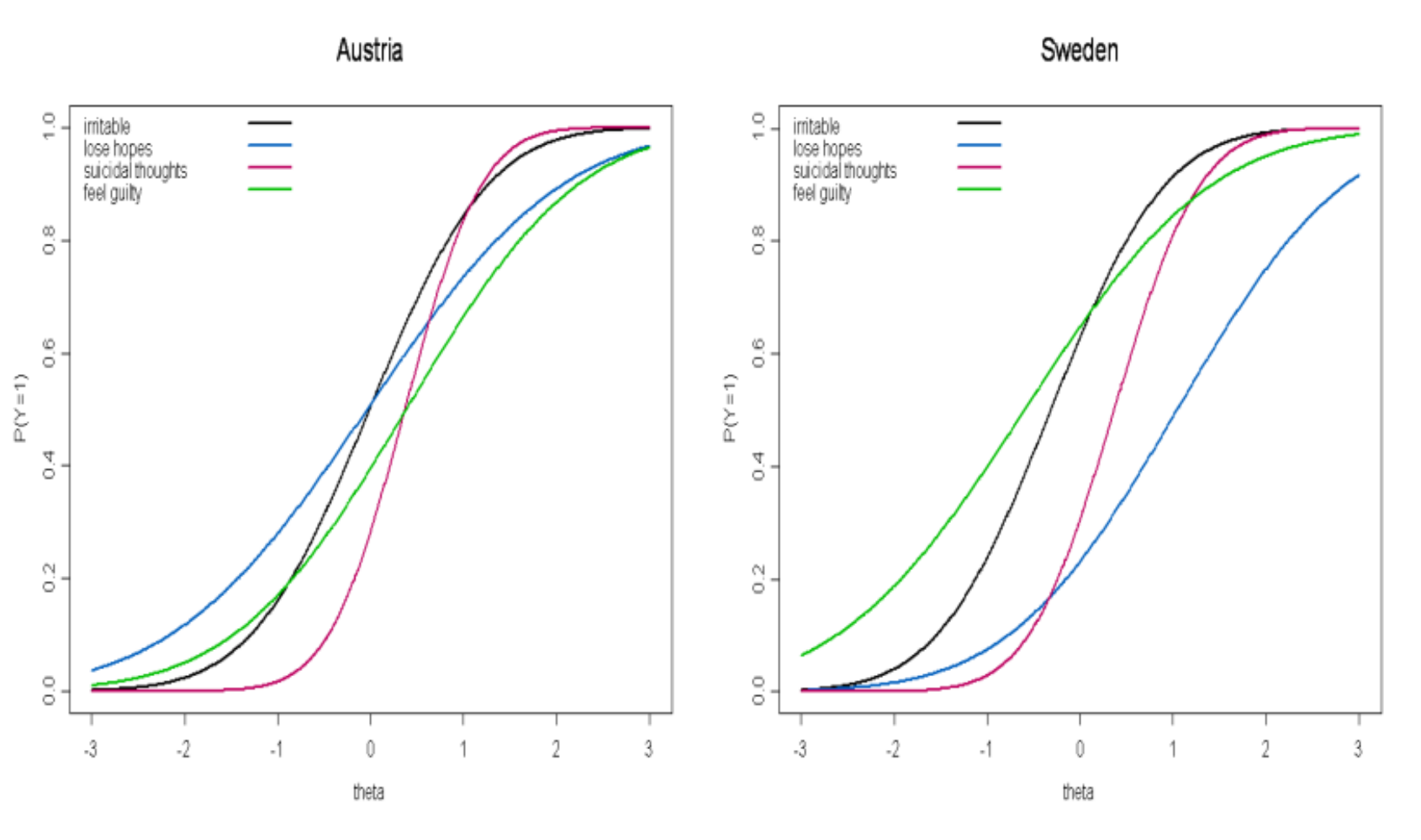
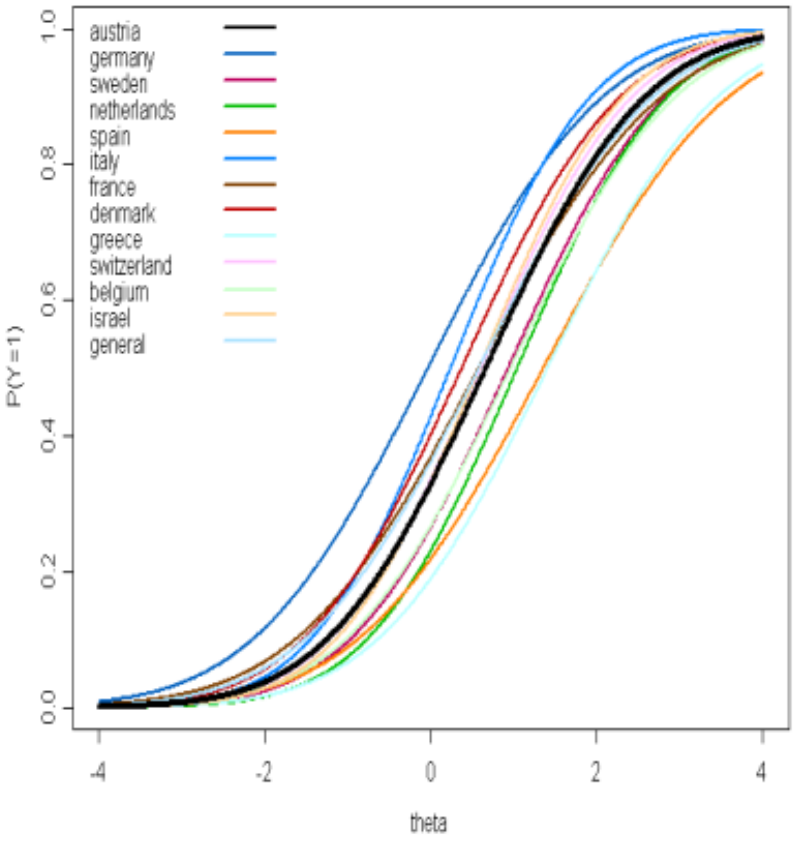
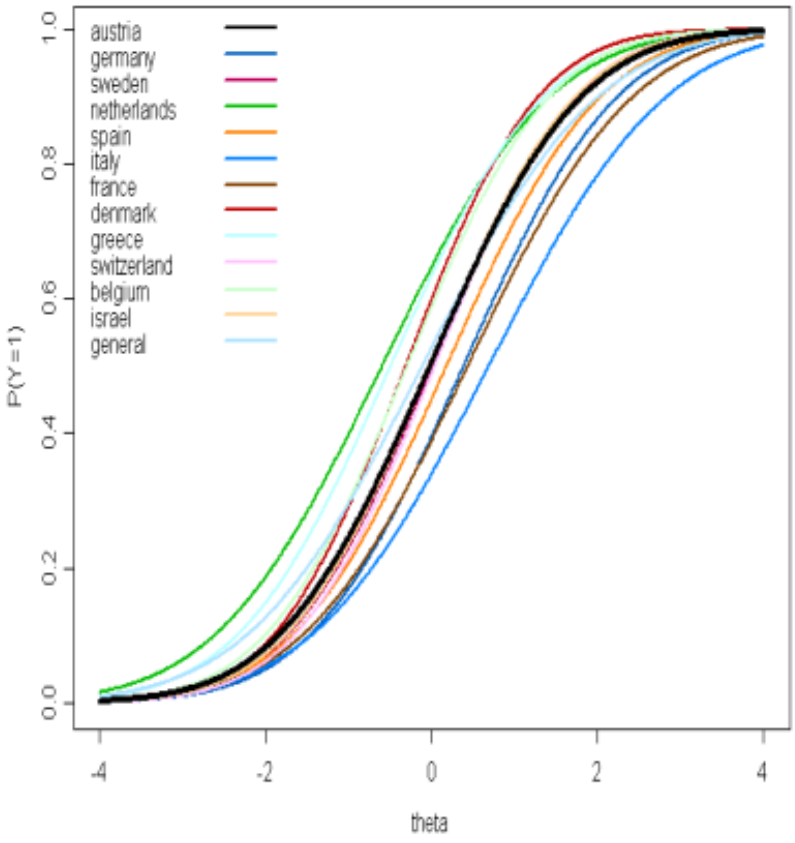


SHARE Depression Scale: Hopes and Guilt





ESS 2002: Attitude Toward Immigrant

- Eight dichotomized items: perceived consequences and allowance of immigration

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- Sample sizes per country varied from 850 to 2,646, where missing values were treated as missing at random.

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- Sample sizes per country varied from 850 to 2,646, where missing values were treated as missing at random.
- Item parameter variation: Meuleman, Davidov, & Billiet, 2009; Welkenhuysen-Gybbels, Billiet,& Cambr, 2003

ESS: Attitude towards immigrants items

1	Allow people of the same race or ethnic group
2	Allow people from the poorer countries outside Europe
3	Country is made a worse or a better place by people from other countries
4	Bad or good for country's economy that people come from other countries
5	Country's cultural life is generally undermined or enriched by people from other countries
6	People who come take jobs away from workers in country
7	People who come here take out more than they put in
8	Country's crime problems made worse or better by people from other countries

Model Extension: Explaining Item-Variance

Variance in country-specific item parameters can be explained by country characteristics $\mathbf{V}_{kj}$:

$$\begin{aligned}
\tilde{a}_{kj} \mid \mathbf{V}_{kj}, \boldsymbol{\delta}_{a_k}, \sigma^2_{a_k} &\sim \mathcal{N}\left(a_k + \mathbf{V}^t_{kj}\boldsymbol{\delta}_{a_k}, \sigma^2_{a_k}\right) \\
\tilde{b}_{kj} \mid \mathbf{V}_{kj}, \boldsymbol{\delta}_{b_k}, \sigma^2_{b_k} &\sim \mathcal{N}\left(b_k + \mathbf{V}^t_{kj}\boldsymbol{\delta}_{b_k}, \sigma^2_{b_k}\right),
\end{aligned}$$

ESS: Attitude Towards Immigrants

	Greece	Norway	Poland	Sweden
Not allow immigrants poor countries	87 %	39%	44%	15%
Make worse country	67%	39%	27%	17%
Take away jobs	78%	19%	52%	12%

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Latent means	1.01	-0.42	-0.36	-1.09
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ESS: Attitude Towards Immigrants

	Greece	Norway	Poland	Sweden
Latent means	1.01	-0.42	-0.36	-1.09
Allow from poor countries	87 %	39%	44%	15%
b_{kj}	-0.69	-0.03	-0.11	0.29
Make worse country	67%	39%	27%	17%
b_{kj}	0.52	-0.06	0.47	0.17
Take away jobs	78%	19%	52%	12%
b_{kj}	-0.18	0.76	-0.35	0.67

Item Parameters, Variances, Bayes Factors

	EAP		BF	EAP		BF
	a_k	$\sigma^2_{a_k}$		b_k	$\sigma^2_{b_k}$	
Allow poor countries	1.00	0.04	1.08	-0.31	0.18	0.00
Allow same ethnicity	0.89	0.03	4.01	0.22	0.13	0.00
Worse country	1.34	0.04	1.65	0.18	0.06	0.45
Bad for economy	1.38	0.04	1.31	0.27	0.14	0.00
Undermine culture	1.14	0.02	5.65	0.67	0.12	0.00
Take away jobs	0.84	0.02	6.53	0.13	0.18	0.00
Take out more	0.91	0.02	5.03	-0.22	0.12	0.00
Worse crime rate	0.76	0.02	8.60	-0.95	0.12	0.00

ESS: Item-Covariate Effects

	δ_{a_k}		
	% immig	% unemp	GDP
allow poor countries	-0.02	0.04	*0.15*
allow same ethnicity	0.07	0.01	0.07
worse country	-0.02	-0.01	0.03
bad for economy	*-0.11*	0.01	-0.04
undermine culture	0.02	-0.08	-0.01
take jobs away	0.01	-0.02	**-0.15**
take out more	0.06	0.01	-0.08
worse crime rate	-0.01	0.04	0.05

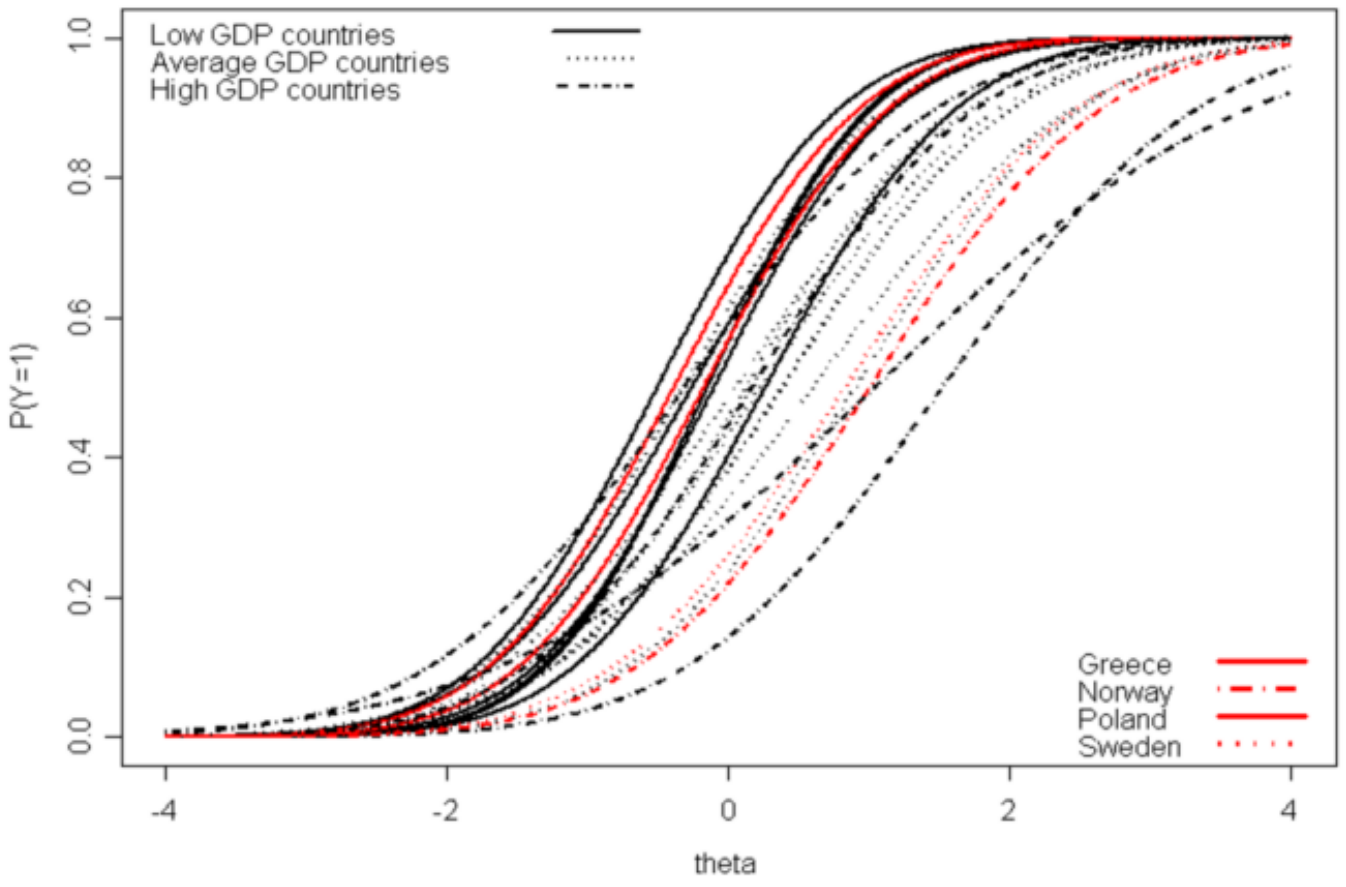
$P(\beta > 0) > .90$

ESS: Item-Covariate Effects

	δ_{b_k}		
	% immig	% unemp	GDP
allow poor countries	-0.03	0.04	0.03
allow same ethnicity	0.05	0.03	-0.02
worse country	0.00	0.05	0.01
bad for economy	0.10	-0.01	-0.02
undermine culture	0.00	0.03	0.00
take jobs away	**-0.18**	-0.06	**0.32**
take out more	0.01	-0.06	*-0.17*
worse crime rate	0.05	-0.03	-0.15

GDP = Gross Domestic product, $P(\beta > 0) >$**.95**

ESS Covariates



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- Survey developed in English (back-translated in the local languages)

Consumer Susceptibility to Normative Influence (SNI)

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- Protective self-presentation efforts (Wooten and Reed 2004)
- Purchase of new products (Steenkamp and Gielens 2003)
- Consumer boycotts (Sen, Gurhan-Canli, and Morwitz 2001).

SNI: Susceptibility to Normative Influence

1	If I want to be like someone, I often try to buy the same brands that they buy.
2	It is important that others like the products and brands I buy
3	I rarely purchase the latest fashion styles until I am sure my friends approve of them.
4	I often identify with other people by purchasing the same products and brands they purchase
5	When buying products, I generally purchase those brands that I think others will approve of
6	I like to know what brands and products make good impressions on others.
7	If other people can see me using a product, I often purchase the brand they expect me to buy
8	I achieve a sense of belonging by purchasing the same products and brands that others purchase

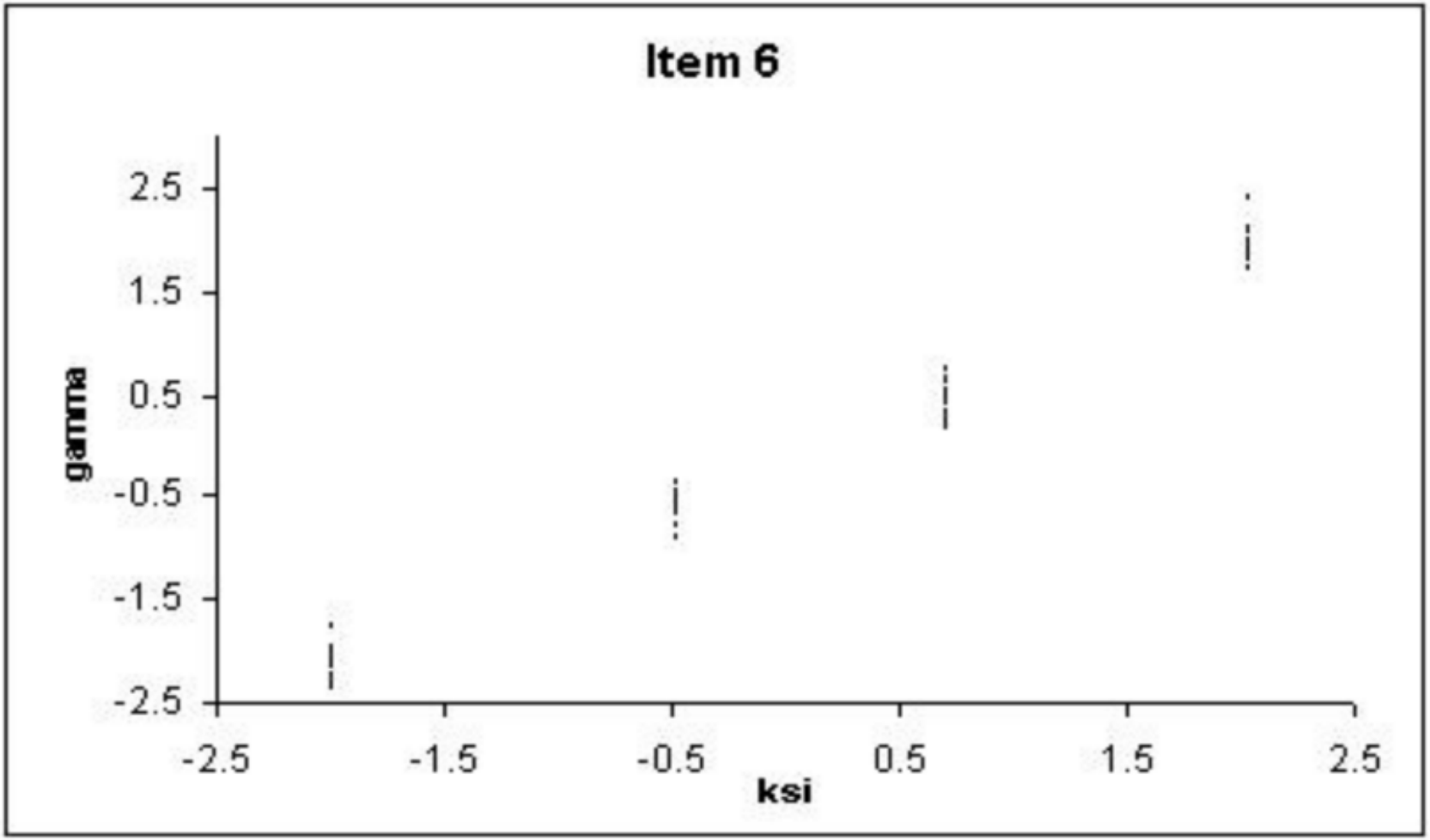
SNI: Discrimination Parameters

Item	1	2	3	4	5	6	7	8
France	0.86	0.65	0.58	1.26	1.27	1.17	1.56	1.09
Netherlands	0.79	0.82	0.58	1.23	1.32	1.08	1.15	1.29
Spain	0.88	0.71	0.89	0.94	1.31	0.89	1.26	1.28
China	1.02	1.03	0.64	1.29	1.07	0.70	1.32	1.15
Poland	0.93	0.88	0.27	1.24	1.42	1.10	1.58	1.51
Brazil	0.88	0.73	0.84	0.76	1.47	1.17	1.33	1.06
Thailand	0.84	0.81	0.52	1.30	1.24	1.03	1.23	1.38
Russia	0.87	1.22	0.40	1.10	1.41	1.26	0.85	1.41
USA	0.76	0.82	0.61	1.13	1.31	1.04	1.28	1.30
Taiwan	0.89	0.91	0.58	1.30	1.30	0.59	1.56	1.37
Japan	1.04	0.78	0.72	1.30	1.25	0.68	1.25	1.24

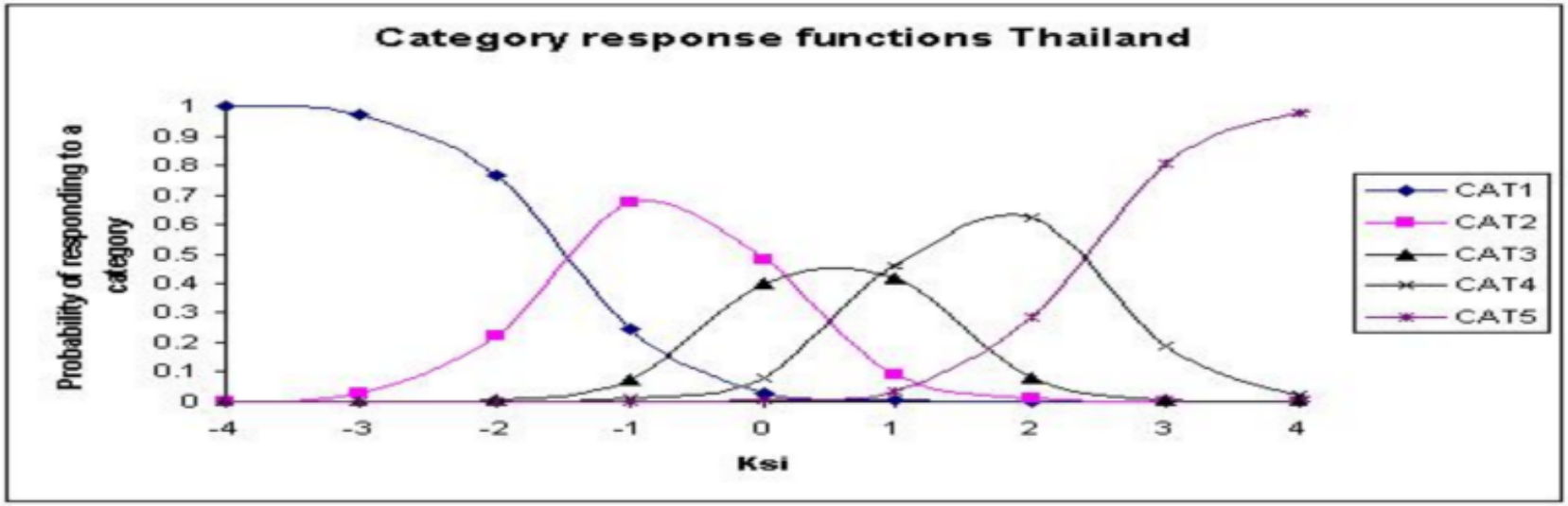
SNI: Variances Discriminations and Thresholds

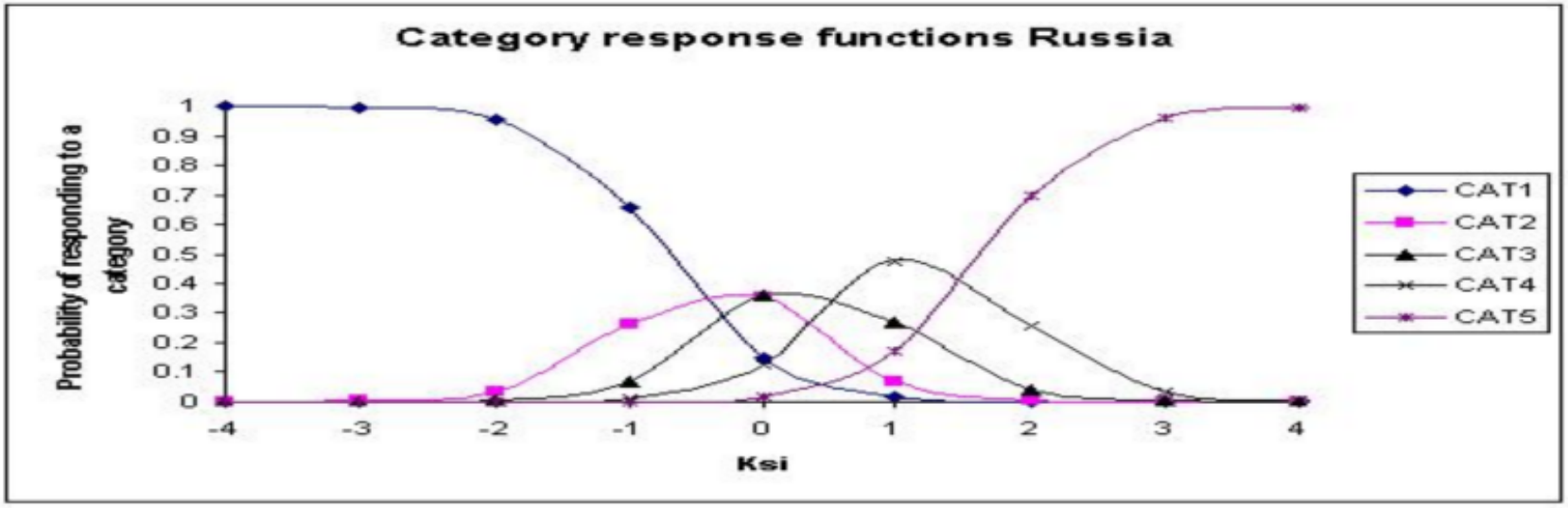
	Discr	CI	Thresh.	CI
Item 1	0.018	(0.010, 0.033)	0.031	(0.014, 0.049)
Item 2	0.030	(0.010, 0.065)	0.099	(0.051, 0.153)
Item 3	0.048	(0.013, 0.102)	0.111	(0.064, 0.167)
Item 4	0.048	(0.010, 0.106)	0.178	(0.100, 0.267)
Item 5	0.035	(0.010, 0.079)	0.089	(0.046, 0.137)
Item 6	0.074	(0.020, 0.157)	0.039	(0.018, 0.062)
Item 7	0.053	(0.011, 0.118)	0.087	(0.044, 0.134)
Item 8	0.036	(0.010, 0.082)	0.127	(0.067, 0.201)

SNI: Posterior Mean Threshold



SNI: RFS For Item 6





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