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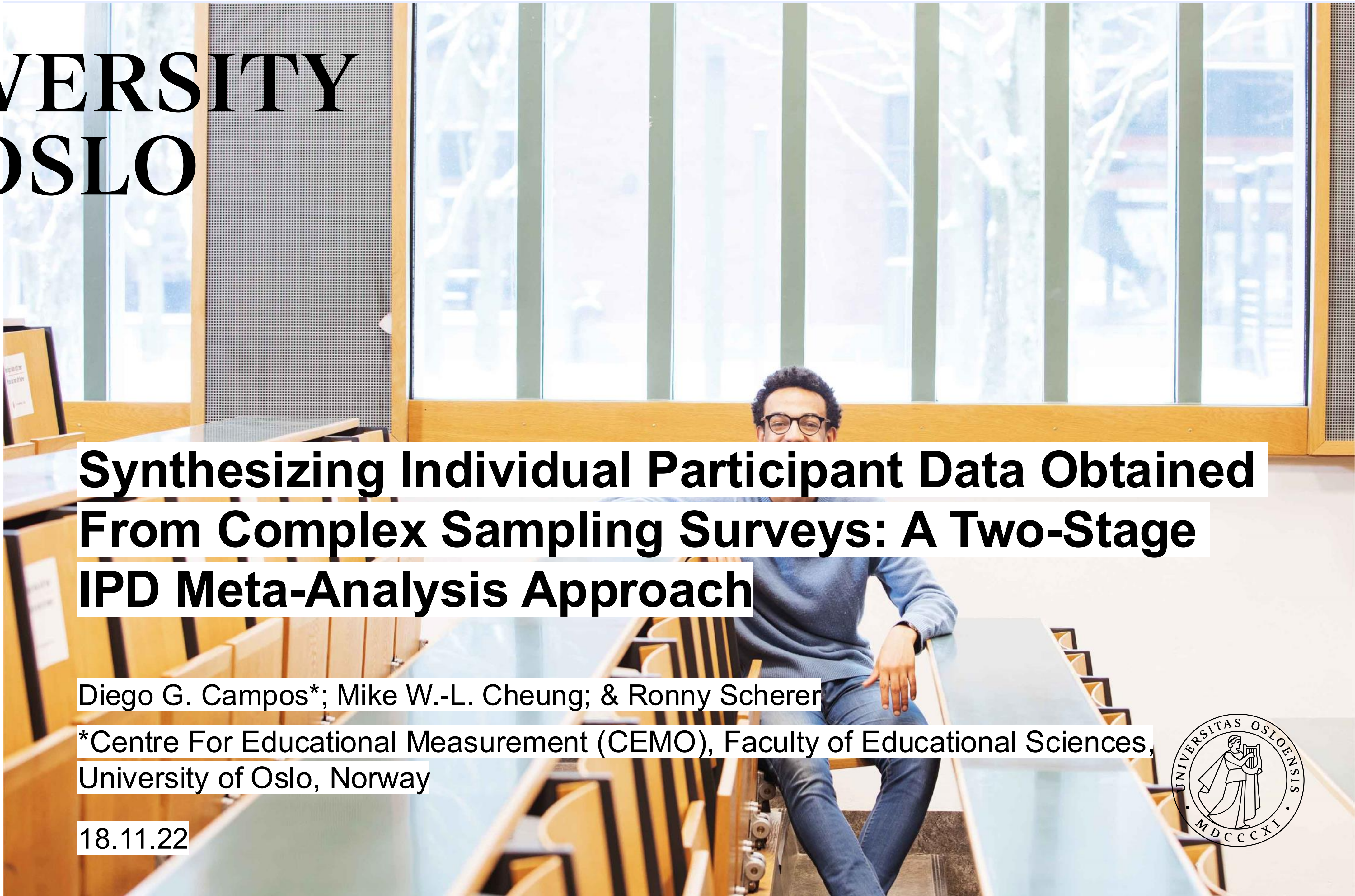

Synthesizing Individual Participant Data Obtained From Complex Sampling Surveys: A Two-Stage IPD Meta-Analysis Approach

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18.11.22

What Are Complex Surveys?
Examples

- Program for International Student Assessment (PISA)
- Trends in International Mathematics and Science Study (TIMSS)
- National Assessment of Educational Progress (NAEP)
- National Educational Panel Study (NEPS)

PISA

IEA TIMSS

NAEP
NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS

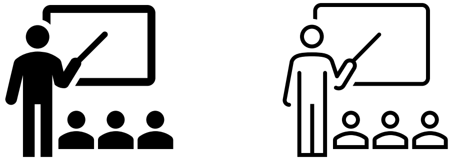
NEPS

What Are Complex Surveys?

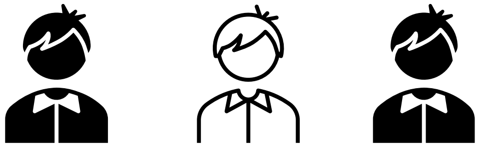
- Increasing the understanding of critical factors influencing teaching and learning
- Identifying key educational issues: educational inequalities
- Informing national strategies for monitor and improve the educational system

Scherer, Siddiq & Nilsen (2021)

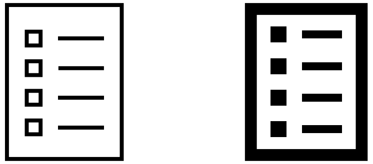
What Are Complex Surveys?



Multistage Sampling



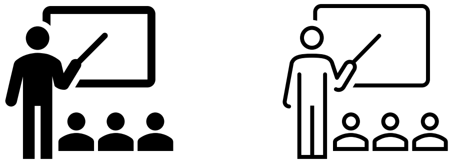
Survey Weights



Rotated Questionnaire Design

Rutkowski, Gonzalez, Joncas & von Davier (2010)

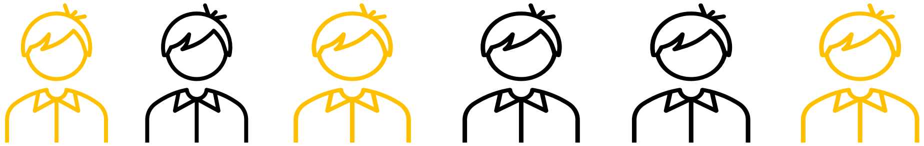
What Are Complex Surveys?



Multistage Sampling

1st stage

2nd stage



Stapleton & Thomas (2008)

What Are Complex Surveys?

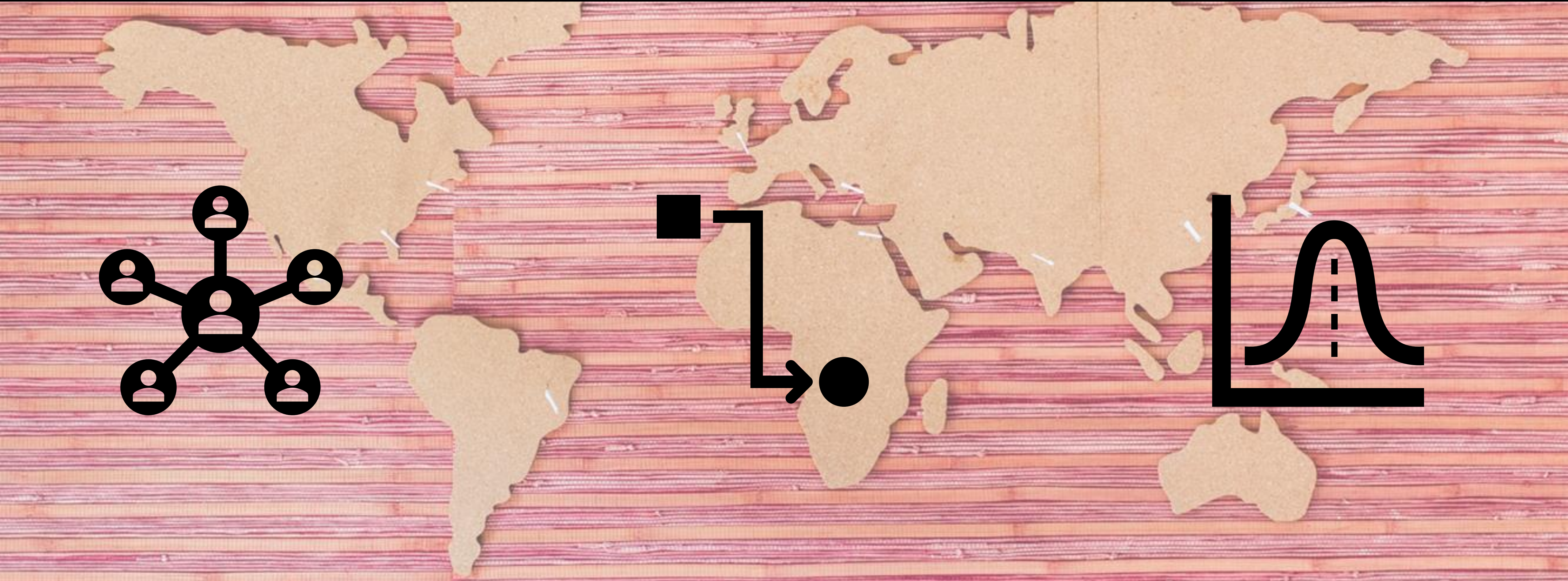
Survey Weights

Total weights refer to the weight components that reflect the inclusion probability of a school and a student of being selected.

$$W_{ij} = \frac{1}{p_{ij}}$$

What Are Complex Surveys?

Large and Representative Samples



Scherer, Siddiq & Nilsen (2021)
Campos, Cheung & Scherer (2022)

Photo by Louis Hansel on Unsplash

High Quality Measures

Scherer, Siddiq & Nilsen (2021)
Campos, Cheung & Scherer (2022)

Photo by Annie Spratt on Unsplash

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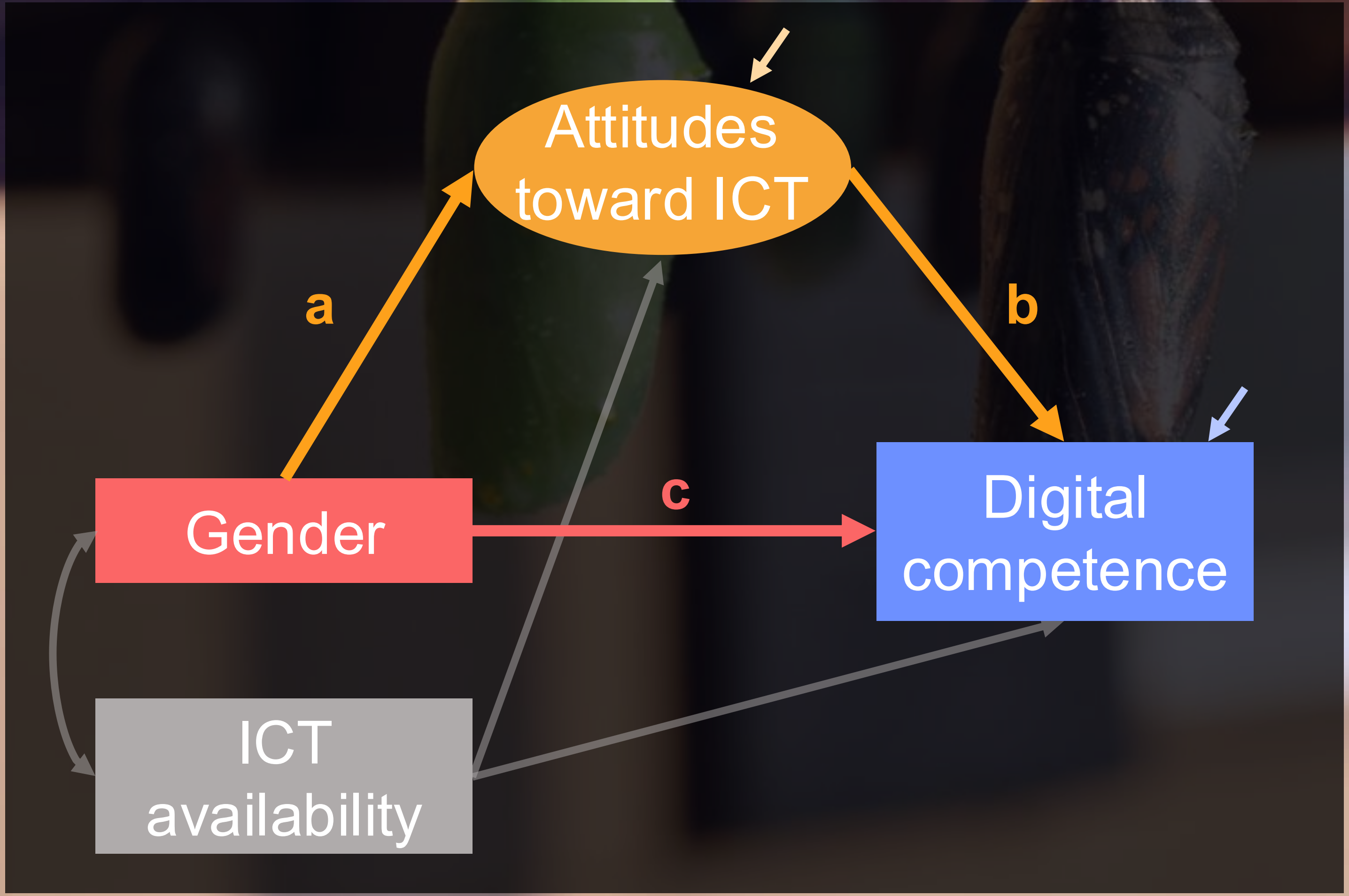
Raw Data



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Scherer, Siddiq & Nilsen (2021)
Campos, Cheung & Scherer (2022)

Photo by Suzanne D. Williams on Unsplash

Challenges of Meta-Analysis in Educational Research

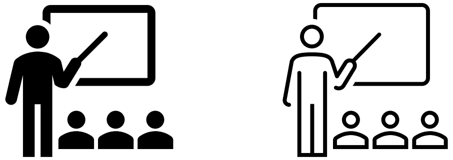
Small samples in primary studies

Study characteristics that may affect the quality and magnitude of effects

Insufficient psychometric quality of outcome measures

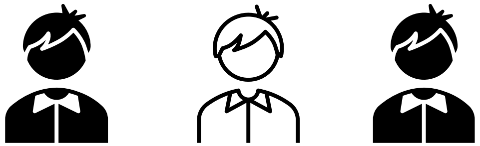
Scherer, Siddiq & Nilsen (2021)
Campos, Cheung & Scherer (2022)

Challenges in the Synthesis of Complex Survey Data



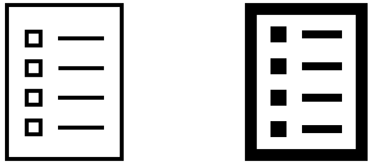
Multistage Sampling

Stapleton et al., (2016)



Survey Weights

Rutkowski, Gonzalez, Joncas & von Davier (2010)

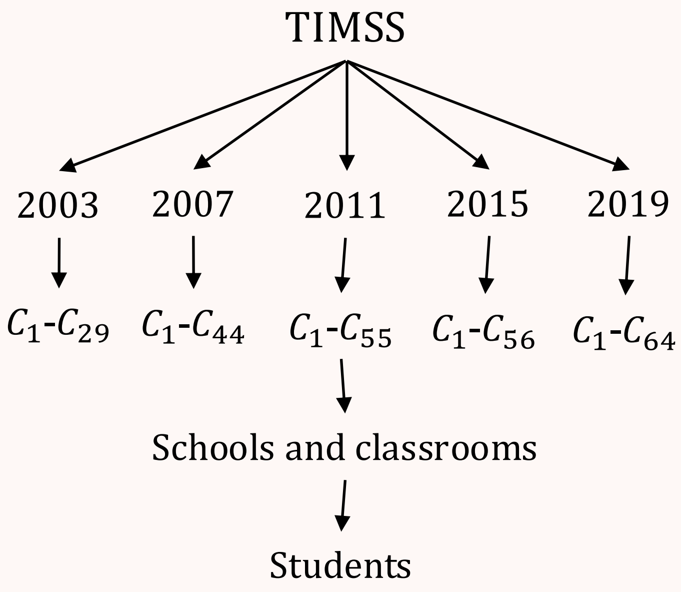


Rotated Questionnaire Designs

von Davier et al., (2009)

Two-Stage Individual Participant Data Meta-Analysis

Stage 1: Raw Data Analysis



- Hierarchical structure
- Sampling weights
- Plausible values
- Measurement Invariance

i: Students, *j*: Classrooms, *k*: Countries

Stage 2: Meta-Analysis

- Multivariate meta-analysis
- Multilevel meta-analysis
- Mixed-effects meta-regression

Two-Stage Individual Participant Data Meta-Analysis

Advantages

Level 1 (individual participants): $Y_{ijk} = \beta_{0jk} + \beta_{1jk}X_{ijk} + e_{ijk}$

Level 2 (clusters): $\beta_{0jk} = \beta_{00k} + \beta_{01k}Z_{jk} + u_{0jk}$

$\beta_{1jk} = \beta_{10k} + u_{1jk}$

Level 3 (primary studies): $\beta_{00k} = \gamma_{000} + v_{00k}$

$\beta_{01k} = \gamma_{010} + v_{01k}$

$\beta_{10k} = \gamma_{100} + v_{10k}$

$\beta_{01k} = \theta_k + r_k$ with $r_k \sim N(0, \sigma^2_{r_k})$.

$\theta_k = \mu + u_k$ with $u_k \sim N(0, \sigma^2_u)$.

Complex Survey Designs

Measurement Heterogeneity

Multilevel Structures

Campos, Cheung & Scherer (2022)
Brunner, et al. (2022)

Analytic Examples
Two-Stage IPD Meta-Analysis Approach

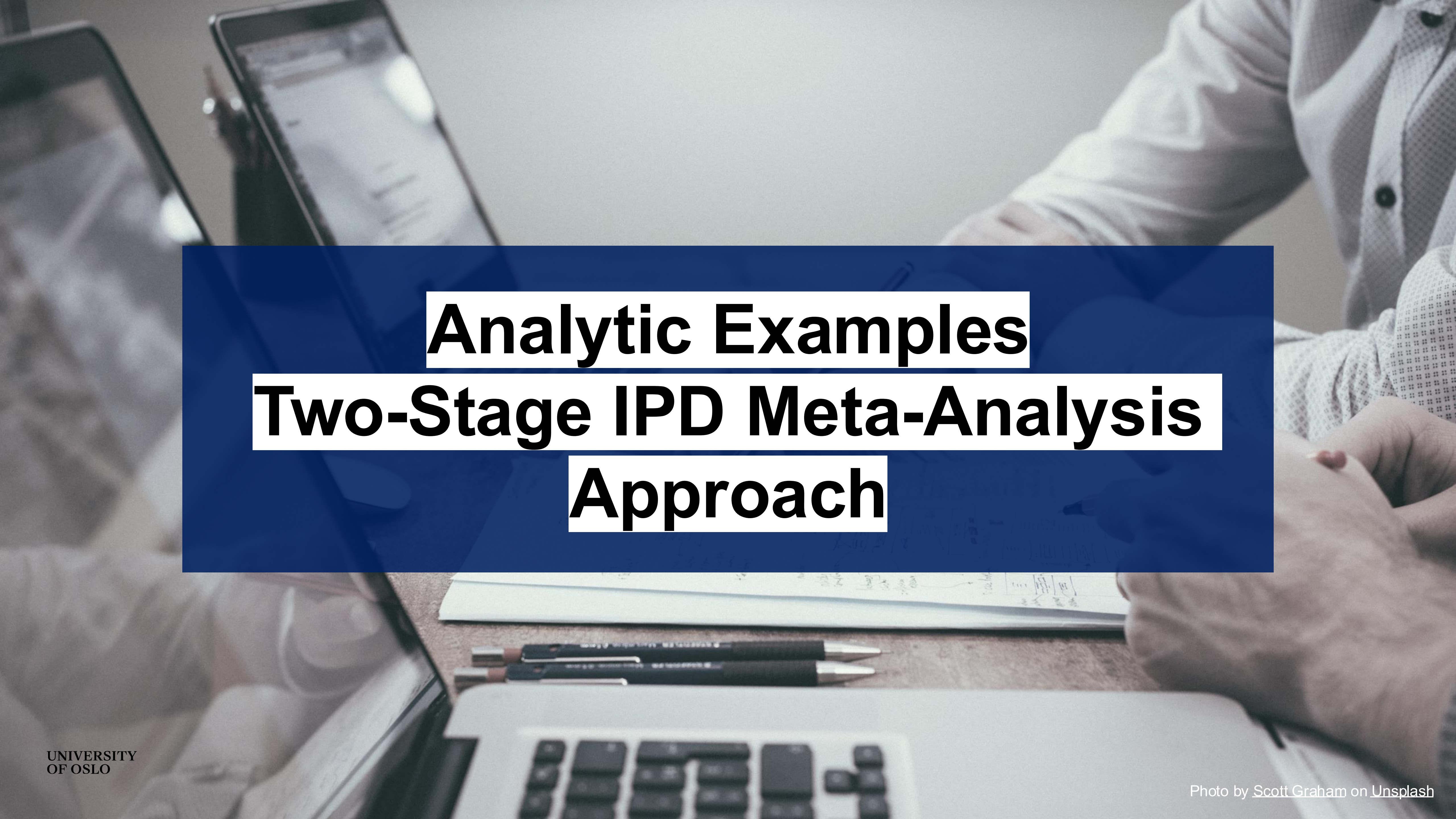


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Photo by Scott Graham on Unsplash

Two-Stage Individual Participant Data Meta-Analysis
Stage 1

To what extent do girls and boys in secondary education differ in their digital skills?

ICILS 2013

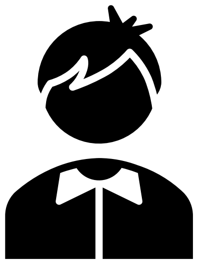
ICILS 2018

Constructs of interest	• Gender • CIL
Complex data structure	• Study ID • Country ID • School ID • Student ID • Student weights • Jacknife codes

Two-Stage Individual Participant Data Meta-Analysis

Stage 1

To what extent do girls and boys in secondary education differ in their digital skills?



$$d = \frac{\bar{X}_G - \bar{X}_B}{\sqrt{\frac{(n_G - 1)SD_G^2 + (n_B - 1)SD_B^2}{n_G + n_B - 2}}} \text{ with } v_d = \frac{n_G + n_B}{n_G n_B} + \frac{d^2}{2(n_G + n_B)}$$

$$g = \left(1 - \frac{3}{4(n_G + n_B - 2) - 1}\right) \cdot d \text{ with } v_g = \left(1 - \frac{3}{4(n_G + n_B - 2) - 1}\right)^2 \cdot v_d$$

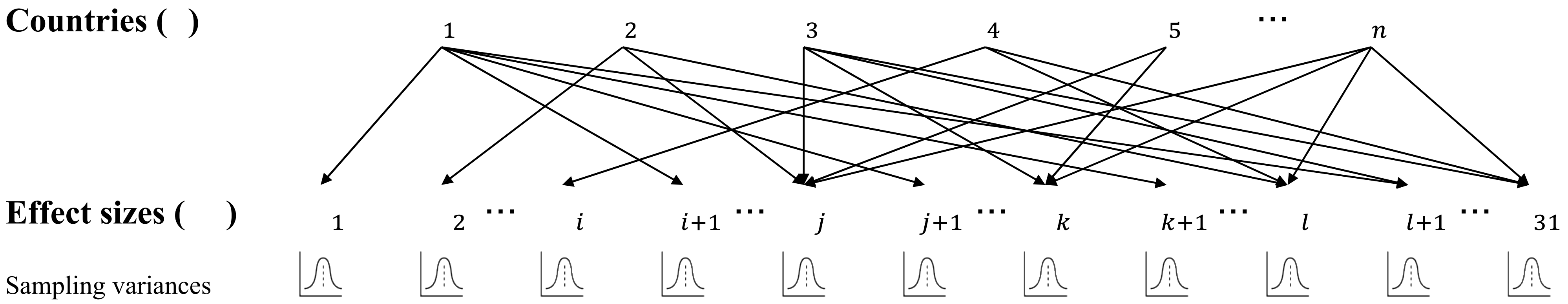
Two-Stage Individual Participant Data Meta-Analysis
Stage 2

Three-level random-effects model with effect sizes nested in countries

Level 1 (sampling variance): $\beta_{jk} = \theta_{jk} + r_{jk}$ $\quad r_{jk} \sim N(0, \sigma_r^2),\ q_{jk} \sim N(0, \sigma_q^2),\ u_k \sim N(0, \sigma_u^2)$

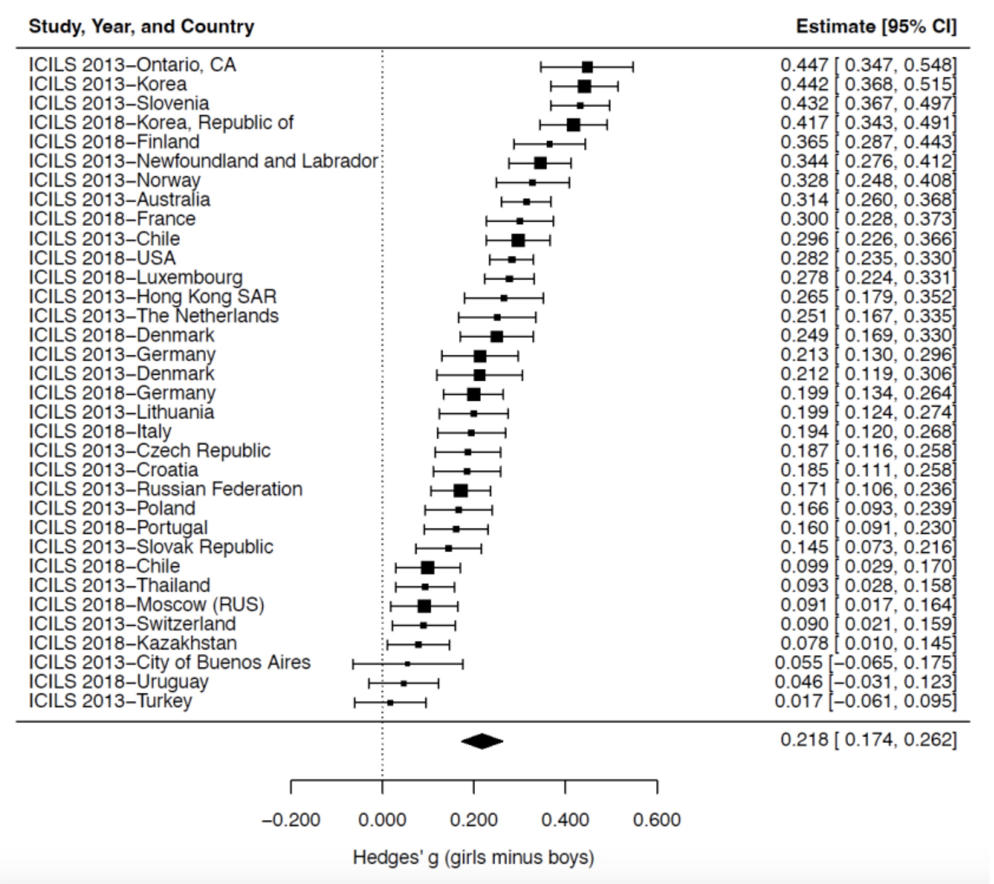
Level 2 (within countries): $\theta_{jk} = \lambda_k + q_{jk}$

Level 3 (between countries): $\lambda_k = \mu + u_k$



Two-Stage Individual Participant Data Meta-Analysis

Individual Participant Data

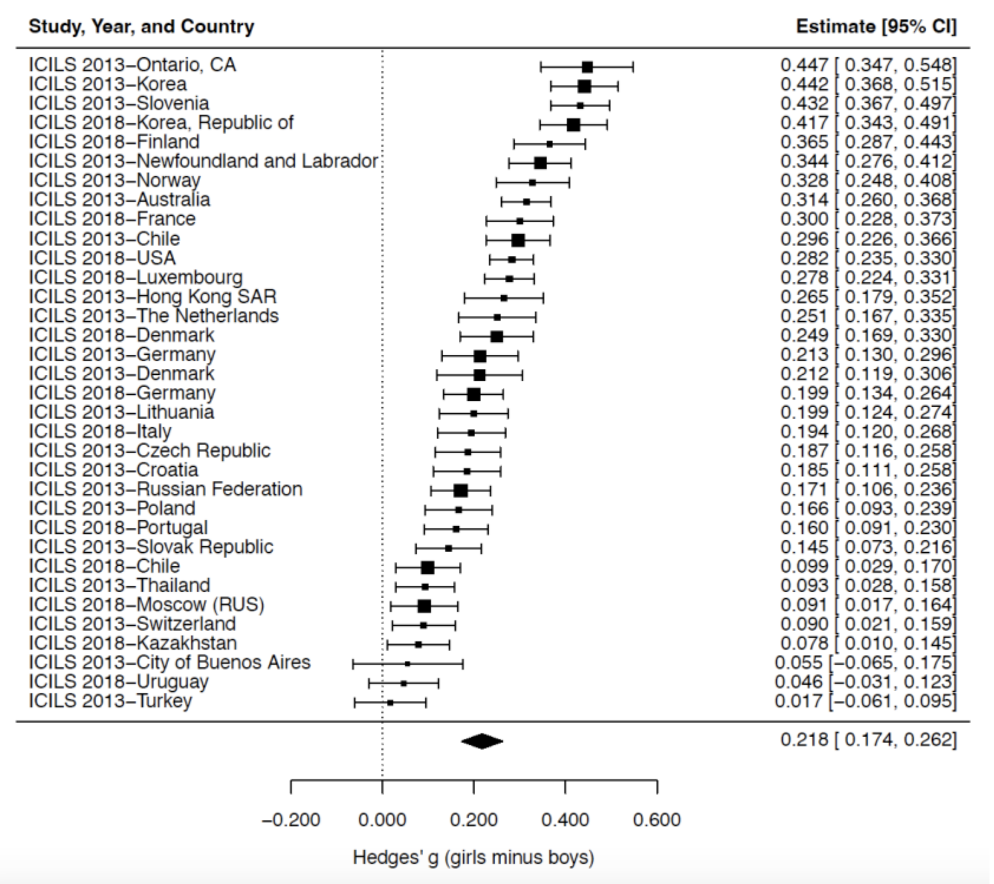


$\bar{g}_{\mathrm{IPD}}$ = 0.218 (95% CI [0.174, 0.262])

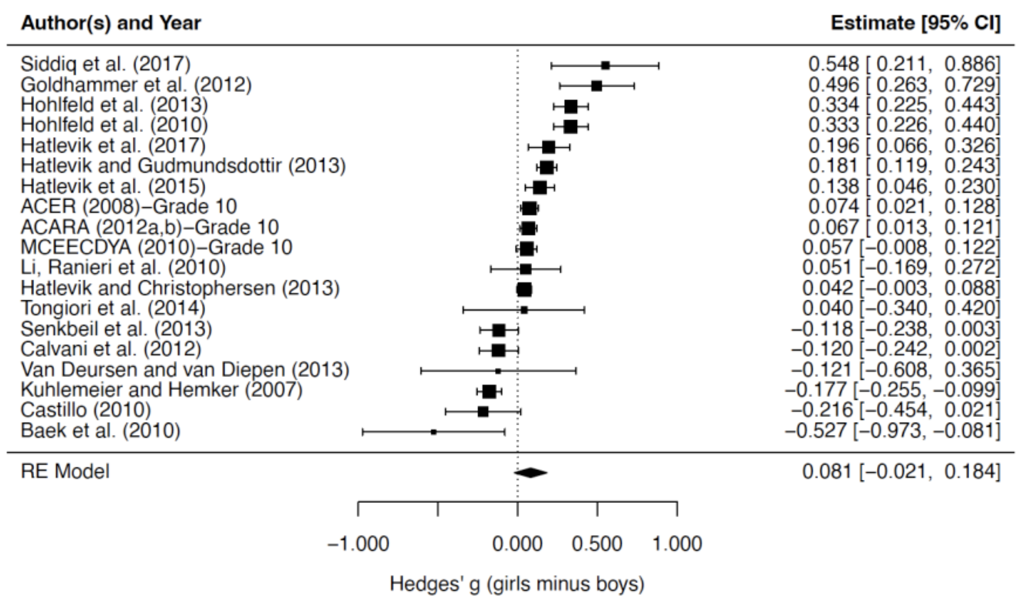
Scherer, Siddiq & Nilsen (2021)
Campos, Cheung & Scherer (2022)

Two-Stage Individual Participant Data Meta-Analysis

Individual Participant Data



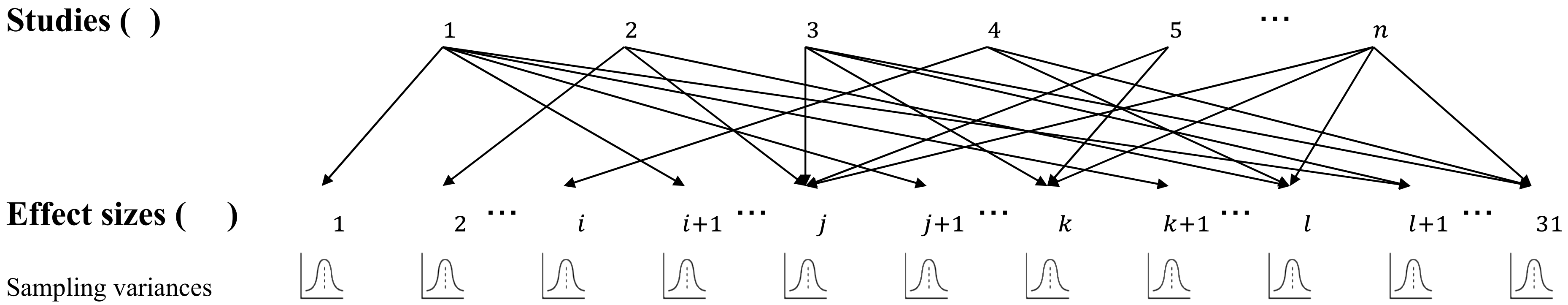
Aggregate Data



Scherer, Siddiq & Nilsen (2021)
Campos, Cheung & Scherer (2022)

Two-Stage Individual Participant Data Meta-Analysis
Combining AD and IPD

Three-level random-effects model with effect sizes nested in countries/studies



IPD ? AD

Two-Stage Individual Participant Data Meta-Analysis

Stage 2 - Moderation Analysis AD vs. IPD

Baseline model	$\hat{\mu}$ [95 % CI]	B [95 % CI]	τ^2_{IPD} [95 % CI]	τ^2_{AD} [95 % CI]	γ^2_{IPD}	γ^2_{AD}
Model 1: Data-specific effect sizes, data-specific between-country, and data-specific between-sample residual heterogeneity	.074 [-.003, .177]	.144 [.032, .256]	.003 [.001,.013]	.035 [.011,.093]	.009 [.001, .020]	.002 [.000, .073]

Two-Stage Individual Participant Data Meta-Analysis

Stage 2 - Moderation Analysis AD vs. IPD

Baseline model	$\hat{\mu}$ [95 % CI]	B [95 % CI]	τ^2_{IPD} [95 % CI]	τ^2_{AD} [95 % CI]	γ^2_{IPD}	γ^2_{AD}
Model 1: Data-specific effect sizes, data-specific between-country, and data-specific between-sample residual heterogeneity	.074 [-.003, .177]	.144 [.032, .256]	.003 [.001,.013]	.035 [.011,.093]	.009 [.001, .020]	.002 [.000, .073]
Model 2: Data-specific effect sizes, overall between-country heterogeneity, and data-specific between-sample residual heterogeneity	.031 [-.079 .140]	.187 [.080, .295]	.003 [.000 .016]	.035 [.013, .095]	.008 [.000, .020]	

```
        df      AIC      BIC     AICc  logLik    LRT   pval       QE tau^2
Full     6 -40.5818 -28.9909 -38.6728 26.2909                479.8761    NA
Reduced  5 -41.3649 -31.7057 -40.0315 25.6824 1.2170 0.2700 479.8761    NA
```

Two-Stage Individual Participant Data Meta-Analysis

Stage 2 - Moderation Analysis AD vs. IPD

<table>
<tr><th>Baseline model</th><th>$\hat{\mu}$ [95 % CI]</th><th>B [95 % CI]</th><th>τ^2_{IPD} [95 % CI]</th><th>τ^2_{AD} [95 % CI]</th><th>γ^2_{IPD}</th><th>γ^2_{AD}</th></tr>
<tr><td>Model 1: Data-specific effect sizes, data-specific between-country, and data-specific between-sample residual heterogeneity</td><td>.074
[-.003, .177]</td><td>.144
[.032, .256]</td><td>.003
[.001,.013]</td><td>.035
[.011,.093]</td><td>.009
[.001, .020]</td><td>.002
[.000, .073]</td></tr>
<tr><td>Model 2: Data-specific effect sizes, overall between-country heterogeneity, and data-specific between-sample residual heterogeneity</td><td>.031
[-.079 .140]</td><td>.187
[.080, .295]</td><td>.003
[.000 .016]</td><td>.035
[.013, .095]</td><td colspan="2">.008
[.000, .020]</td></tr>
<tr><td>Model 3: Data-specific effect sizes, overall between-country heterogeneity, and overall between-sample residual heterogeneity</td><td>.065
[-.012, .142]</td><td>.158
[.070, .245]</td><td colspan="2">.002
[.000, .013]</td><td colspan="2">.002
[.000, .013]</td></tr>
</table>

Two-Stage Individual Participant Data Meta-Analysis
Example 2

To what extent is class-average student achievement in mathematics related to individual students' mathematics self-concept after controlling for students' individual mathematics performance in primary school (BFLPE)?

IEA
TIMSS

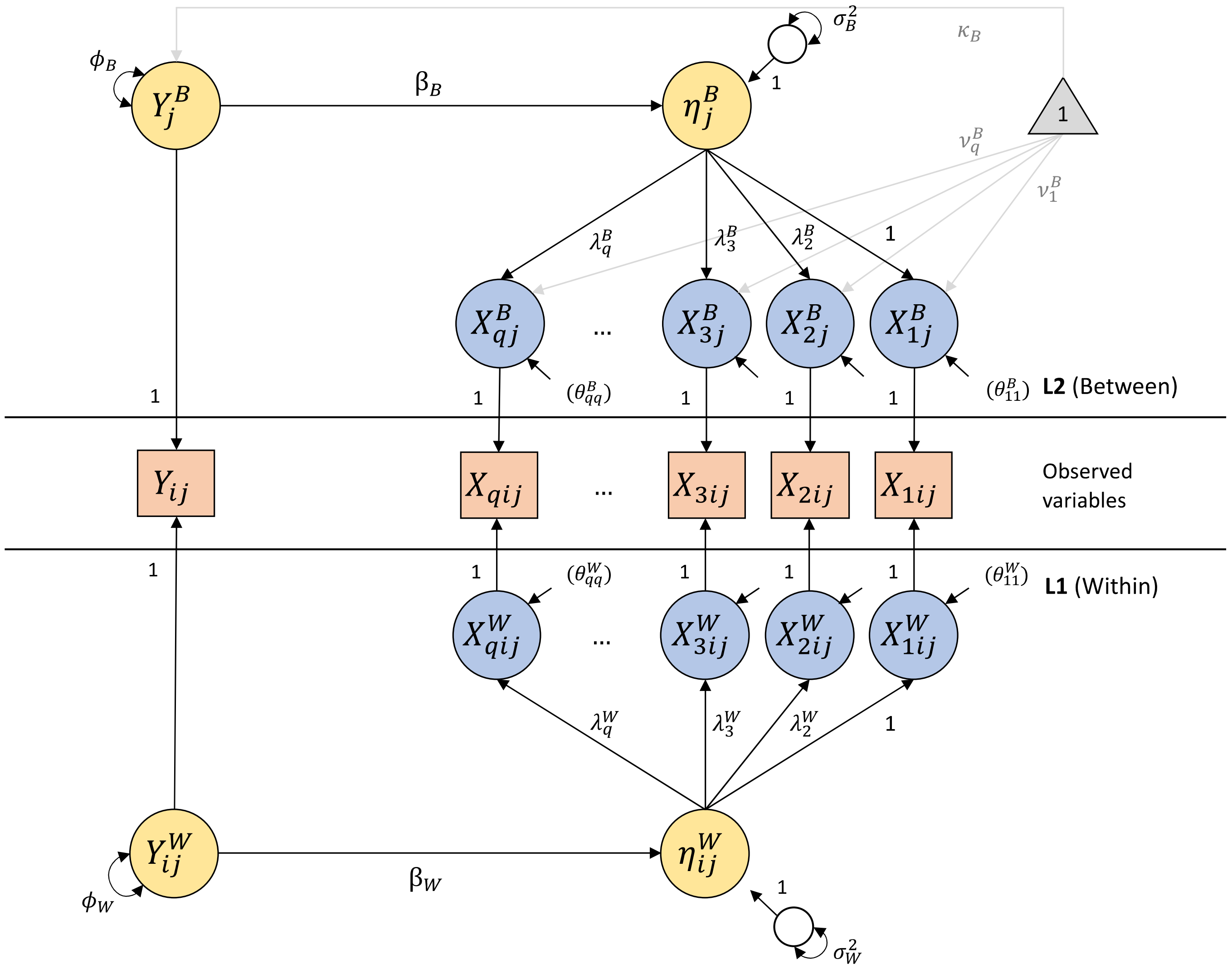
Constructs of interest	• Mathematics achievement • Self-concept
Complex data structure	• Study ID • Country ID • Classroom ID • Student ID • Student weights • Classroom weights

Two-Stage Individual Participant Data Meta-Analysis

Stage 1

Multilevel SEM to estimate contextual effects

$$ES_{BFLPE} = (\beta_B - \beta_W)$$



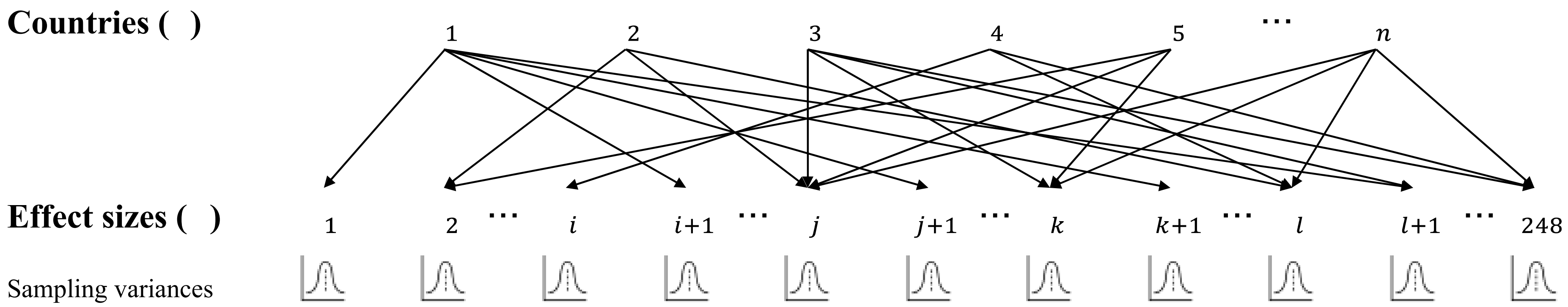
Two-Stage Individual Participant Data Meta-Analysis
Stage 2

Three-level random-effects model with effect sizes nested in countries

Level 1 (sampling variance): $\beta_{jk} = \theta_{jk} + r_{jk}$ $\quad r_{jk} \sim N(0, \sigma_r^2),\ q_{jk} \sim N(0, \sigma_q^2),\ u_k \sim N(0, \sigma_u^2)$

Level 2 (within countries): $\theta_{jk} = \lambda_k + q_{jk}$

Level 3 (between countries): $\lambda_k = \mu + u_k$



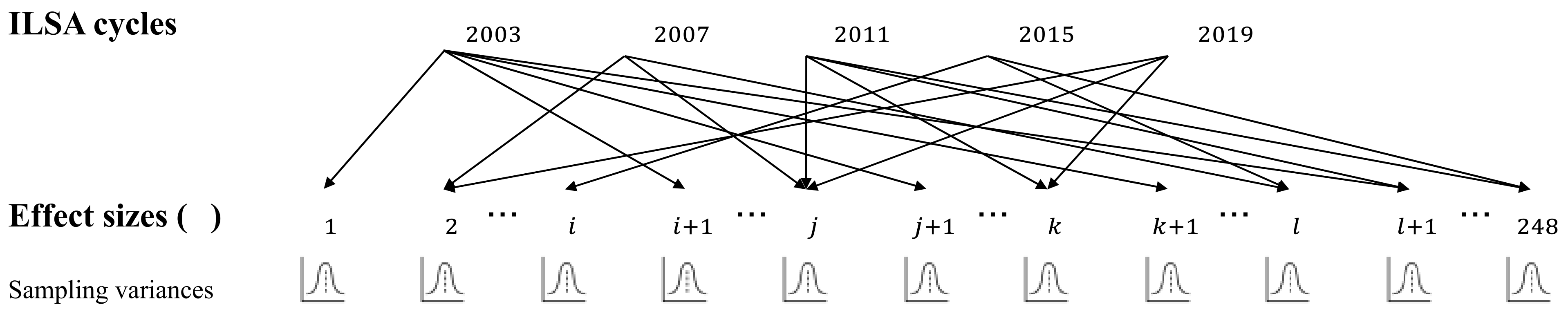
Two-Stage Individual Participant Data Meta-Analysis
Stage 2

Three-level random-effects model with effect sizes nested in cycles

Level 1 (sampling variance): $\beta_{jk} = \theta_{jk} + r_{jk}$ $\quad r_{jk} \sim N(0, \sigma_r^2),\ q_{jk} \sim N(0, \sigma_q^2),\ u_k \sim N(0, \sigma_u^2)$

Level 2 (within cycles): $\theta_{jk} = \lambda_k + q_{jk}$

Level 3 (between cycles): $\lambda_k = \mu + u_k$



Two-Stage Individual Participant Data Meta-Analysis
Stage 2

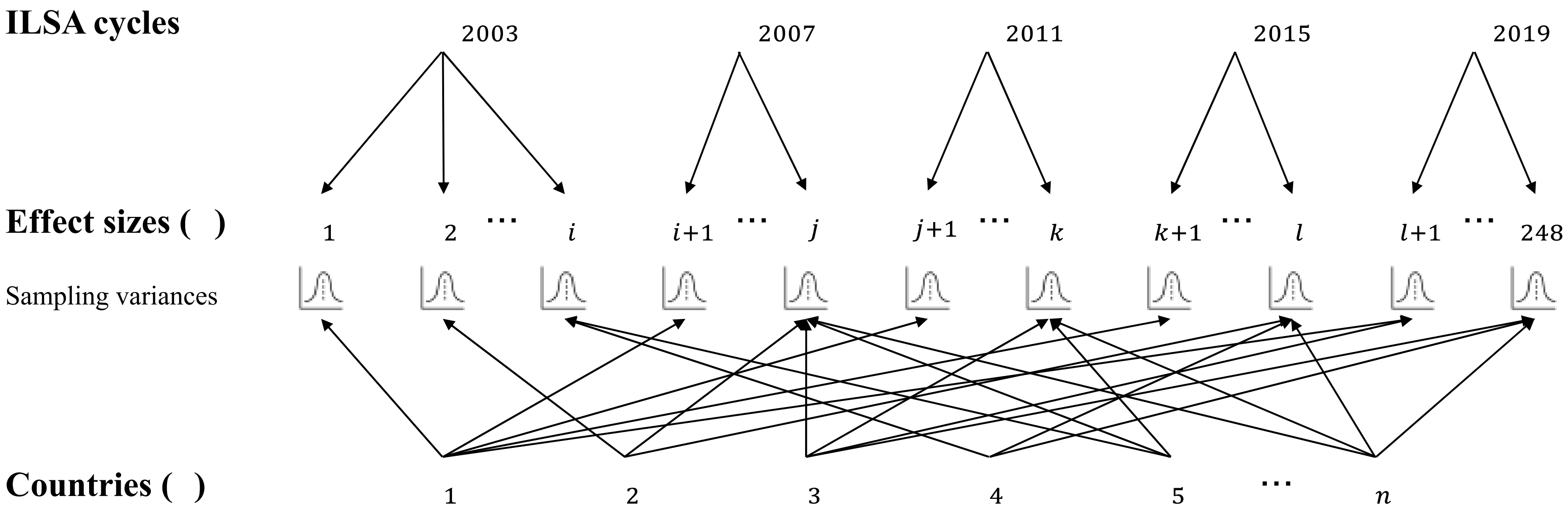
Four-level cross-classified random-effects model with countries and cycles

Level 1: $\beta_{j(kl)} = \theta_{j(kl)} + r_{j(kl)}$

Level 2: $\theta_{j(kl)} = \lambda_{(kl)} + q_{j(kl)}$

Levels 3 and 4: $\lambda_{(kl)} = \mu + u_k + p_l$

$r_{j(kl)} \sim N(0, \sigma_r^2)$, $q_{j(kl)} \sim N(0, \sigma_q^2)$, $u_k \sim N(0, \sigma_u^2)$, $p_l \sim N(0, \sigma_p^2)$



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Two-Stage Individual Participant Data Meta-Analysis
Stage 2

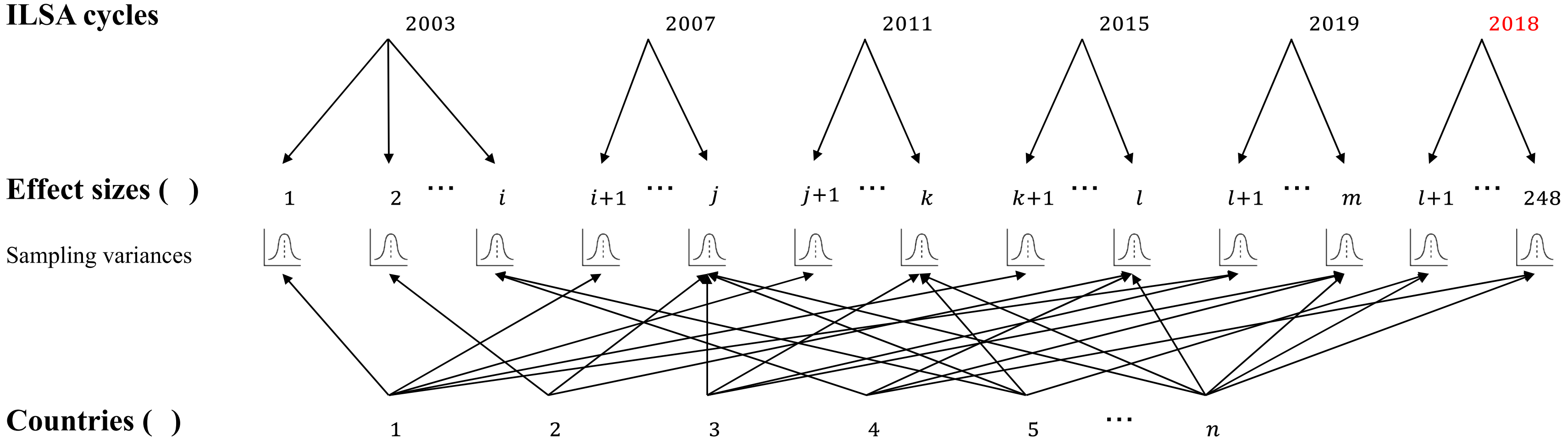
Four-level cross-classified random-effects model with countries and cycles

Level 1: $\beta_{j(kl)} = \theta_{j(kl)} + r_{j(kl)}$

Level 2: $\theta_{j(kl)} = \lambda_{(kl)} + q_{j(kl)}$

Levels 3 and 4: $\lambda_{(kl)} = \mu + u_k + p_l$

$r_{j(kl)} \sim N(0, \sigma_r^2)$, $q_{j(kl)} \sim N(0, \sigma_q^2)$,
$u_k \sim N(0, \sigma_u^2)$, $p_l \sim N(0, \sigma_p^2)$



Two-Stage Individual Participant Data Meta-Analysis

Stage 2

Baseline model	$\hat{\mu}$ [95 % CI]	τ^2_{ES} [95 % CI]	σ^2_C [95 % CI]	σ^2_S [95 % CI]	I^2_{ES}	I^2_C	I^2_S
Model 1: Standard random-effects model	-.458 [-.481, -.436]	.025 [.020, .030]	-	-	82.4 %	-	-
Model 2: Three-level random-effects model with effect sizes nested in countries	-.451 [-.486, -.416]	.004 [.002, .006]	.021 [.014, .031]	-	12.1 %	70.0 %	-
Model 3: Three-level random-effects model with effect sizes nested in TIMSS cycles	-.458 [-.484, -.432]	.025 [.020, .031]	-	.000 [.000, .002]	82.4 %	-	0.0 %
Model 5: Four-level cross-classified random-effects model	-.452 [-.489, -.415]	.003 [.001, .006]	.021 [.014, .031]	.000 [.000, .002]	10.9 %	70.6 %	0.7 %

Two-Stage Individual Participant Data Meta-Analysis
Stage 2

Moderator	Three-level mixed-effects meta-regression			
	Model 2a		Model 2b	
	B	*SE*	*B*	*SE*
Intercept	-0.137	0.174	-0.812	0.225
Cultural dimensions				
PDI	-0.002	0.002	-	-
IDV	-0.002	0.001	-	-
MAS	-0.001	0.001	-	-
UAI	-0.001	0.001	-	-
LTO	0.000	0.001	-	-
IVR	0.000	0.002	-	-
Economic development			-	-
HDI	-	-	0.426*	0.258
Moderator test				
Q_M(df)	8.6 (6), *p* = .20		5.5 (1), *p* = .02	
Variance explanation				
R^2_{ES}	0.0%		2.5%	
R^2_{C}	5.5%		12.3%	

Potential of Two-Stage IPD Meta-Analysis

1. Enlarge the generalizability of meta-analytic conclusions
2. Two-stage IPD meta-analysis enables researchers to synthesize information from complex surveys studies
3. Standardized analyses across studies
4. Direct and model-based generation of the effect sizes of interest
5. Appropriate handling of statistical dependencies in meta-analytic data sets from complex sampling surveys

Campos, D, Cheung, W.-L.M., & Scherer, R. (2022). A Primer on Synthesizing Individual Participant Data Obtained From Complex Sampling Surveys: A Two-Stage IPD Meta-Analysis Approach. (Accepted for Publication: *Psychological Methods*)

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