

estat heterogeneity (me) — Compute multilevel heterogeneity statistics

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Description

`estat heterogeneity` computes multilevel heterogeneity statistics after multilevel meta-regression fit by `meta multilevel` or `meta meregress`.

Menu for estat

Statistics > Postestimation

Syntax

```
estat heterogeneity [ , relevel(levelvar) ]
```

Option

Main

`relevel(levelvar)` displays the amount of the total heterogeneity that can be attributed to a specific level of hierarchy defined by *levelvar*. This option affects the multilevel Higgins–Thompson I^2 statistic.

Remarks and examples

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For multilevel meta-regression models, `estat heterogeneity` reports Cochran’s statistic and the Higgins–Thompson I^2 statistic. Cochran’s I_Q^2 is available for all models fit by `meta meregress` or `meta multilevel`, whereas the Higgins–Thompson I_{HT}^2 and $I_{HT,l}^2$ statistics are available after `meta multilevel` and random-intercepts multilevel models (models with no random slopes) fit by `meta meregress`.

The Cochran I_Q^2 is based on Q_M , a multilevel extension of the Cochran statistic Q_{res} defined in (3) in *Methods and formulas* of [META] [meta regress](#). Cochran’s I_Q^2 does not depend on the random-effects component of the multilevel meta-regression model; therefore, its value does not change for models with the same fixed-effects component. Because I_Q^2 does not depend on the random-effects component of the model, it may be computed for all multilevel meta-regression models (with or without random slopes). It quantifies the heterogeneity among the effect sizes jointly for all levels of hierarchy and has a similar interpretation to the I^2 statistic reported in standard meta-analysis or standard meta-regression. This statistic reduces to the I_{res}^2 [see (4) in *Methods and formulas* of [META] [meta regress](#)] based on the DerSimonian–Laird random-effects method in the standard meta-analysis setting.

The multilevel Higgins–Thompson I_{HT}^2 and $I_{HT,l}^2$ (Nakagawa and Santos 2012; Cheung 2014) statistics are defined for multilevel models with random intercepts only (without random slopes). These statistics can be computed separately for each level of hierarchy and jointly for all levels of hierarchy in the model. Therefore, they quantify the contribution of each level of hierarchy to the total heterogeneity, in addition to their joint contribution.

See [example 3](#) of [\[META\] meta meregress](#) for assessing heterogeneity in multilevel meta-analysis models.

Stored results

estat heterogeneity stores the following in `r()`:

Scalars

`r(I2_Q)` Cochran I_Q^2 heterogeneity statistic

Matrices

`r(I2_HT)` Higgins–Thompson I_{HT}^2 and $I_{HT,l}^2$ heterogeneity statistics

Methods and formulas

Methods and formulas are presented under the following headings:

Multilevel heterogeneity statistics

Cochran heterogeneity statistic

Higgins–Thompson heterogeneity statistics

Multilevel heterogeneity statistics

See [Methods and formulas](#) of [\[META\] meta meregress](#). We will discuss two types of multilevel I^2 statistics: Cochran’s I_Q^2 and the Higgins–Thompson $I_{HT,l}^2$ and I_{HT}^2 . Cochran’s I_Q^2 does not depend on the random-effects component of the multilevel meta-regression model, whereas the Higgins–Thompson $I_{HT,l}^2$ and I_{HT}^2 are defined for multilevel models with random intercepts only (with no random slopes). Therefore, we will use the random-intercepts three-level meta-regression to illustrate their computations.

Consider the three-level random-intercepts meta-regression model

$$\hat{\theta}_{jkr} = \mathbf{x}_{jkr}\beta + u_j^{(3)} + u_{jk}^{(2)} + \epsilon_{jkr}$$

where $u_j^{(3)} \sim N(0, \tau_3^2)$ and $u_{jk}^{(2)} \sim N(0, \tau_2^2)$. Let \mathbf{X}_j , $\hat{\theta}_j$, and ϵ_j be defined as in [Methods and formulas](#) of [\[META\] meta meregress](#), and then the model can be written in matrix form as

$$\hat{\theta}_j = \mathbf{X}_j\beta + \dot{\mathbf{Z}}_j\dot{\mathbf{u}}_j + \epsilon_j, \quad j = 1, 2, \dots, M$$

where $m_j \times (m_j + 1)$ matrix $\dot{\mathbf{Z}}_j = (\mathbf{1}_{m_j}, \oplus_{k=1}^{m_j} \mathbf{1}_{m_{jk}})$ and $(m_j + 1) \times 1$ vector of random effects $\dot{\mathbf{u}}_j = (u_j^{(3)}, u_{j1}^{(2)}, u_{j2}^{(2)}, \dots, u_{jm_j}^{(2)})'$.

Cochran heterogeneity statistic

The multilevel Q_M is defined as

$$Q_M = \sum_{j=1}^M \left(\hat{\theta}_j - \mathbf{X}_j \hat{\beta}_f \right)' \Lambda_j^{-1} \left(\hat{\theta}_j - \mathbf{X}_j \hat{\beta}_f \right)$$

where $\hat{\beta}_f$ is a fixed-effects estimator obtained by fitting a standard fixed-effects meta-regression (see [META] meta regress) of the $\hat{\theta}_{jk}$'s on the moderators defining the \mathbf{X}_j matrix. Cochran's I_Q^2 is defined as

$$I_Q^2 = 100 \times \max \left(0, \frac{Q_M - n + p}{Q_M} \right)$$

One drawback of the Cochran statistic is that it assesses only the impact of heterogeneity jointly for all levels of hierarchy. It may be of interest to separately investigate the extent of each level of hierarchy's contribution to the total variability. This will be possible with the heterogeneity statistics discussed below.

Higgins–Thompson heterogeneity statistics

For a level l ($l = 2$ and $l = 3$ here), the Higgins–Thompson I_{HT}^2 statistics are defined as

$$I_{HT,l}^2 = \frac{\hat{\tau}_l^2}{\hat{\tau}_2^2 + \hat{\tau}_3^2 + s_{HT}^2}, \quad l = 2, 3$$

$$I_{HT}^2 = \frac{\hat{\tau}_2^2 + \hat{\tau}_3^2}{\hat{\tau}_2^2 + \hat{\tau}_3^2 + s_{HT}^2}$$

where $\hat{\tau}_l^2$ is the estimated variance of the random intercepts at level $l = 2, 3$ and s_{HT}^2 is defined below. When option `relevel(levelvar)` is specified, then only $I_{HT,l}^2$ is reported by `estat heterogeneity`, where l corresponds to the level identified by variable `levelvar`.

Let $\mathbf{X} = (\mathbf{X}'_1, \mathbf{X}'_2, \dots, \mathbf{X}'_M)'$ and $\Lambda = \bigoplus_{j=1}^M \Lambda_j$. The level-1 variance s_{HT}^2 is computed similarly to s^2 in *Residual heterogeneity measures* in *Methods and formulas* in [META] meta regress and is given by

$$s_{HT}^2 = \frac{n - p}{\text{tr}(\mathbf{P})}$$

where $n = \sum_{j=1}^M m_j$ is the total number of observations and

$$\mathbf{P} = \Lambda^{-1} - \Lambda^{-1} \mathbf{X} (\mathbf{X}' \Lambda^{-1} \mathbf{X})^{-1} \mathbf{X}' \Lambda^{-1}.$$

The $I_{HT,l}^2$ and I_{HT}^2 statistics reduce to I_{res}^2 reported by (4) in *Methods and formulas* of [META] meta regress when there are two levels of hierarchy in the model.

References

- Cheung, M. W.-L. 2014. Modeling dependent effect sizes with three-level meta-analyses: A structural equation modeling approach. *Psychological Methods* 19: 211–229. <https://psycnet.apa.org/doi/10.1037/a0032968>.
- Nakagawa, S., and E. S. A. Santos. 2012. Methodological issues and advances in biological meta-analysis. *Evolutionary Ecology* 26: 1253–1274. <https://doi.org/10.1007/s10682-012-9555-5>.

Also see

[META] **meta me postestimation** — Postestimation tools for multilevel mixed-effects meta-analysis

[META] **meta meregress** — Multilevel mixed-effects meta-regression

[META] **meta multilevel** — Multilevel random-intercepts meta-regression

[U] **20 Estimation and postestimation commands**

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