

Package ‘GECal’

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Type Package

Title Generalized Entropy Calibration

Version 0.1.7

Description Generalized Entropy Calibration produces calibration weights using generalized entropy as the objective function for optimization. This approach, as implemented in the 'GECal' package, is based on Kwon, Kim, and Qiu (2024) <[doi:10.48550/arXiv.2404.01076](https://doi.org/10.48550/arXiv.2404.01076)>. 'GECal' incorporates design weights into the constraints to maintain design consistency, rather than including them in the objective function itself.

Encoding UTF-8

URL <https://github.com/yonghyun-K/GECal>

BugReports <https://github.com/yonghyun-K/GECal/issues>

Depends R (>= 2.10.0)

LazyData true

Imports nleqslv

Suggests sampling

RoxygenNote 7.3.2

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NeedsCompilation no

Author Yonghyun Kwon [aut, cre] (ORCID: <<https://orcid.org/0000-0001-9923-6790>>),
Jae Kwang Kim [aut] (ORCID: <<https://orcid.org/0000-0002-0246-6029>>),
Yumou Qiu [aut] (ORCID: <<https://orcid.org/0000-0003-4846-1263>>)

Maintainer Yonghyun Kwon <yhkwon@kma.ac.kr>

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estimate	<i>Performing statistical inference after calibration</i>
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Description

estimate performs statistical inference after calibration.

Usage

```
estimate(formula, data = NULL, calibration, pimat = NULL)
```

Arguments

formula	An object of class "formula" specifying the calibration model.
data	An optional data frame containing the variables in the model (specified by formula).
calibration	An object of class "calibration", generated by GEcalib.
pimat	An optional matrix containing the joint inclusion probability matrix used for variance estimation.

Value

A list of class estimation including the point estimates and its standard error.

References

Kwon, Y., Kim, J., & Qiu, Y. (2024). Debiased calibration estimation using generalized entropy in survey sampling. Arxiv preprint <<https://arxiv.org/abs/2404.01076>>

Deville, J. C., and Särndal, C. E. (1992). Calibration estimators in survey sampling. *Journal of the American statistical Association*, 87(418), 376-382.

Examples

```

set.seed(11)
N = 10000
x = data.frame(x1 = rnorm(N, 2, 1), x2= runif(N, 0, 4))
pi = pt((-x[,1] / 2 - x[,2] / 2), 3);
pi = ifelse(pi >.7, .7, pi)

delta = rbinom(N, 1, pi)
Index_S = (delta == 1)
pi_S = pi[Index_S]; d_S = 1 / pi_S
x_S = x[Index_S,,drop = FALSE]
# pimat = diag(d_S^2 - d_S) / N^2 # 1 / pi_i * (1 - 1 / pi_i)

e = rnorm(N, 0, 1)
y = x[,1] + x[,2] + e;
y_S = y[Index_S] # plot(x_S, y_S)

calibration0 <- GECal::GEcalib(~ 1, dweight = d_S, data = x_S,
                             const = N,
                             entropy = "SL", method = "DS")
GECal::estimate(y_S ~ 1, calibration = calibration0)$estimate # Hajek estimator
# sum(y_S * d_S) * N / sum(d_S)

calibration <- GECal::GEcalib(~ 0, dweight = d_S, data = x_S,
                             const = numeric(0),
                             entropy = "SL", method = "DS")
GECal::estimate(y_S ~ 1, calibration = calibration)$estimate # HT estimator

calibration1 <- GECal::GEcalib(~ ., dweight = d_S, data = x_S,
                              const = colSums(cbind(1, x)),
                              entropy = "ET", method = "DS")
GECal::estimate(y_S ~ 1, calibration = calibration1)$estimate

calibration2 <- GECal::GEcalib(~ ., dweight = d_S, data = x_S,
                              const = colSums(cbind(1, x)),
                              entropy = "ET", method = "GEC0")
GECal::estimate(y_S ~ 1, calibration = calibration2)$estimate

calibration3 <- GECal::GEcalib(~ . + g(d_S), dweight = d_S, data = x_S,
                              const = colSums(cbind(1, x, log(1 / pi))),
                              entropy = "ET", method = "GEC")
GECal::estimate(y_S ~ 1, calibration = calibration3)$estimate

calibration4 <- GECal::GEcalib(~ . + g(d_S), dweight = d_S, data = x_S,
                              const = colSums(cbind(1, x, NA)),
                              entropy = "ET", method = "GEC")
GECal::estimate(y_S ~ 1, calibration = calibration4)$estimate

calibration5 <- GECal::GEcalib(~ . + g(d_S), dweight = d_S, data = x_S,
                              const = colSums(cbind(1, x, NA)),
                              entropy = "ET", method = "GEC", K_alpha = "log")
GECal::estimate(y_S ~ 1, calibration = calibration5)$estimate

```

*g**Debiasing covariate for GECalib*

Description

It returns the debiasing covariate, which is equivalent to the first order derivative of the generalized entropy G .

Usage

```
g(x, entropy = NULL, del = NULL)
```

Arguments

x A vector of design weights

entropy An optional data frame containing the variables in the model (specified by formula).

del The optional vector for threshold (δ) when `entropy == "PH"`.

Value

A vector of debiasing covariate.

Examples

```
set.seed(11)
N = 10000
x = data.frame(x1 = rnorm(N, 2, 1), x2= runif(N, 0, 4))
pi = pt((-x[,1] / 2 - x[,2] / 2), 3);
pi = ifelse(pi >.7, .7, pi)

g_EL <- g(1 / pi, entropy = 1)
g_ET <- g(1 / pi, entropy = 0)
g_EL <- g(1 / pi, entropy = -1)
```

Description

GEcalib computes the calibration weights. Generalized entropy calibration weights maximize the generalized entropy:

$$H(\boldsymbol{\omega}) = - \sum_{i \in A} G(\omega_i),$$

subject to the calibration constraints $\sum_{i \in A} \omega_i z_i = \sum_{i \in U} z_i$, where A denotes the sample index, and U represents the population index. The auxiliary variables, whose population totals are known, are defined as $\mathbf{z}_i^T = (\mathbf{x}_i^T, g(d_i))$, where g is the first-order derivative of the generalized entropy G , and d_i is the design weight for each sampled unit $i \in A$.

Usage

```

GEcalib(
  formula,
  dweight,
  data = NULL,
  const,
  method = c("GEC", "GEC0", "DS"),
  entropy = c("SL", "EL", "ET", "CE", "HD", "PH"),
  weight.scale = 1,
  G.scale = 1,
  K_alpha = NULL,
  is.total = TRUE,
  del = NULL,
  xtol = 1e-16,
  maxit = 1e+05,
  allowSingular = T
)

```

Arguments

formula	An object of class "formula" specifying the calibration model.
dweight	A vector of sampling weights.
data	An optional data frame containing the variables in the model (specified by formula).
const	A vector used in the calibration constraint for population totals(or means).
method	The method to be used in calibration. See "Details" for more information.
entropy	The generalized entropy used in calibration, which can be either a numeric value or a string. If numeric, entropy represents the order of Renyi's entropy, where $G(\omega) = r^{-1}(r+1)^{-1}\omega^{r+1}$ if $r \neq 0, -1$. If a string, valid options include: "SL" (Squared-loss, $r = 1$), "EL" (Empirical Likelihood, $r = -1$), "ET" (Exponential Tilting, $r = 0$), "HD" (Hellinger Distance, $r = -1/2$), "CE" (Cross-Entropy), and "PH" (Pseudo-Huber). See "Summary" for details.

<code>weight.scale</code>	Positive scaling factor for the calibration weights ω_i . Asymptotics justify setting <code>weight.scale</code> to the finite population correction ($fpc = n/N$).
<code>G.scale</code>	Positive scaling factor for the generalized entropy function G . Asymptotics justify setting <code>G.scale</code> to the variance of the error term in a linear super-population model.
<code>K_alpha</code>	The K function used in joint optimization when the const of the debiasing covariate $g(d_i)$ is not available. <code>K_alpha</code> can be NULL, "log", or custom functions. See "Details".
<code>is.total</code>	Logical, TRUE if <code>sum(const[1])</code> equals the population size.
<code>del</code>	The optional threshold (δ) used when Pseudo-Huber (PH) entropy is selected.
<code>xtol</code>	Optional relative steplength tolerance in <code>nleqslv</code>
<code>maxit</code>	Optional maximum number of major iterations in <code>nleqslv</code>
<code>allowSingular</code>	Optional logical value indicating if a small correction to the Jacobian is allowed in <code>nleqslv del = quantile(dweight, 0.75)</code> if not specified.

Details

The `GEcal` object returns the calibration weights and necessary information for estimating population totals(or mean).

The terms to the right of the \sim symbol in the formula argument define the calibration constraints. When `method == "GEC"`, the debiasing covariate `g(dweight)` must be included in the formula. If the population total(mean) of `g(dweight)` is unavailable, `const` that corresponds to `g(dweight)` can be set to NA. In this case, `GEcalib` performs joint optimization over both the calibration weights ω_i and the missing value of `const`.

The length of the `const` vector should match the number of columns in the `model.matrix` generated by formula. Additionally, the condition number of the `model.matrix` must exceed `.Machine$double.eps` to ensure its invertibility.

Both `weight.scale` and `G.scale` are positive scaling factors used for calibration. Note that `weight.scale` is not supported when `method == "DS"`.

Let q_i be the scaling factor for the generalized entropy function G , and ϕ_i be the scaling factor for the calibration weights ω_i .

If `method == "GEC"`, `GEcalib` minimizes the negative entropy:

$$\sum_{i \in A} q_i G(\phi_i \omega_i),$$

with respect to ω subject to the calibration constraints $\sum_{i \in A} \omega_i z_i = \sum_{i \in U} z_i$, where $z_i^T = (\mathbf{x}_i^T, q_i \phi_i g(\phi_i d_i))$, A denotes the sample index, and U represents the population index.

If `method == "GEC"`, but an element of `const` corresponding to the debiasing covariate $g(d_i)$ is NA, `GEcalib` minimizes the negative adjusted entropy:

$$\sum_{i \in A} q_i G(\phi_i \omega_i) - K(\alpha),$$

with respect to ω and α subject to the calibration constraints $\sum_{i \in A} \omega_i (\mathbf{x}_i^T, q_i \phi_i g(\phi_i d_i)) = (\sum_{i \in U} \mathbf{x}_i, \alpha)$, where the solution $\hat{\alpha}$ is an estimate of population total for $g(d_i)$. Examples of $K(\alpha)$ includes $K(\alpha) = \alpha$ when `K_alpha == NULL`, and

$$K(\alpha) = \left(\sum_{i \in A} d_i g(d_i) + N \right) \log \left| \frac{1}{N} \sum_{i \in A} q_i \phi_i \omega_i g(\phi_i \omega_i) + 1 \right|$$

when `K_alpha == "log"`.

If `method == "GEC0"`, GCalib minimizes the negative adjusted entropy:

$$\sum_{i \in A} q_i G(\phi_i \omega_i) - q_i \phi_i \omega_i g(\phi_i d_i)$$

with respect to ω subject to the calibration constraints $\sum_{i \in A} \omega_i \mathbf{x}_i = \sum_{i \in U} \mathbf{x}_i$.

If `method == "DS"`, GCalib minimizes the divergence between ω and \mathbf{d} :

$$\sum_{i \in A} q_i d_i \tilde{G}(\omega_i / d_i)$$

with respect to ω subject to the calibration constraints $\sum_{i \in A} \omega_i \mathbf{x}_i = \sum_{i \in U} \mathbf{x}_i$. When `method == "DS"`, `weight.scale`, the scaling factor for the calibration weights ϕ_i , is not applicable.

Examples of G and \tilde{G} are given in "Summary".

Value

A list of class calibration including the calibration weights and data needed for estimation.

Summary

The table below provides a comparison between the **GEC** and **DS** methods.

GEC	DS
$\min_{\omega} (-H(\omega)) = \sum_{i \in A} G(\omega_i)$	$\min_{\omega} D(\omega, \mathbf{d}) = \sum_{i \in A} d_i \tilde{G}(\omega_i / d_i)$
s.t. $\sum_{i \in A} \omega_i (\mathbf{x}_i^T, g(d_i)) = \sum_{i \in U} (\mathbf{x}_i^T, g(d_i))$	s.t. $\sum_{i \in A} \omega_i \mathbf{x}_i^T = \sum_{i \in U} \mathbf{x}_i^T$
$G(\omega) = \begin{cases} \frac{1}{r(r+1)} \omega^{r+1} & r \neq 0, -1 \\ \omega \log \omega - \omega & r = 0(\text{ET}) \\ -\log \omega & r = -1(\text{EL}) \end{cases}$	$\tilde{G}(\omega) = \begin{cases} \frac{1}{r(r+1)} (\omega^{r+1} - (r+1)\omega + r) & r \neq 0, -1 \\ \omega \log \omega - \omega + 1 & r = 0(\text{ET}) \\ -\log \omega + \omega - 1 & r = -1(\text{EL}) \end{cases}$

If `method == "GEC"`, further examples include

$$G(\omega) = (\omega - 1) \log(\omega - 1) - \omega \log \omega$$

when `entropy == "CE"`, and

$$G(\omega) = \delta^2 (1 + (\omega/\delta)^2)^{1/2}$$

for a threshold δ when `entropy == "PH"`.

Author(s)

Yonghyun Kwon

References

Kwon, Y., Kim, J., & Qiu, Y. (2024). Debiased calibration estimation using generalized entropy in survey sampling. Arxiv preprint <<https://arxiv.org/abs/2404.01076>>

Deville, J. C., and Särndal, C. E. (1992). Calibration estimators in survey sampling. *Journal of the American statistical Association*, 87(418), 376-382.

Examples

```
set.seed(11)
N = 10000
x = data.frame(x1 = rnorm(N, 2, 1), x2= runif(N, 0, 4))
pi = pt((-x[,1] / 2 - x[,2] / 2), 3);
pi = ifelse(pi >.7, .7, pi)

delta = rbinom(N, 1, pi)
Index_S = (delta == 1)
pi_S = pi[Index_S]; d_S = 1 / pi_S
x_S = x[Index_S,]

# Deville & Sarndal(1992)'s calibration using divergence
w1 <- GECal::GEcalib(~ ., dweight = d_S, data = x_S,
                    const = colSums(cbind(1, x)),
                    entropy = "ET", method = "DS")$w

# Generalized entropy calibration without debiasing covariate
w2 <- GECal::GEcalib(~ ., dweight = d_S, data = x_S,
                    const = colSums(cbind(1, x)),
                    entropy = "ET", method = "GEC0")$w

all.equal(w1, w2)

# Generalized entropy calibration with debiasing covariate
w3 <- GECal::GEcalib(~ . + g(d_S), dweight = d_S, data = x_S,
                    const = colSums(cbind(1, x, log(1 / pi))),
                    entropy = "ET", method = "GEC")$w

# Generalized entropy calibration with debiasing covariate
# when its population total is unknown
w4 <- GECal::GEcalib(~ . + g(d_S), dweight = d_S, data = x_S,
                    const = colSums(cbind(1, x, NA)),
                    entropy = "ET", method = "GEC")$w

all.equal(w1, w4)

w5 <- GECal::GEcalib(~ . + g(d_S), dweight = d_S, data = x_S,
                    const = colSums(cbind(1, x, NA)),
                    entropy = "ET", method = "GEC", K_alpha = "log")$w
```



```

calibration <- GECal::GECalib(~ 0 + . -y -d, dweight = d, data = IAdat,
                             const = total,
                             entropy = "SL", method = "DS")
GECal::estimate(y ~ 1, data = IAdat, calibration = calibration, pimat = IApimat)$estimate

calibration <- GECal::GECalib(~ 0 + . -y -d, dweight = d, data = IAdat,
                             const = c(total),
                             entropy = "ET", method = "DS")
GECal::estimate(y ~ 1, data = IAdat, calibration = calibration, pimat = IApimat)$estimate

calibration <- GECal::GECalib(~ 0 + . -y -d + g(d), dweight = d, data = IAdat,
                             const = c(total, NA),
                             entropy = "HD", method = "GEC")
GECal::estimate(y ~ 1, data = IAdat, calibration = calibration, pimat = IApimat)$estimate

calibration <- GECal::GECalib(~ 0 + . -y -d, dweight = d, data = IAdat,
                             const = total,
                             entropy = "HD", method = "GEC0")
GECal::estimate(y ~ 1, data = IAdat, calibration = calibration, pimat = IApimat)$estimate

```

IApimat

A matrix used for variance estimation in IAdat

Description

The matrix that is used for variance estimation in IAdat. The sample is collected from a stratified random sampling.

Examples

```
data(IApimat)
```

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