

Package: saeproj.multilevel (via r-universe)

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Title Small Area Estimation Using a Projection Estimator with a Multilevel Regression Model

Version 0.1.0

Description Provides tools for small area estimation using a projection estimator with a linear multilevel working model. The main function fits a multilevel model to a smaller survey containing the response variable and auxiliary predictors, predicts outcomes in a larger projection survey, and computes domain-level estimates with a design-based residual correction.

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Contents

as.data.frame.sae_ml_linear	2
print.sae_ml_linear	2
sae_ml_linear	3
saeml_modelsvy	7
saeml_projsvy	8
summary.sae_ml_linear	9

Index	11
--------------	-----------

as.data.frame.sae_ml_linear	
	<i>Coerce an sae_ml_linear object to a data frame</i>

Description

Coerce an sae_ml_linear object to a data frame

Usage

```
## S3 method for class 'sae_ml_linear'
as.data.frame(x, row.names = NULL, optional = FALSE, ...)
```

Arguments

x	Object of class "sae_ml_linear".
row.names	Ignored.
optional	Ignored.
...	Further arguments.

Value

A data frame containing domain-level estimates.

print.sae_ml_linear	<i>Print method for sae_ml_linear</i>
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Description

Print method for sae_ml_linear

Usage

```
## S3 method for class 'sae_ml_linear'
print(x, n = 6L, ...)
```

Arguments

x	Object of class "sae_ml_linear".
n	Number of rows to display.
...	Further arguments.

Value

Invisibly returns x.

sae_ml_linear	<i>Small Area Estimation Using a Projection Estimator with a Linear Multilevel Regression Model</i>
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Description

sae_ml_linear() implements a projection estimator for small area estimation using a linear multilevel regression working model fitted with [lmer](#).

The function is designed for situations where information is available from two related surveys:

- **Model survey:** a smaller survey containing the response variable and auxiliary variables.
- **Projection survey:** a larger survey containing auxiliary variables and survey design information, but not the response variable.

The function fits a linear multilevel model using the model survey, predicts the response variable for all units in the projection survey, and produces domain-level projection estimates.

Usage

```
sae_ml_linear(
  formula,
  data_model,
  data_proj,
  domain,
  cluster_ids = ~1,
  weight = NULL,
  strata = NULL,
  summary_function = "mean",
  keep_unit = FALSE,
  seed = 1L,
  control = lme4::lmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 2e+05)),
  return_direct = FALSE,
  ...
)
```

Arguments

formula	A two-sided linear multilevel model formula written using <code>lme4::lmer()</code> syntax. The formula must include at least one random-effect term. For example, $Y \sim X1 + X2 + (1 \mid kab_kota)$.
data_model	A data frame containing model-survey data. It must contain the response variable, all fixed-effect variables, random-effect grouping variables, domain variables, and survey design variables used in estimation.
data_proj	A data frame containing projection-survey data. It must contain all fixed-effect variables, random-effect grouping variables, domain variables, and survey design variables. The response variable is not required in <code>data_proj</code> .
domain	A character vector or one-sided formula identifying the domain variable or variables used for domain-level aggregation. For example, <code>"kab_kota"</code> , <code>c("prov", "kab_kota")</code> , or <code>~prov + kab_kota</code> .
cluster_ids	A character vector or one-sided formula identifying cluster or primary sampling unit variables used in the survey design. Use <code>~1</code> when clustering is not used. The default is <code>~1</code> .
weight	A character string or one-sided formula identifying the survey weight variable. The specification must identify exactly one variable. Use <code>NULL</code> when sampling weights are not available. The default is <code>NULL</code> .
strata	A character string or one-sided formula identifying the stratification variable used in the survey design. Use <code>NULL</code> when stratification is not used. The default is <code>NULL</code> .
summary_function	Character string specifying the domain-level estimand. Available options are <code>"mean"</code> for domain means and <code>"total"</code> for domain totals. The default is <code>"mean"</code> .
keep_unit	Logical. If <code>TRUE</code> , the returned object includes unit-level predictions for <code>data_proj</code> , and unit-level fitted values and model residuals for <code>data_model</code> . The default is <code>FALSE</code> .
seed	Integer value used to set the random seed before model fitting. The default is 1.
control	A control object created by <code>lme4::lmerControl()</code> and passed to <code>lme4::lmer()</code> . The default uses the <code>"bobyqa"</code> optimizer with <code>maxfun = 2e5</code> .
return_direct	Logical. If <code>TRUE</code> , direct design-based estimates are calculated from <code>data_model</code> and included in the returned object. The default is <code>FALSE</code> .
...	Additional arguments passed to <code>survey::svydesign()</code> . For example, <code>nest = TRUE</code> can be supplied for nested cluster designs.

Details

The model formula must follow `lme4::lmer()` syntax and must include at least one random-effect term.

A random-intercept model can be specified as:

$$Y \sim X1 + X2 + Z1 + Z2 + (1 \mid kab_kota)$$

where Y is the response variable, $X1$ and $X2$ are unit-level auxiliary variables, $Z1$ and $Z2$ are auxiliary variables, and kab_kota identifies the random-intercept grouping level.

The estimation procedure consists of three main steps:

1. A linear multilevel model is fitted to `data_model` using `lme4::lmer()` with restricted maximum likelihood estimation.
2. Unit-level predictions are generated for all observations in `data_proj`. Predictions use `re.form = NULL` and `allow.new.levels = TRUE`.
3. Predicted values are aggregated by domain to obtain synthetic estimates. A design-based residual correction calculated from `data_model` is added to obtain the final projection estimate.

For domain d , the final projection estimator is:

$$\hat{Y}^{PR} * d = \hat{Y}^{SYN} * d + \hat{B} * d$$

where $\hat{Y}^{SYN} * d$ is the synthetic estimate obtained from the projection survey and $\hat{B} * d$ is the design-based residual correction obtained from the model survey.

The plug-in variance estimator is:

$$\widehat{Var}(\hat{Y}^{PR} * d) = \widehat{Var}(\hat{Y}^{SYN} * d) + \widehat{Var}(\hat{B} * d)$$

The plug-in variance does not account for uncertainty in the estimated multilevel model parameters. Fixed-effect predictors in `data_proj` must have levels that already exist in `data_model`. New factor levels for fixed-effect predictors produce an error. In contrast, new grouping levels for random effects are allowed and receive a random-effect contribution of zero.

Fixed-effect predictors with zero variance in `data_model` are removed automatically before model fitting. A note identifying removed predictors is stored in the returned object.

If a domain appears in `data_proj` but has no observations in `data_model`, the residual correction and its variance are set to zero. The final estimate for that domain is therefore equal to its synthetic estimate.

Survey design variables, including cluster identifiers, strata, and sampling weights, are used for domain-level aggregation and residual correction through the **survey** package. They are not used as fitting weights in `lme4::lmer()`.

Value

An object of class "sae_ml_linear" containing:

call The matched function call.

formula The final model formula used for estimation after removal of any zero-variance fixed-effect predictors.

estimator A character string identifying the estimator as "bias_corrected".

fitted_model The fitted `lmerMod` object returned by `lme4::lmer()`.

model_parameters A list containing fixed effects, random effects, variance components, residual standard deviation, and residual variance.

estimates A data frame containing one row for each domain. It includes domain identifiers, estimate, variance, se, and rse.

estimation_details A data frame containing domain identifiers, estimate_synthetic, variance_synthetic, correction, variance_correction, estimate_final, variance_final, se_final, rse_final, n_model, and n_proj.

diagnostics A list containing model diagnostics, including residual standard deviation, residual variance, random-effect variance components, intraclass correlation coefficient where applicable, singularity status, convergence information, number of observations, REML status, log-likelihood, AIC, and BIC.

notes A character vector containing notes generated during estimation, such as removed zero-variance predictors, singular fits, convergence issues, negative variances clamped to zero, or domains without residual correction.

unit_projection Returned only when keep_unit = TRUE. A data frame containing data_proj with an additional .prediction column.

unit_model_residual Returned only when keep_unit = TRUE. A data frame containing data_model with additional .fitted_model and .model_residual columns.

direct_estimator Returned only when return_direct = TRUE. A data frame containing direct design-based estimates, variances, and relative standard errors for each domain.

References

- Kim, J. K., & Rao, J. N. K. (2012). Combining data from two independent surveys: A model-assisted approach. *Biometrika*, 99(1), 85–100.
- Moura, F. A. S., & Holt, D. (1999). Small area estimation using multilevel models. *Survey Methodology*, 25(1), 73–80.
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- Food and Agriculture Organization of the United Nations. (2021). *Guidelines on data disaggregation for SDG indicators using survey data* (1st ed.). <https://doi.org/10.4060/cb3253en>
- Finch, W. H., Bolin, J. E., & Kelley, K. (2014). *Multilevel Modeling Using R*. CRC Press.
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See Also

[lmer](#) for fitting linear multilevel models, [svydesign](#) for survey design specification, and [isSingular](#) for diagnosing singular fits.

Examples

```
data("saeml_modelsvy", package = "saeproject.multilevel")
data("saeml_projsvy", package = "saeproject.multilevel")

result <- sae_ml_linear(
  formula = Y ~ X1 + X2 + X3 + X4 + Z1 + Z2 + (1 | kab_kota),
  data_model = saeml_modelsvy,
```

```

    data_proj = saeml_projsvy,
    domain = "kab_kota",
    cluster_ids = ~1,
    weight = "WEIND",
    strata = "kab_kota",
    summary_function = "mean"
)

summary(result)

```

saeml_modelsvy

saeml_modelsvy

Description

A simulated small-survey dataset used to demonstrate projection-based small area estimation with a linear multilevel regression model.

The dataset is one fixed replication from the simulation design used in the package examples. It contains the target variable and auxiliary variables, and is intended to be used as `data_model` in `sae_ml_linear()`.

Usage

```
saeml_modelsvy
```

Format

A data frame with 250 rows, 11 variables, and 50 domains.

prov Province identifier.

kab_kota District or city identifier used as the domain variable.

id_individu Unique sampled-unit identifier. It is not a PSU or cluster identifier.

Z1 First area-level auxiliary variable.

Z2 Second area-level auxiliary variable.

X1 First unit-level auxiliary variable.

X2 Binary unit-level auxiliary variable.

X3 Third unit-level auxiliary variable.

X4 Fourth unit-level auxiliary variable.

Y Target variable.

WEIND Survey sampling weight.

Details

Simulated model-survey data for saeproj.multilevel.

The dataset contains five sampled units in each of 50 domains. The target variable Y was generated from a random-intercept multilevel population model.

It is designed to be used together with saeml_projsvy.

The simulated survey design does not include a separate PSU or cluster identifier. Therefore, package examples use cluster_ids = ~1.

Source

Simulated data generated from the package study-simulation design.

See Also

[saeml_projsvy](#) and [sae_ml_linear](#).

Examples

```
data(saeml_modelsvy)

dim(saeml_modelsvy)
head(saeml_modelsvy)
table(saeml_modelsvy$kab_kota)
```

saeml_projsvy	<i>saeml_projsvy</i>
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Description

A simulated large-survey dataset used to demonstrate projection-based small area estimation with a linear multilevel regression model.

The dataset is one fixed replication from the simulation design used in the package examples. It contains auxiliary variables and survey design variables, but does not contain the target variable.

It is intended to be used as data_proj in sae_ml_linear().

Usage

```
saeml_projsvy
```

Format

A data frame with 15,000 rows, 10 variables, and 50 domains.

prov Province identifier.

kab_kota District or city identifier used as the domain variable.

id_individu Unique sampled-unit identifier. It is not a PSU or cluster identifier.

Z1 First area-level auxiliary variable.
Z2 Second area-level auxiliary variable.
X1 First unit-level auxiliary variable.
X2 Binary unit-level auxiliary variable.
X3 Third unit-level auxiliary variable.
X4 Fourth unit-level auxiliary variable.
WEIND Survey sampling weight.

Details

Simulated projection-survey data for saeproj.multilevel.

The dataset contains 300 sampled units in each of 50 domains. It is drawn from the same fixed simulated population as saeml_modelsvy, but does not contain the target variable Y.

It is used to generate unit-level predictions and domain-level synthetic estimates.

The simulated survey design does not include a separate PSU or cluster identifier. Therefore, package examples use cluster_ids = ~1.

Source

Simulated data generated from the package study-simulation design.

See Also

[saeml_modelsvy](#) and [sae_ml_linear](#).

Examples

```
data(saeml_projsvy)

dim(saeml_projsvy)
head(saeml_projsvy)
table(saeml_projsvy$kab_kota)
"Y" %in% names(saeml_projsvy)
```

summary.sae_ml_linear *Summary method for sae_ml_linear*

Description

Summary method for sae_ml_linear

Usage

```
## S3 method for class 'sae_ml_linear'
summary(object, n = 6L, ...)
```

Arguments

object	Object of class "sae_ml_linear".
n	Number of rows to display.
...	Further arguments.

Value

Invisibly returns object.

Index

* datasets

saeml_modelsvy, [7](#)

saeml_projsvy, [8](#)

as.data.frame.sae_ml_linear, [2](#)

isSingular, [6](#)

lmer, [3](#), [6](#)

print.sae_ml_linear, [2](#)

sae_ml_linear, [3](#), [8](#), [9](#)

saeml_modelsvy, [7](#), [9](#)

saeml_projsvy, [8](#), [8](#)

summary.sae_ml_linear, [9](#)

svydesign, [6](#)