

Package ‘lphom’

October 13, 2022

Type Package

Title Ecological Inference by Linear Programming under Homogeneity

Version 0.3.1-1

Description Provides a bunch of algorithms based on linear programming for estimating, under the homogeneity hypothesis, RxC ecological contingency tables (or vote transition matrices) using exclusively aggregate data (from voting units). References:
Romero, Pavía, Martín and Romero (2020) <[doi:10.1080/02664763.2020.1804842](https://doi.org/10.1080/02664763.2020.1804842)>.
Pavía and Romero (2021a) <[doi:10.31124/advance.14716638.v1](https://doi.org/10.31124/advance.14716638.v1)>.
Pavía and Romero (2021b) Symmetry estimating RxC vote transfer matrices from aggregate data.

License EPL | file LICENSE

Encoding UTF-8

Imports stats, lpSolve

Depends R (>= 3.5.0)

Suggests ggplot2, scales, Rsymphony (>= 0.1-30)

LazyData true

RoxygenNote 7.1.1

NeedsCompilation no

Author Jose M. Pavía [aut, cre] (<<https://orcid.org/0000-0002-0129-726X>>),
Rafael Romero [aut]

Maintainer Jose M. Pavía <jose.m.pavia@uv.es>

Repository CRAN

Date/Publication 2022-03-21 08:50:02 UTC

R topics documented:

| | |
|------------------------------------|---|
| adjust2integers | 2 |
| confidence_intervals_pjk | 3 |
| error_lphom | 4 |
| France2017D | 6 |
| France2017P | 7 |

| | |
|-------------------------------|-----------|
| lclphom | 8 |
| lphom | 13 |
| lphom_dual | 16 |
| lphom_joint | 18 |
| lp_apriori | 20 |
| ns_lphom | 24 |
| ns_lphom_dual | 29 |
| ns_lphom_joint | 32 |
| plot.lphom | 34 |
| print.lphom | 36 |
| print.summary.lphom | 37 |
| summary.lphom | 37 |
| ts_lphom | 38 |
| ts_lphom_dual | 42 |
| ts_lphom_joint | 45 |
| Index | 48 |

| | |
|-----------------|---|
| adjust2integers | <i>Integer-adjusting of outputs of the lphom-family functions</i> |
|-----------------|---|

Description

Takes as input an object generated with an algorithm of the lphom-family (lphom, ts_lphom, ns_lphom, ts_lphom_dual, ns_lphom_joint, ...) and returns as output an object of the same class as the input object with all their relevant estimated (local and global) transfer matrices of counts updated to their closest integer matrices. The rest of main components of the object are also accordingly updated.

Usage

```
adjust2integers(x, solver = "symphony", ...)
```

Arguments

| | |
|--------|--|
| x | An object output of a lphom family algorithm |
| solver | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only symphony and lp_solve are allowed. By default, symphony. The package Rsymphony needs to be installed for the option symphony to be used. |
| ... | Other arguments passed on the method. Not currently used. |

Details

The updating of the matrices is performed using integer linear programming after imposing all the row- and column-constraints.

Value

An object of the same class and components as `x` with its components properly updated after adjusting the estimated count matrices in `x` using integer linear programming

Author(s)

Jose M. Pavia, <pavia@uv.es>

References

...

Examples

```
mt.ts <- tslphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
mt.ts <- adjust2integers(mt.ts, solver = "lp_solve")
```

confidence_intervals_pjk

Confidence Intervals for lphom estimates

Description

Estimates confidence intervals for the (vote) transfer probabilities obtained with **lphom()**

Usage

```
confidence_intervals_pjk(lphom.object, level = 0.9, num.d = 11, B = 30)
```

Arguments

| | |
|---------------------------|---|
| <code>lphom.object</code> | An object output of the lphom() function. |
| <code>level</code> | A number between 0 and 1 to be used as level of confidence for the intervals. By default 0.90 |
| <code>num.d</code> | Number maximum of different disturbances, <code>d</code> , to be initially considered. Positive integer greater than or equal to 5. By default, 11. |
| <code>B</code> | Integer that determines the number of simulations to be performed for each disturbance value. By default, 30. |

Value

A list with the following components

| | |
|----------------------------|--|
| <code>TM.estimation</code> | Transfer matrix of probability point estimates. |
| <code>TM.lower</code> | Transfer matrix of lower values for the probability estimates. |
| <code>TM.upper</code> | Transfer matrix of upper values for the probability estimates. |
| <code>level</code> | Confidence level used when computing the confidence intervals. |

Author(s)

Jose M. Pavia, <pavia@uv.es>
 Rafael Romero <rromero@eio.upv.es>

References

Romero, R, Pavia, JM, Martin, J and Romero G (2020). Assessing uncertainty of voter transitions estimated from aggregated data. Application to the 2017 French presidential election. *Journal of Applied Statistics*, 47(13-15), 2711-2736. doi: [10.1080/02664763.2020.1804842](https://doi.org/10.1080/02664763.2020.1804842)

Martin, J (2020). Analisis de la incertidumbre en la estimacion de la movilidad electoral mediante el procedimiento plhom. PhD Dissertation.

See Also

[lphom](#) [error_lphom](#)

Examples

```
# Do not run
# mt.lphom <- lphom(France2017P[, 1:8], France2017P[, 9:12], "raw", NULL, FALSE)
# set.seed(533423)
# confidence_intervals_pjk(mt.lphom, level = 0.90, num.d = 5, B = 8)
```

error_lphom

Global error of a lphom estimated table

Description

Estimation of the error index (EI) of a RxC vote transfer matrix obtained with **lphom()**

Usage

```
error_lphom(
  lphom.object,
  upper.alfa = 0.1,
  show.plot = TRUE,
  num.d = 11,
  B = 30
)
```

Arguments

`lphom.object` An object output of the **lphom()** function.
`upper.alfa` Upper bound that will not be exceeded by the EI estimate with a confidence $1 - \alpha$. By default, 0.10.

| | |
|-----------|--|
| show.plot | TRUE/FALSE. Indicates whether the plot showing the relationship between EI and HETe estimated by simulation for the election under study should be displayed as a side-effect. By default, TRUE. |
| num.d | Number maximum of different disturbances, d, to be initially considered. Positive integer greater than or equal to 5. By default, 11. |
| B | Integer that determines the number of simulations to be performed for each disturbance value. By default, 30. |

Value

A list with the following components

| | |
|--------------|--|
| EI.estimate | Point estimate for EI. |
| EI.upper | Upper bound with confidence $1 - \alpha$ of the EI estimate |
| figure | ggplot2 object describing the graphical representation of the relationship between EI and HETe. |
| equation | lm object of the adjustment between EI and HETe. |
| statistics | A four column matrix with the values of HET, HETe, EI and d associated with each simulated scenario. |
| TMs.real | Array with the simulated real transfer matrices associated with each scenario. |
| TMs.estimate | Array with the estimated transfer matrices associated with each scenario. |

Note

ggplot2 is needed to be installed for this function to work.

See equation (12) in Romero et al. (2020) for a definition of the EI index.

Author(s)

Jose M. Pavia, <pavia@uv.es>

Rafael Romero <rromero@eio.upv.es>

References

Romero, R, Pavia, JM, Martin, J and Romero G (2020). Assessing uncertainty of voter transitions estimated from aggregated data. Application to the 2017 French presidential election. *Journal of Applied Statistics*, 47(13-15), 2711-2736. doi: [10.1080/02664763.2020.1804842](https://doi.org/10.1080/02664763.2020.1804842)

See Also

[lphom confidence_intervals_pjk](#)

Examples

```
mt.lphom <- lphom(France2017P[, 1:8], France2017P[, 9:12], "raw", NULL, FALSE)
set.seed(253443)
example <- error_lphom(mt.lphom, upper.alfa = 0.10, show.plot = FALSE, num.d = 5, B = 8)
example$EI.estimate
```

 France2017D

 2017 French Presidential Election. Department official results.

Description

Data frame containing the official results recorded in the first and second rounds of the 2017 French presidential election in the 107 territorial French departments and in an artificial department that groups the French electors living abroad.

Usage

```
data(France2017D)
```

Format

A table containing 108 observations and 13 variables:

ABSTENTION Number of people abstaining (NonVoters) in the first-round of 2017 Presidential Election.

BLANK_NULL Number of people voting either blank or null in the first-round of 2017 Presidential Election.

MACRON Number of votes gained at a national level by Emmanuel Macron in the first-round of 2017 Presidential Election.

LE_PEN Number of votes gained at a national level by Marine Le Pen in the first-round of 2017 Presidential Election.

FILLON Number of votes gained at a national level by Francois Fillon in the first-round of 2017 Presidential Election.

MELENCHON Number of votes gained at a national level by Jean-Luc Melenchon in the first-round of 2017 Presidential Election.

HAMON Number of votes gained at a national level by Benoit Hamon in the first-round of 2017 Presidential Election.

DUPONT.AIGNAN Number of votes gained at a national level by Nicolas Dupont-Aignan in the first-round of 2017 Presidential Election.

OTHERS Number of votes gained at a national level by the rest of candidates in the first-round of 2017 Presidential Election.

ABSTENTION2 Number of people abstaining (NonVoters) in the second-round of 2017 Presidential Election.

BLANK_NULL2 Number of people voting either blank or null in the second-round of 2017 Presidential Election.

MACRON2 Number of votes gained at a national level by Emmanuel Macron in the second-round of 2017 Presidential Election

LE_PEN2 Number of votes gained at a national level by Marine Le Pen in the second-round of 2017 Presidential Election

Source

Own elaboration from data available in <https://www.conseil-constitutionnel.fr/>, retrieved 3 March 2020.

 France2017P

2017 French Presidential Election. Regional provisional results.

Description

Data frame containing the provisional results of the first and second rounds of the 2017 French presidential election in the 12 French continental regions (Auvergne-Rhone-Alpes, Bourgogne-Franche-Comte, Brittany, Centre-Val de Loire, Grand Est, Hauts-de-France, Ile-de-France, Normandy, Nouvelle-Aquitaine, Occitanie, Pays de la Loire, Provence-Alpes-Cote d'Azur) plus an additional region that covers Corsica and the rest of French overseas regions.

Usage

`data(France2017P)`

Format

A table containing 13 observations and 12 variables:

ABSTENTION Number of people abstaining (NonVoters) and voting either blank or null in the first-round of 2017 Presidential Election.

MACRON Number of votes gained at a national level by Emmanuel Macron in the first-round of 2017 Presidential Election.

LE_PEN Number of votes gained at a national level by Marine Le Pen in the first-round of 2017 Presidential Election.

FILLON Number of votes gained at a national level by Francois Fillon in the first-round of 2017 Presidential Election.

MELENCHON Number of votes gained at a national level by Jean-Luc Melenchon in the first-round of 2017 Presidential Election.

HAMON Number of votes gained at a national level by Benoit Hamon in the first-round of 2017 Presidential Election.

DUPONT Number of votes gained at a national level by Nicolas Dupont-Aignan in the first-round of 2017 Presidential Election.

OTHERS Number of votes gained at a national level by the rest of candidates in the first-round of 2017 Presidential Election.

ABSTENTION2 Number of people abstaining (NonVoters) in the second-round of 2017 Presidential Election.

BLANK_NULL Number of people voting either blank or null in the second-round of 2017 Presidential Election.

MACRON2 Number of votes gained at a national level by Emmanuel Macron in the second-round of 2017 Presidential Election

LE_PEN2 Number of votes gained at a national level by Marine Le Pen in the second-round of 2017 Presidential Election

Source

Own elaboration from data available in <https://www.francetvinfo.fr/elections/resultats/>, retrieved 7 May 2017.

| | |
|---------|-------------------------------------|
| lclphom | <i>Implements lclphom algorithm</i> |
|---------|-------------------------------------|

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with lclphom

Usage

```
lclphom(
  votes_election1,
  votes_election2,
  new_and_exit_voters = c("raw", "regular", "simultaneous", "full", "gold"),
  structural_zeros = NULL,
  iter.max = 1000,
  uniform = TRUE,
  distance.local = c("abs", "max", "none"),
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  verbose = FALSE,
  ...
)
```

Arguments

`votes_election1`

data.frame (or matrix) of order IxJ (likely of final order Ix(J-1) in regular and raw scenarios when net entries are estimated by the function) with the votes gained by the *J* political options competing on election 1 (or origin) in the *I* territorial units considered. In general, the row marginals of the *I* tables.

`votes_election2`

data.frame (or matrix) of order IxK (likely of final order Ix(K-1) in regular and raw scenarios when net exits are estimated by the function) with the votes gained by the *K* political options competing on election 2 (or destination) in the *I* territorial units considered. In general, the column marginals of the *I* tables.

`new_and_exit_voters`

A character string indicating the level of information available regarding new entries and exits of the election censuses between the two elections. This argument captures the different options discussed on Section 3 of Romero et al. (2020). This argument admits five values: raw, regular, simultaneous, full and gold. Default, raw. The argument simultaneous should be used in a typical ecological inference problem.

| | |
|-------------------------------|--|
| <code>structural_zeros</code> | Default, NULL. A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2. For instance, when <code>new_and_exit_voters</code> is set to "regular", lphom implicitly states <code>structural_zeros = list(c(J, K))</code> in case exits and/or entries are computed because the sum by rows of <code>votes_election1</code> and <code>votes_election2</code> does not coincide. |
| <code>iter.max</code> | Maximum number of iterations to be performed. The process ends when either the number of iterations reaches <code>iter.max</code> or when there is no error reduction in any local unit between two consecutive iterations. By default, 1000. |
| <code>uniform</code> | A TRUE/FALSE value that indicates if census exits affects all the electoral options in a (relatively) similar fashion in each voting unit: equation (13) of Pavia and Romero (2021a). Default, TRUE. |
| <code>distance.local</code> | A string argument that indicates whether the second step of the <code>lphom_local</code> algorithm should be performed to solve potential indeterminacies of local solutions. Default, "abs". If <code>distance.local = "abs"</code> <code>lphom_local</code> selects in its second step the matrix closer to the temporary global solution under L_1 norm, among the first step compatible matrices. If <code>distance.local = "max"</code> <code>lphom_local</code> selects in its second step the matrix closer to the temporary global solution under L_∞ norm, among the first step compatible matrices. If <code>distance.local = "none"</code> , the second step of <code>lphom_local</code> is not performed. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in each iteration, including zero (<code>lphom</code>) and local solutions. Initial LP matrices are approximate to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>verbose</code> | A TRUE/FALSE value that indicates if the main outputs of the function should be printed on the screen. Default, FALSE. |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Details

Description of the `new_and_exit_voters` argument in more detail.

- `raw`: The default value. This argument accounts for the most plausible scenario when estimating vote transfer matrices: A scenario with two elections elapsed at least some months where only the raw election data recorded in the I territorial units, in which the area under study is divided, are available. In this scenario, net exits (basically deaths) and net entries (basically new young voters) are estimated according to equation (7) of Romero et al. (2020). Constraints defined by equations (8) and (9) of Romero et al. (2020) and (13) of Pavia and

Romero (2021a) are imposed. In this scenario, when net exits and/or net entries are negligible (such as between the first- and second-round of French Presidential elections), they are omitted in the outputs.

- **regular:** For estimating vote transfer matrices, this value accounts for a scenario with two elections elapsed at least some months where (i) the column J of `votes_election1` corresponds to new young electors who have the right to vote for the first time, (ii) net exits (basically a consequence of mortality), and maybe other additional net entries, are computed according equation (7) of Romero et al. (2020), and (iii), when `uniform = TRUE`, within each unit it is assumed that net exits affect equally all the first $J-1$ options of election 1, i.e., equation (13) of Pavia and Romero (2021a) is applied. Constraints (8) and (9) of Romero et al. (2020) are imposed to start the process.
- **simultaneous:** This is the value to be used in a classical ecological inference problems, such as for racial voting, and in a scenario with two simultaneous elections. In this scenario, the sum by rows of `votes_election1` and `votes_election2` must coincide. Constraints defined by equations (8) and (9) of Romero et al. (2020) and (13) of Pavia and Romero (2021a) are not included in the model.
- **full:** This value accounts for a scenario with two elections elapsed at least some months, where: (i) the column $J-1$ of `votes_election1` totals new young electors that have the right to vote for the first time; (ii) the column J of `votes_election1` measures new immigrants that have the right to vote; and (iii) the column K of `votes_election2` corresponds to total exits of the census lists (due to death or emigration). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree and constraints (8) and (9) of Romero et al. (2020) are imposed.
- **gold:** This value accounts for a scenario similar to full, where total exits are separated out between exits due to emigration (column $K-1$ of `votes_election2`) and death (column K of `votes_election2`). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree. The same restrictions as in the above scenario apply but for both columns $K-1$ and K of the vote transition probability matrix

Value

A list with the following components

| | |
|--------------|--|
| VTM | A matrix of order $J \times K$ with the estimated percentages of row-standardized vote transitions from election 1 to election 2. |
| VTM.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2. |
| OTM | A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2. |
| HETe | The estimated heterogeneity index as defined in equation (15) of Pavia and Romero (2021a). |
| VTM.complete | A matrix of order $J' \times K'$ with the estimated proportions of row-standardized vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to <code>net_entries</code> and <code>net_exits</code> even when they are really small, less than 1% in all units. |

| | |
|---------------------------|---|
| VTM.complete.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units. |
| VTM.prop.units | An array of order $J \times K \times I$ with the estimated proportions of vote transitions from election 1 to election 2 attained for each unit in the solution. |
| VTM.votes.units | An array of order $J \times K \times I$ with the estimated matrix of vote transitions from election 1 to election 2 attained for for each unit in the solution. |
| VTM.complete.last.iter | A matrix of order $J \times K$ with the estimated proportions of vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units, corresponding to the final iteration. |
| VTM.sequence | Array of order $J \times K \times (\text{iter}+1)$ (where iter is the efective number of iterations performed) of the intermediate estimated matrices corresponding to each iteration. |
| HETe.sequence | Numeric vector of length iter+1 with the HETe coefficients corresponding to the matrices in VTM.sequence. |
| VTM.prop.units.last.iter | An array of order $J \times K \times I$ with the estimated proportions of vote transitions from election 1 to election 2 attained for each unit in the final iteration. |
| VTM.votes.units.last.iter | An array of order $J \times K \times I$ with the estimated matrix of vote transitions from election 1 to election 2 attained for each unit in the final iteration. |
| zeros | A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2. |
| iter | The real final number of iterations performed before ending the process. |
| iter.units | A matrix of order $I \times (\text{iter}+1)$ with the number of iteration corresponding to the solution selected for each unit in each iteration. |
| errors | A vector of length I with the minimal error observed in the sequence for each unit. It corresponds to the unit-error associated with the solution linked with either VTM.prop.units or VTM.votes.units. |
| inputs | A list containing all the objects with the values used as arguments by the function. |
| origin | A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| destination | A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| EHet | A matrix of order $I \times K$ measuring in each spatial unit a distance to the homogeneity hypothesis, that is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results with the solution in each territorial unit for each option of election 2. |

`solution_init` A list with the main outputs produced by **lphom()**.

- `VTM_init`: A matrix of order $J \times K$ with the estimated percentages of vote transitions from election 1 to election 2 initially obtained by **lphom()**.
- `VTM.votes_init`: A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2 initially obtained by **lphom()**.
- `OTM_init`: A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2 initially obtained by **lphom()**.
- `HETe_init`: The estimated heterogeneity index defined in equation (10) of Romero et al. (2020).
- `EHet_init`: A matrix of order $I \times K$ measuring in each spatial unit the distance to the homogeneity hypothesis, that is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results, using the **lphom()** solution, in each territorial unit for each option of election 2.
- `VTM.complete_init`: A matrix of order $J' \times K'$ with the estimated proportions of vote transitions from election 1 to election 2 initially obtained by **lphom()**, including in regular and raw scenarios the row and the column corresponding to `net_entries` and `net_exits` even when they are really small, less than 1% in all units.
- `VTM.complete.votes_init`: A matrix of order $J' \times K'$ with the estimated vote transitions from election 1 to election 2 initially obtained by **lphom()**, including in regular and raw scenarios the row and the column corresponding to `net_entries` and `net_exits` even when they are really small, less than 1% in all units.

Author(s)

Jose M. Pavia, <pavia@uv.es>

See Also

[lphom](#) [tslphom](#) [nslphom](#)

Other linear programming ecological inference functions: [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
mt.lc <- lclphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
mt.lc$VTM
mt.lc$HETe
mt.lc$solution_init$HETe_init
```

| | |
|-------|-----------------------------------|
| lphom | <i>Implements lphom algorithm</i> |
|-------|-----------------------------------|

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with lphom

Usage

```
lphom(
  votes_election1,
  votes_election2,
  new_and_exit_voters = c("raw", "regular", "simultaneous", "full", "gold"),
  structural_zeros = NULL,
  integers = FALSE,
  verbose = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  ...
)
```

Arguments

votes_election1
data.frame (or matrix) of order IxJ (likely of final order Ix(J-1) in regular and raw scenarios when net entries are estimated by the function) with the votes gained by the *J* political options competing on election 1 (or origin) in the *I* territorial units considered. In general, the row marginals of the *I* tables.

votes_election2
data.frame (or matrix) of order IxK (likely of final order Ix(K-1) in regular and raw scenarios when net exits are estimated by the function) with the votes gained by the *K* political options competing on election 2 (or destination) in the *I* territorial units considered. In general, the column marginals of the *I* tables.

new_and_exit_voters
A character string indicating the level of information available regarding new entries and exits of the election censuses between the two elections. This argument captures the different options discussed on Section 3 of Romero et al. (2020). This argument admits five values: raw, regular, simultaneous, full and gold. Default, raw. The argument simultaneous should be used in a typical ecological inference problem.

structural_zeros
Default NULL. A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2. For instance, when new_and_exit_voters is set to "regular", lphom implicitly states structural_zeros = list(c(J, K)) in case exits and/or entries are computed because the sum by rows of votes_election1 and votes_election2 does not coincide.

| | |
|------------------------------|--|
| <code>integers</code> | A TRUE/FALSE value that indicates whether the LP solution of counts (votes) must be approximate to the closest integer solution using ILP to generate the final solution. Default, FALSE. |
| <code>verbose</code> | A TRUE/FALSE value that indicates if the main outputs of the function should be printed on the screen. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Details

Description of the `new_and_exit_voters` argument in more detail.

- `raw`: The default value. This argument accounts for the most plausible scenario when estimating vote transfer matrices: A scenario with two elections elapsed at least some months where only the raw election data recorded in the I territorial units, in which the area under study is divided, are available. In this scenario, net exits (basically deaths) and net entries (basically new young voters) are estimated according to equation (7) of Romero et al. (2020). Constraints defined by equations (8) and (9) of Romero et al. (2020) are imposed. In this scenario, when net exits and/or net entries are negligible (such as between the first- and second-round of French Presidential elections), they are omitted in the outputs.
- `regular`: For estimating vote transfer matrices, this value accounts for a scenario with two elections elapsed at least some months where (i) the column J of `votes_election1` corresponds to new young electors who have the right to vote for the first time and (ii) net exits (basically a consequence of mortality), and maybe other additional net entries, are computed according equation (7) of Romero et al. (2020), and (iii) we assume net exits affect equally all the first $J-I$ options of election 1, hence (8) and (9) constraints of Romero et al. (2020) are imposed.
- `simultaneous`: This is the value to be used in a classical ecological inference problems, such as for racial voting, and in a scenario with two simultaneous elections. In this scenario, the sum by rows of `votes_election1` and `votes_election2` must coincide. Constraints defined by equations (8) and (9) of Romero et al. (2020) are not included in the model.
- `full`: This value accounts for a scenario with two elections elapsed at least some months, where: (i) the column $J-I$ of `votes_election1` totals new young electors that have the right to vote for the first time; (ii) the column J of `votes_election1` measures new immigrants that have the right to vote; and (iii) the column K of `votes_election2` corresponds to total exits of the census lists (due to death or emigration). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree and constraints (8) and (9) of Romero et al. (2020) are imposed.
- `gold`: This value accounts for a scenario similar to `full`, where total exits are separated out between exits due to emigration (column $K-I$ of `votes_election2`) and death (column K of

votes_election2). In this scenario, the sum by rows of votes_election1 and votes_election2 must agree. The same restrictions as in the above scenario apply but for both columns $K-1$ and K of the vote transition probability matrix

Value

A list with the following components

| | |
|--------------------|--|
| VTM | A matrix of order $J \times K$ with the estimated percentages of row-standardized vote transitions from election 1 to election 2. |
| VTM.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2. |
| OTM | A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2. |
| HETe | The estimated heterogeneity index defined in equation (11) of Romero et al. (2020). |
| VTM.complete | A matrix of order $J' \times K'$ with the estimated proportions of row-standardized vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units. |
| VTM.complete.votes | A matrix of order $J' \times K'$ with the estimated vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units. |
| inputs | A list containing all the objects with the values used as arguments by the function. |
| origin | A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| destination | A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| EHet | A matrix of order $I \times K$ measuring in each spatial unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election 2. |

Author(s)

Jose M. Pavia, <pavia@uv.es>

Rafael Romero <rromero@eio.upv.es>

References

Romero, R, Pavia, JM, Martin, J and Romero G (2020). Assessing uncertainty of voter transitions estimated from aggregated data. Application to the 2017 French presidential election. *Journal of Applied Statistics*, 47(13-15), 2711-2736. doi: [10.1080/02664763.2020.1804842](https://doi.org/10.1080/02664763.2020.1804842)

See Also

[tslphom](#) [nslphom](#) [lclphom](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
lphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
```

| | |
|------------|--|
| lphom_dual | <i>Implements lphom_dual algorithm</i> |
|------------|--|

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with `lphom_dual`

Usage

```
lphom_dual(
  votes_election1,
  votes_election2,
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  ...
)
```

Arguments

| | |
|-----------------|--|
| votes_election1 | data.frame (or matrix) of order IxJ with the counts to be initially mapped to rows. When estimating vote transfer matrices, the votes gained by the <i>J</i> political options competing on election 1 (or origin) in the <i>I</i> territorial units considered. The sum by rows of votes_election1 and votes_election2 must coincide. |
| votes_election2 | data.frame (or matrix) of order IxK with the counts to be initially mapped to columns. When estimating vote transfer matrices, the votes gained by the <i>K</i> political options competing on election 2 (or destination) in the <i>I</i> territorial units considered. In general, The sum by rows of votes_election1 and votes_election2 must coincide. |
| integers | A TRUE/FALSE value that indicates whether the LP solution of counts (votes) must be approximate to the closest integer solution using ILP. Default, FALSE. |
| solver | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |

| | |
|------------------------------|--|
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Value

A list with the following components

| | |
|------------------------------|--|
| <code>VTM.votes.w</code> | The matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
| <code>VTM.votes.a</code> | The matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2, attained simple averaging the two dual solutions. |
| <code>HTEe.w</code> | Estimated heterogeneity index associated to the <code>VTM.votes.w</code> solution. |
| <code>HTEe.a</code> | Estimated heterogeneity index associated to the <code>VTM.votes.a</code> solution. |
| <code>VTM12.w</code> | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the <code>VTM.votes.w</code> solution. |
| <code>VTM21.w</code> | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the <code>VTM.votes.w</code> solution. |
| <code>VTM12.a</code> | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the <code>VTM.votes.a</code> solution. |
| <code>VTM21.a</code> | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the <code>VTM.votes.a</code> solution. |
| <code>lphom.object.12</code> | The output of the <code>lphom</code> function attained solving the problem $X \rightarrow Y$. That is, mapping <code>votes_election1</code> to rows and <code>votes_election2</code> to columns. |
| <code>lphom.object.21</code> | The output of the <code>lphom</code> function attained solving the problem $Y \rightarrow X$. That is, mapping <code>votes_election2</code> to rows and <code>votes_election1</code> to columns. |
| <code>inputs</code> | A list containing all the objects with the values used as arguments by the function. |

Author(s)

Jose M. Pavia, <pavia@uv.es>
 Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM and Romero, R (2021). Symmetry estimating $R \times C$ vote transfer matrices from aggregate data, mimeo.

See Also

[lphom](#) [tslphom_dual](#) [nslphom_dual](#) [lphom_joint](#) [tslphom_joint](#) [nslphom_joint](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
x <- France2017P[, 1:8]
y <- France2017P[, 9:12]
y[,1] <- y[,1] - (rowSums(y) - rowSums(x))
mt <- lphom_dual(x, y)
mt$VTM.votes.w
mt$HETe.w
```

lphom_joint

Implements the lphom_joint algorithm

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with `lphom_joint`

Usage

```
lphom_joint(
  votes_election1,
  votes_election2,
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  ...
)
```

Arguments

`votes_election1`

data.frame (or matrix) of order IxJ with the counts to be initially mapped to rows. When estimating vote transfer matrices, the votes gained by the *J* political options competing on election 1 (or origin) in the *I* territorial units considered. The sum by rows of `votes_election1` and `votes_election2` must coincide.

`votes_election2`

data.frame (or matrix) of order IxK with the counts to be initially mapped to columns. When estimating vote transfer matrices, the votes gained by the *K* political options competing on election 2 (or destination) in the *I* territorial units considered. In general, The sum by rows of `votes_election1` and `votes_election2` must coincide.

| | |
|-----------------|--|
| integers | A TRUE/FALSE value that indicates whether the LP solution of counts (votes) must be approximate to the closest integer solution using ILP. Default, FALSE. |
| solver | A character string indicating the linear programming solver to be used, only lp_solve and symphony are allowed. By default, lp_solve. The package Rsymphony needs to be installed for the option symphony to be used. |
| integers.solver | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only symphony and lp_solve are allowed. By default, symphony. The package Rsymphony needs to be installed for the option symphony to be used. Only used when integers = TRUE. |
| ... | Other arguments to be passed to the function. Not currently used. |

Value

A list with the following components

| | |
|-----------|---|
| VTM.votes | A matrix of order JxK with the estimated cross-distribution of votes of elections 1 and 2. |
| HETe | The estimated heterogeneity index associated to the VTM.votes solution. |
| VTM12 | The matrix of order JxK with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the VTM.votes solution. |
| VTM21 | The matrix of order KxJ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the VTM.votes solution. |
| EHet12 | A matrix of order IxK measuring in each unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election two. The matrix Eik. |
| EHet21 | A matrix of order IxJ measuring in each unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election one. The matrix Eij. |
| inputs | A list containing all the objects with the values used as arguments by the function. |

Author(s)

Jose M. Pavia, <pavia@uv.es>

Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM and Romero, R (2021). Symmetry estimating RxC vote transfer matrices from aggregate data, mimeo.

See Also

[lphom](#) [lphom_dual](#) [tslphom_dual](#) [nslphom_dual](#) [tslphom_joint](#) [nslphom_joint](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
x <- France2017P[, 1:8]
y <- France2017P[, 9:12]
y[,1] <- y[,1] - (rowSums(y) - rowSums(x))
mt <- lphom_joint(x, y)
mt$VTM.votes
mt$HETe
```

lp_apriori

Implements lp_apriori models

Description

Adjusts an initial $J_0 \times K_0$ vote transfer matrix (ecological contingency table) to guarantee (i) congruency with aggregate results and (ii) completeness.

Usage

```
lp_apriori(
  votes_election1,
  votes_election2,
  apriori,
  weights = "constant",
  new_and_exit_voters = "raw",
  uniform = TRUE,
  solver = "lp_solve",
  integers = TRUE,
  integers.solver = "symphony",
  ...
)
```

Arguments

votes_election1

data.frame (or matrix) of order $I \times J_1$ (or vector of length J_1) with the votes gained by (or the numbers corresponding to) the J_1 political options competing on election 1 (or origin) in the I territorial units considered.

votes_election2

data.frame (or matrix) of order $I \times K_2$ (or vector of length K_2) with the votes gained by (or the numbers corresponding to) the K_2 political options competing on election 2 (or destination) in the I territorial units considered.

| | |
|---------------------|--|
| apriori | data.frame (or matrix) of order $J_0 \times K_0$ with an initial estimate of the (row-standardized) voter transition proportions/factions, p_{jk0} , between the first J_0 election options of election 1 and the first K_0 election options of election 2. It could be also a data.frame (matrix) of counts. This matrix can contain some missing values. |
| weights | Either a numeric matrix (or data.frame) of order $J_0 \times K_0$ of weights, w_{jk} , or a character string indicating the structure of weights to be used. As character string this argument admits seven different values: constant, x, xy, expected, counts, sqrt, or sd. Default, constant (i.e., $w_{jk} = 1$). The w_{jk} coefficients measure the (relative) degree of confidence we have in the a priori values p_{jk0} . Everything else constant, the greater a weight w_{jk} the closer the estimated p_{jk} and the p_{jk0} proportions will be. As numeric matrix, this matrix can contain some missing values, usually located in the same cells than the missing values of apriori. |
| new_and_exit_voters | A character string indicating the level of information available regarding new entries and exits of the election censuses between the two elections. This argument captures the different options discussed in Pavia (2022). This argument admits eight values: raw, regular, ordinary, simultaneous, enriched, semifull, full and gold. Default, raw. |
| uniform | A TRUE/FALSE value that indicates if census exits affect all the electoral options in a (relatively) similar fashion; depending on the scenario any equation(s) among equations (6) to (11) of Pavia (2022) could be used in the underlying model. Default, TRUE. |
| solver | A character string indicating the linear programming solver to be used, only lp_solve and symphony are allowed. By default, lp_solve. The package Rsymphony needs to be installed for the option symphony to be used. |
| integers | A TRUE/FALSE value that indicates whether the LP solution of counts (votes) must be approximate to the closest integer solution using ILP to generate the final solution. Default, TRUE. |
| integers.solver | A character string indicating the linear programming solver to be used to the closest integer solution, only symphony and lp_solve are allowed. By default, symphony. The package Rsymphony needs to be installed for the option symphony to be used. Only used when integers = TRUE. |
| ... | Other arguments to be passed to the function. Not currently used. |

Details

Description of the new_and_exit_voters argument in more detail.

- raw: The default value. This argument accounts for the most plausible scenario when adjusting vote transfer matrices. A scenario with two elections elapsed at least some months where only the raw election data recorded in I territorial units (where I can be equal to one), in which the area under study is divided, are available. In this scenario, net exits and net entries are estimated according to equation (7) of Romero et al. (2020). When both net entries and exits are no null, constraint (15) of Pavia (2022) applies. If uniform = TRUE constraints (7) of Pavia

(2022) are also imposed. In this scenario, J could be equal to J_1 or $J_1 + 1$ and K equal to K_2 or $K_2 + 1$.

- **simultaneous**: This is the value to be used in simultaneous elections and when the user is interested in adjusting other type of transfer matrices such as the one that typically arise in classical ecological inference problems, In this scenario, the sum by rows of `votes_election1` and `votes_election2` must coincide. In this case, the function just implements the basic model defined by equations (1) to (5) of Pavia (2022).
- **regular**: This value accounts for a scenario with two elections elapsed at least some months where (i) the column J_1 of `votes_election1` corresponds to new young electors who have the right to vote for the first time, (ii) net exits and maybe other additional net entries are computed according to equation (7) of Romero et al. (2020), and (iii) we can (or not) assume that net exits affect equally all the first $J_1 - 1$ options of election 1. When both net entries and exits are no null, constraints (12) and (15) of Pavia (2022) apply and if `uniform = TRUE` constraints (11) of Pavia (2022) are also imposed. In this scenario, J could be equal to J_1 or $J_1 + 1$ and K equal to K_2 or $K_2 + 1$.
- **ordinary**: This value accounts for a scenario with two elections elapsed at least some months where (i) the column K_1 of `votes_election2` corresponds to electors who died in the interperiod election, (ii) net entries and maybe other additional net exits are computed according to equation (7) of Romero et al. (2020), and (iii) we can assume that exits affect equally all the J_1 options of election 1. When both net entries and exits are no null, constraints (13) and (15) of Pavia (2022) apply and if `uniform = TRUE` constraints (8) and (9) of Pavia (2022) are also imposed. In this scenario, J could be equal to J_1 or $J_1 + 1$ and K equal to K_2 or $K_2 + 1$.
- **enriched**: This value accounts for a scenario that somewhat combine `regular` and `ordinary` ecenarios. We consider two elections elapsed at least some months where (i) the column J_1 of `votes_election1` corresponds to new young electors who have the right to vote for the first time, (ii) the column K_1 of `votes_election2` corresponds to electors who died in the interperiod election, (iii) other (net) entries and (net) exits are computed according to equation (7) of Romero et al. (2020), and (iv) we can assume (or not) that exits affect equally all the $J_1 - 1$ options of election 1. When both net entries and exits are no null, constraints (12) to (15) of Pavia (2022) apply and if `uniform = TRUE` constraints (10) and (11) of Pavia (2022) are also imposed. In this scenario, J could be equal to J_1 or $J_1 + 1$ and K equal to K_2 or $K_2 + 1$.
- **semi full**: This value accounts for a scenario with two elections elapsed at least some months, where: (i) the column J of `votes_election1` totals new electors (young and immigrants) that have the right to vote for the first time and (ii) the column K of `votes_election2` corresponds to total exits of the census lists (due to death or emigration). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree and constraint (15) of Pavia (2022) apply. Additionally, if `uniform = TRUE` constraints (8) of Pavia (2022) are also imposed.
- **full**: This value accounts for a scenario with two elections elapsed at least some months, where (i) the column $J - 1$ of `votes_election1` totals new young electors that have the right to vote for the first time, (ii) the column J of `votes_election1` measures new immigrants that have the right to vote and (iii) the column K of `votes_election2` corresponds to total exits of the census lists (due to death or emigration). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree and constraints (13) and (15) of Pavia (2022) apply. Additionally, if `uniform = TRUE` constraints (11) of Pavia (2022) are also imposed.

- gold: This value accounts for a scenario similar to full, where total exits are separated out between exits due to emigration (column $K - 1$ of `votes_election2`) and death (column K of `votes_election2`). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree. Constraints (12) to (15) of Pavia (2022) apply and if `uniform = TRUE` constraints (10) and (11) of Pavia (2022) are also imposed.

Value

A list with the following components

| | |
|--------------------|--|
| VTM | A matrix of order $J \times K$ with the estimated percentages of row-standardized vote transitions from election 1 to election 2. In raw, regular, ordinary and enriched scenarios when the percentage of net entries is small, less than 1% of the census, net entries are omitted (i.e., $J = J0$) even if estimates for net entries different from zero are obtained. Likewise, in the same scenarios When the percentage of net exits is small, less than 1% of the census, net exits are omitted (i.e., $K = K0$) even if estimates for net exits different from zero are obtained. |
| VTM.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2. In raw, regular, ordinary and enriched scenarios when the percentage of net entries is small, less than 1% of the census, net entries are omitted (i.e., $J = J0$) even if estimates for net entries different from zero are obtained. Likewise, in the same scenarios When the percentage of net exits is small, less than 1% of the census, net exits are omitted (i.e., $K = K0$) even if estimates for net exits different from zero are obtained. |
| weights | A matrix of order $J \times K$ with the weights used to adjust the a priori vote transitions from election 1 to election 2. |
| OTM | A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2. |
| VTM.complete | A matrix of order $J \times K$ with the estimated proportions of row-standardized vote transitions from election 1 to election 2. In raw, regular, ordinary and enriched scenarios, this matrix includes the row and the column corresponding to net entries and net exits (when they are present) even when they are really small. |
| VTM.complete.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2. In raw, regular, ordinary and enriched scenarios, this matrix includes the row and the column corresponding to net entries and net exits (when they are present) even when they are really small. |
| inputs | A list containing all the objects with the values used as arguments by the function. |
| origin | A vector with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| destination | A vector with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |

Author(s)

Jose M. Pavia, <pavia@uv.es>

References

Pavia, JM (2022). Adjusting initial estimates of voter transition probabilities to guarantee consistency and completeness. The function `lp_apriori` of the R-package `lphom`.

See Also

[lphom](#) [tslphom](#) [nslphom](#) [lclphom](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
P0 <- matrix(c(.75, .02, .15, .08, .01, .01, .97, .01,
              .01, .01, .01, .97, .01, .10, .80, .09,
              .20, .30, .30, .20, .10, .10, .50, .30,
              .10, .30, NA, NA, .25, .20, NA, NA),
            byrow = TRUE, 8, 4)
mt <- lp_apriori(France2017P[, 1:8], France2017P[, 9:12], P0, integers = FALSE)
```

nslphom

Implements nslphom algorithm

Description

Estimates $R \times C$ vote transfer matrices (ecological contingency tables) with `nslphom`

Usage

```
nslphom(
  votes_election1,
  votes_election2,
  new_and_exit_voters = c("raw", "regular", "simultaneous", "full", "gold"),
  structural_zeros = NULL,
  iter.max = 10,
  min.first = FALSE,
  uniform = TRUE,
  distance.local = c("abs", "max", "none"),
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  burnin = 0,
  verbose = FALSE,
```



```

    tol = 10^-5,
    ...
)

```

Arguments

- `votes_election1` data.frame (or matrix) of order $I \times J$ (likely of final order $I \times (J-1)$ in regular and raw scenarios when net entries are estimated by the function) with the votes gained by the J political options competing on election 1 (or origin) in the I territorial units considered. In general, the row marginals of the I tables.
- `votes_election2` data.frame (or matrix) of order $I \times K$ (likely of final order $I \times (K-1)$ in regular and raw scenarios when net exits are estimated by the function) with the votes gained by the K political options competing on election 2 (or destination) in the I territorial units considered. In general, the column marginals of the I tables.
- `new_and_exit_voters` A character string indicating the level of information available regarding new entries and exits of the election censuses between the two elections. This argument captures the different options discussed on Section 3 of Romero et al. (2020). This argument admits five values: raw, regular, simultaneous, full and gold. Default, raw. The argument simultaneous should be used in a typical ecological inference problem.
- `structural_zeros` Default, NULL. A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2. For instance, when `new_and_exit_voters` is set to "regular", `lphom` implicitly states `structural_zeros = list(c(J, K))` in case exits and/or entries are computed because the sum by rows of `votes_election1` and `votes_election2` does not coincide.
- `iter.max` Maximum number of iterations to be performed. The process ends when either the number of iterations reaches `iter.max` or when the maximum variation between two consecutive estimates of the probability transfer matrix is less than `tol`. By default, 10.
- `min.first` A TRUE/FALSE value. If FALSE, the matrix associated with the minimum HETe after performing `iter.max` iterations is taken as solution. If TRUE, the associated matrix to the instant in which the first decrease of HETe occurs is taken as solution. The process stops at that moment. In this last scenario (when `min.first = TRUE`), `burnin = 0` is forced and `iter.max` is at least 100. Default, FALSE.
- `uniform` A TRUE/FALSE value that indicates if census exits affects all the electoral options in a (relatively) similar fashion in each voting unit: equation (13) of Pavia and Romero (2021). Default, TRUE.
- `distance.local` A string argument that indicates whether the second step of the `lphom_local` algorithm should be performed to solve potential indeterminacies of local solutions. Default, "abs". If `distance.local = "abs"` `lphom_local` selects in its second step the matrix closer to the temporary global solution under L_1

| | |
|------------------------------|--|
| | norm, among the first step compatible matrices. If <code>distance.local = "max"</code> <code>lphom_local</code> selects in its second step the matrix closer to the temporary global solution under <code>L_Inf</code> norm, among the first step compatible matrices. If <code>distance.local = "none"</code> , the second step of <code>lphom_local</code> is not performed. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in each iteration, including iteration zero (<code>lphom</code>) and intermediate and final local solutions. If TRUE, the initial LP matrices are approximated in each iteration to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>burnin</code> | Number of initial solutions to be discarded before determining the final solution. By default, 0. |
| <code>verbose</code> | A TRUE/FALSE value that indicates if the main outputs of the function should be printed on the screen. Default, FALSE. |
| <code>tol</code> | Maximum deviation allowed between two consecutive iterations. The process ends when the maximum variation between two proportions for the estimation of the transfer matrix between two consecutive iterations is less than <code>tol</code> or the maximum number of iterations, <code>iter.max</code> , has been reached. By default, 0.00001. |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Details

Description of the `new_and_exit_voters` argument in more detail.

- `raw`: The default value. This argument accounts for the most plausible scenario when estimating vote transfer matrices: A scenario with two elections elapsed at least some months where only the raw election data recorded in the I territorial units, in which the area under study is divided, are available. In this scenario, net exits (basically deaths) and net entries (basically new young voters) are estimated according to equation (7) of Romero et al. (2020). Constraints defined by equations (8) and (9) of Romero et al. (2020) and (13) of Pavia and Romero (2021a) are imposed. In this scenario, when net exits and/or net entries are negligible (such as between the first- and second-round of French Presidential elections), they are omitted in the outputs.
- `regular`: For estimating vote transfer matrices, this value accounts for a scenario with two elections elapsed at least some months where (i) the column J of `votes_election1` corresponds to new young electors who have the right to vote for the first time, (ii) net exits (basically a consequence of mortality), and maybe other additional net entries, are computed according equation (7) of Romero et al. (2020), and (iii), when `uniform = TRUE`, within each

unit it is assumed that net exits affect equally all the first $J-1$ options of election 1, i.e., equation (13) of Pavia and Romero (2021a) is applied. Constraints (8) and (9) of Romero et al. (2020) are imposed to start the process.

- **simultaneous:** This is the value to be used in a classical ecological inference problems, such as for racial voting, and in a scenario with two simultaneous elections. In this scenario, the sum by rows of `votes_election1` and `votes_election2` must coincide. Constraints defined by equations (8) and (9) of Romero et al. (2020) and (13) of Pavia and Romero (2021a) are not included in the model.
- **full:** This value accounts for a scenario with two elections elapsed at least some months, where: (i) the column $J-1$ of `votes_election1` totals new young electors that have the right to vote for the first time; (ii) the column J of `votes_election1` measures new immigrants that have the right to vote; and (iii) the column K of `votes_election2` corresponds to total exits of the census lists (due to death or emigration). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree and constraints (8) and (9) of Romero et al. (2020) are imposed.
- **gold:** This value accounts for a scenario similar to full, where total exits are separated out between exits due to emigration (column $K-1$ of `votes_election2`) and death (column K of `votes_election2`). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree. The same restrictions as in the above scenario apply but for both columns $K-1$ and K of the vote transition probability matrix

Value

A list with the following components

| | |
|--------------------|--|
| VTM | A matrix of order $J \times K$ with the estimated percentages of row-standardized vote transitions from election 1 to election 2. |
| VTM.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2. |
| OTM | A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2. |
| HETe | The estimated heterogeneity index as defined in equation (15) of Pavia and Romero (2021). |
| VTM.complete | A matrix of order $J' \times K'$ with the estimated proportions of row-standardized vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to <code>net_entries</code> and <code>net_exits</code> even when they are really small, less than 1% in all units. |
| VTM.complete.votes | A matrix of order $J' \times K'$ with the estimated vote transitions from election 1 to election 2, including in regular and raw scenarios the row and the column corresponding to <code>net_entries</code> and <code>net_exits</code> even when they are really small, less than 1% in all units. |
| VTM.sequence | Array of order $J' \times K' \times (\text{iter}+1)$ (where <code>iter</code> is the effective number of iterations performed) of the estimated matrices corresponding to each iteration. |
| HETe.sequence | Numeric vector of length <code>iter+1</code> with the HETe coefficients corresponding to the matrices in <code>VTM.sequence</code> . |

| | |
|-----------------|--|
| VTM.prop.units | An array of order $J \times K \times I$ with the estimated proportions of vote transitions from election 1 to election 2 attained for each unit in the selected iteration. |
| VTM.votes.units | An array of order $J \times K \times I$ with the estimated matrix of vote transitions from election 1 to election 2 attained for for each unit in the selected iteration. |
| zeros | A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2. |
| iter | The real final number of iterations performed before ending the process. |
| iter.min | Number of the iteration associated to the selected VTM solution. |
| inputs | A list containing all the objects with the values used as arguments by the function. |
| origin | A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| destination | A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections. |
| EHet | A matrix of order $I \times K$ measuring in each spatial unit a distance to the homogeneity hypothesis, that is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results with the solution in each territorial unit for each option of election 2. |
| solution_init | A list with the main outputs produced by lphom() . <ul style="list-style-type: none"> • VTM_init: A matrix of order $J \times K$ with the estimated percentages of vote transitions from election 1 to election 2 initially obtained by lphom(). • VTM.votes_init: A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2 initially obtained by lphom(). • OTM_init: A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2 initially obtained by lphom(). • HETe_init: The estimated heterogeneity index defined in equation (10) of Romero et al. (2020). • EHet_init: A matrix of order $I \times K$ measuring in each spatial unit the distance to the homogeneity hypothesis, that is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results, using the lphom() solution, in each territorial unit for each option of election 2. • VTM.complete_init: A matrix of order $J \times K$ with the estimated proportions of vote transitions from election 1 to election 2 initially obtained by lphom(), including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units. • VTM.complete.votes_init: A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2 initially obtained by lphom(), including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units. |

Author(s)

Jose M. Pavia, <pavia@uv.es>

Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM, and Romero, R (2021). Improving estimates accuracy of voter transitions. Two new algorithms for ecological inference based on linear programming. doi: [10.31124/advance.14716638.v1](https://doi.org/10.31124/advance.14716638.v1).

See Also

[lphom](#) [tslphom](#) [lclphom](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
mt.ns <- nslphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
mt.ns$VTM
mt.ns$HETe
mt.ns$solution_init$HETe_init
```

nslphom_dual

Implements the nslphom_dual algorithm

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with nslphom_dual

Usage

```
nslphom_dual(
  votes_election1,
  votes_election2,
  iter.max = 10,
  min.first = FALSE,
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  tol = 10^-5,
  ...
)
```

Arguments

| | |
|------------------------------|---|
| <code>votes_election1</code> | data.frame (or matrix) of order $I \times J$ with the counts to be initially mapped to rows. When estimating vote transfer matrices, the votes gained by the J political options competing on election 1 (or origin) in the I territorial units considered. The sum by rows of <code>votes_election1</code> and <code>votes_election2</code> must coincide. |
| <code>votes_election2</code> | data.frame (or matrix) of order $I \times K$ with the counts to be initially mapped to columns. When estimating vote transfer matrices, the votes gained by the K political options competing on election 2 (or destination) in the I territorial units considered. In general, The sum by rows of <code>votes_election1</code> and <code>votes_election2</code> must coincide. |
| <code>iter.max</code> | Maximum number of iterations to be performed in each dual linear program. The process ends independently in each system when either the number of iterations reaches <code>iter.max</code> or when the maximum variation between two consecutive estimates of the probability transfer matrix is less than <code>tol</code> . By default, 10. |
| <code>min.first</code> | A TRUE/FALSE value. If FALSE, the matrix associated with the minimum HETe after performing <code>iter.max</code> iterations is taken as solution. If TRUE, the associated matrix to the instant in which the first decrease of HETe occurs is taken as solution. The process stops at that moment. In this last scenario (when <code>min.first = TRUE</code>), <code>iter.max</code> is forced to be at least 100. Default, FALSE. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in each iteration: zero (<code>lphom</code>) and intermediate and final (including unit) solutions. If TRUE, the initial LP matrices are approximated in each iteration to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>tol</code> | Maximum deviation allowed between two consecutive iterations. The process ends when the maximum variation between two proportions for the estimation of the transfer matrix between two consecutive iterations is less than <code>tol</code> or the maximum number of iterations, <code>iter.max</code> , has been reached. By default, 0.00001. |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Value

A list with the following components

| | |
|--------------------------|--|
| <code>VTM.votes.w</code> | The matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
|--------------------------|--|

| | |
|-------------------|---|
| VTM.votes.units.w | The array of order $J \times K \times I$ with the local estimated cross-distributions of votes of elections 1 and 2 by unit, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
| VTM.votes.a | The matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2, attained simple averaging the two dual solutions. |
| VTM.votes.units.a | The matrix of order $J \times K \times I$ with the estimated cross-distributions of votes of elections 1 and 2 by unit, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
| HTEe.w | Estimated heterogeneity index associated to the VTM.votes.w solution. |
| HTEe.a | Estimated heterogeneity index associated to the VTM.votes.a solution. |
| VTM12.w | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the VTM.votes.w solution. |
| VTM21.w | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the VTM.votes.w solution. |
| VTM12.a | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the VTM.votes.a solution. |
| VTM21.a | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the VTM.votes.a solution. |
| nslphom.object.12 | The output of the nslphom function attained solving the problem $X \rightarrow Y$, that is, mapping votes_election1 to rows and votes_election2 to columns. |
| nslphom.object.21 | The output of the nslphom function attained solving the problem $Y \rightarrow X$, that is, mapping votes_election2 to rows and votes_election1 to columns. |
| inputs | A list containing all the objects with the values used as arguments by the function. |

Author(s)

Jose M. Pavia, <pavia@uv.es>
 Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM and Romero, R (2021). Symmetry estimating $R \times C$ vote transfer matrices from aggregate data, mimeo.

See Also

[nslphom](#) [lphom_dual](#) [tslphom_dual](#) [lphom_joint](#) [tslphom_joint](#) [nslphom_joint](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
x <- France2017P[, 1:8]
y <- France2017P[, 9:12]
y[,1] <- y[,1] - (rowSums(y) - rowSums(x))
mt <- nslphom_dual(x, y)
mt$VTM.votes.w
mt$HETe.w
```

nslphom_joint

Implements the nslphom_joint algorithm

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with nslphom_joint

Usage

```
nslphom_joint(
  votes_election1,
  votes_election2,
  iter.max = 10,
  min.first = FALSE,
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  tol = 0.001,
  ...
)
```

Arguments

votes_election1 data.frame (or matrix) of order IxJ with the counts to be initially mapped to rows. When estimating vote transfer matrices, the votes gained by the *J* political options competing on election 1 (or origin) in the *I* territorial units considered. The sum by rows of votes_election1 and votes_election2 must coincide.

votes_election2 data.frame (or matrix) of order IxK with the counts to be initially mapped to columns. When estimating vote transfer matrices, the votes gained by the *K* political options competing on election 2 (or destination) in the *I* territorial units considered. In general, The sum by rows of votes_election1 and votes_election2 must coincide.

iter.max Maximum number of iterations to be performed. The process ends independently when either the number of iterations reaches iter.max or when the maximum variation between two consecutive estimates of both ways probability transfer matrices are less than tol. By default, 10.

| | |
|------------------------------|---|
| <code>min.first</code> | A TRUE/FALSE value. If FALSE, the matrix associated with the minimum HETe after performing <code>iter.max</code> iterations is taken as solution. If TRUE, the associated matrix to the instant in which the first decrease of HETe occurs is taken as solution. The process stops at that moment. In this last scenario (when <code>min.first = TRUE</code>), <code>iter.max</code> is forced to be at least 100. Default, FALSE. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in each iteration: zero (lphom) and intermediate and final (including unit) solutions. If TRUE, the initial LP matrices are approximated in each iteration to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>tol</code> | Maximum deviation allowed between two consecutive iterations. The process ends when the maximum variation between the estimated cross-distributions of votes between two consecutive iterations is less than <code>tol</code> or the maximum number of iterations, <code>iter.max</code> , has been reached. By default, 0.001. |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Value

A list with the following components

| | |
|------------------------------|--|
| <code>VTM.votes</code> | A matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2. |
| <code>HETe</code> | The estimated heterogeneity index associated to the <code>VTM.votes</code> solution. |
| <code>VTM12</code> | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the <code>VTM.votes</code> solution. |
| <code>VTM21</code> | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the <code>VTM.votes</code> solution. |
| <code>VTM.votes.units</code> | An array of order $J \times K \times I$ with the estimated matrix of cross-distributions of votes of elections 1 and 2 attained for each unit in iteration of the solution. |
| <code>iter</code> | The real final number of iterations performed before ending the process. |
| <code>iter.min</code> | Number of the iteration associated to the selected <code>VTM.votes</code> solution. |
| <code>EHet12</code> | A matrix of order $I \times K$ measuring in each unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election two. The matrix E_{ik} . |

| | |
|---------------|--|
| EHet21 | A matrix of order $I \times J$ measuring in each unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election one. The matrix E_{ij} . |
| inputs | A list containing all the objects with the values used as arguments by the function. |
| solution_init | A list with the main outputs produced by lphom_joint() . |

Author(s)

Jose M. Pavia, <pavia@uv.es>
 Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM and Romero, R (2021). Symmetry estimating $R \times C$ vote transfer matrices from aggregate data, mimeo.

See Also

[nslphom](#) [lphom_dual](#) [tslphom_dual](#) [nslphom_dual](#) [lphom_joint](#) [tslphom_joint](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
x <- France2017P[, 1:8]
y <- France2017P[, 9:12]
y[,1] <- y[,1] - (rowSums(y) - rowSums(x))
mt <- nslphom_joint(x, y, iter.max = 3)
mt$VTM.votes
mt$HETe
```

| | |
|------------|--|
| plot.lphom | <i>Graphical representation of a $R \times C$ ecological inference (vote transfer) matrix</i> |
|------------|--|

Description

Plot method for objects obtained with an algorithm of the lphom-family (lphom, tslphom, nslphom, tslphom_dual, nslphom_joint, ...).

Usage

```
## S3 method for class 'lphom'
plot(
  x,
  complete = FALSE,
  margins = TRUE,
  digits = 2,
  row.names = NULL,
  col.names = NULL,
  size.numbers = 6,
  size.labels = 4,
  size.margins = 4,
  colour.cells = "deeppink3",
  colour.grid = "blanchedalmond",
  alpha = 0.5,
  which = NULL,
  ...,
  type = "w",
  show.plot = TRUE
)
```

Arguments

| | |
|--------------|--|
| x | An object output of a lphom family algorithm. |
| complete | A TRUE/FALSE argument informing if the complete matrix should be displayed. In regular and raw scenarios this matrix includes the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units. Default, FALSE |
| margins | A TRUE/FALSE argument informing if the margins of the matrix should be displayed. Default TRUE. |
| digits | Integer indicating the number of decimal places to be shown. Default, 2. |
| row.names | Names to be used for the rows of the matrix. |
| col.names | Names to be used for the columns of the matrix. |
| size.numbers | A reference number indicating the average font size to be used for the transfer numbers. Default, 6. |
| size.labels | A number indicating the font size to be used for labels. Default, 4. |
| size.margins | A number indicating the font size to be used for margin numbers. Default, 4. |
| colour.cells | Background base colour for cells. |
| colour.grid | Colour to be used for grid lines. |
| alpha | A [0,1] number of colour transparency. |
| which | A vector of integers informing the units for which the aggregate transfer matrix should be plotted. Default, NULL, the global matrix is shown. |
| ... | Other arguments passed on to methods. Not currently used. |

| | |
|-----------|--|
| type | A character string indicating the solution (transfer matrix) to be plotted. Only valid for _dual algorithms. type = "w" stands for the weighted solution and type = "a" for the simple average solution. Default w. |
| show.plot | A TRUE/FALSE indicating if the plot should be displayed as a side-effect. By default, TRUE. |

Value

Invisibly returns the (ggplot) description of the plot, which is a list with components that contain the plot itself, the data, information about the scales, panels etc.

Note

ggplot2 is needed to be installed for this function to work.

Author(s)

Jose M. Pavia, <pavia@uv.es>

Examples

```
mt.ns <- nslphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
p <- plot(mt.ns, show.plot = FALSE)
p
```

print.lphom

Print a summary of a lphom-family object

Description

Print method for objects obtained with an algorithm of the lphom-family (lphom, tslphom, nslphom, tslphom_dual, nslphom_joint, ...).

Usage

```
## S3 method for class 'lphom'
print(x, ..., margins = TRUE, digits = 2)
```

Arguments

| | |
|---------|---|
| x | An object output of a lphom family algorithm. |
| ... | Other arguments passed on to methods. Not currently used. |
| margins | A TRUE/FALSE argument informing if the margins of the matrix should be displayed. Default TRUE. |
| digits | Integer indicating the number of decimal places to be shown. Default, 2. |

Author(s)

Jose M. Pavia, <pavia@uv.es>

Examples

```
mt.ns <- nslphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
print(mt.ns, digits = 2, margins = TRUE)
```

print.summary.lphom *Print a summary of a lphom-family object*

Description

Print method for summary.lphom objects

Usage

```
## S3 method for class 'summary.lphom'
print(x, ..., margins = TRUE, digits = 2)
```

Arguments

| | |
|---------|---|
| x | An summary.lphom class object. |
| ... | Other arguments passed on to methods. Not currently used. |
| margins | A TRUE/FALSE argument informing if the margins of the matrix should be displayed. Default TRUE. |
| digits | Integer indicating the number of decimal places to be shown. Default, 2. |

summary.lphom *Summarize a lphom-family object*

Description

Summary method for objects obtained with an algorithm of the lphom-family (lphom, tslphom, nslphom, tslphom_dual, nslphom_joint, ...).

Usage

```
## S3 method for class 'lphom'
summary(object, ...)
```

Arguments

| | |
|--------|---|
| object | An object output of a lphom family algorithm. |
| ... | Other arguments passed on to methods. Not currently used. |

Value

An object of class "summary_lphom".

Author(s)

Jose M. Pavia, <pavia@uv.es>

Examples

```
mt.ns <- nslphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
summary(mt.ns)
```

tslphom

Implements tslphom algorithm

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with tslphom

Usage

```
tslphom(
  votes_election1,
  votes_election2,
  new_and_exit_voters = c("raw", "regular", "simultaneous", "full", "gold"),
  structural_zeros = NULL,
  uniform = TRUE,
  distance.local = c("abs", "max", "none"),
  integers = FALSE,
  verbose = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  ...
)
```

Arguments

votes_election1

data.frame (or matrix) of order IxJ (likely of final order Ix(J-1) in regular and raw scenarios when net entries are estimated by the function) with the votes gained by the *J* political options competing on election 1 (or origin) in the *I* territorial units considered. In general, the row marginals of the *I* tables.

votes_election2

data.frame (or matrix) of order IxK (likely of final order Ix(K-1) in regular and raw scenarios when net exits are estimated by the function) with the votes gained by the *K* political options competing on election 2 (or destination) in the *I* territorial units considered. In general, the column marginals of the *I* tables.

| | |
|----------------------------------|--|
| <code>new_and_exit_voters</code> | A character string indicating the level of information available regarding new entries and exits of the election censuses between the two elections. This argument captures the different options discussed on Section 3 of Romero et al. (2020). This argument admits five values: <code>raw</code> , <code>regular</code> , <code>simultaneous</code> , <code>full</code> and <code>gold</code> . Default, <code>raw</code> . The argument <code>simultaneous</code> should be used in a typical ecological inference problem. |
| <code>structural_zeros</code> | Default NULL. A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2. For instance, when <code>new_and_exit_voters</code> is set to <code>"regular"</code> , <code>lphom</code> implicitly states <code>structural_zeros = list(c(J, K))</code> in case exits and/or entries are computed because the sum by rows of <code>votes_election1</code> and <code>votes_election2</code> does not coincide. |
| <code>uniform</code> | A TRUE/FALSE value that indicates if census exits affects all the electoral options in a (relatively) similar fashion in each voting unit: equation (13) of Pavia and Romero (2021). Default, TRUE. |
| <code>distance.local</code> | A string argument that indicates whether the second step of the <code>lphom_local</code> algorithm should be performed to solve potential indeterminacies of local solutions. Default, <code>"abs"</code> . If <code>distance.local = "abs"</code> <code>lphom_local</code> selects in its second step the matrix closer to the temporary global solution under L_1 norm, among the first step compatible matrices. If <code>distance.local = "max"</code> <code>lphom_local</code> selects in its second step the matrix closer to the temporary global solution under L_∞ norm, among the first step compatible matrices. If <code>distance.local = "none"</code> , the second step of <code>lphom_local</code> is not performed. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in both iterations, including iteration zero (<code>lphom</code>) and final (including unit) solutions. If TRUE, the LP matrices are approximated to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>verbose</code> | A TRUE/FALSE value that indicates if the main outputs of the function should be printed on the screen. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Details

Description of the `new_and_exit_voters` argument in more detail.

- `raw`: The default value. This argument accounts for the most plausible scenario when estimating vote transfer matrices: A scenario with two elections elapsed at least some months

where only the raw election data recorded in the I territorial units, in which the area under study is divided, are available. In this scenario, net exits (basically deaths) and net entries (basically new young voters) are estimated according to equation (7) of Romero et al. (2020). Constraints defined by equations (8) and (9) of Romero et al. (2020) and (13) of Pavia and Romero (2021a) are imposed. In this scenario, when net exits and/or net entries are negligible (such as between the first- and second-round of French Presidential elections), they are omitted in the outputs.

- **regular:** For estimating vote transfer matrices, this value accounts for a scenario with two elections elapsed at least some months where (i) the column J of `votes_election1` corresponds to new young electors who have the right to vote for the first time, (ii) net exits (basically a consequence of mortality), and maybe other additional net entries, are computed according equation (7) of Romero et al. (2020), and (iii), when `uniform = TRUE`, within each unit it is assumed that net exits affect equally all the first $J-1$ options of election 1, i.e., equation (13) of Pavia and Romero (2021a) is applied. Constraints (8) and (9) of Romero et al. (2020) are imposed to start the process.
- **simultaneous:** This is the value to be used in a classical ecological inference problems, such as for racial voting, and in a scenario with two simultaneous elections. In this scenario, the sum by rows of `votes_election1` and `votes_election2` must coincide. Constraints defined by equations (8) and (9) of Romero et al. (2020) and (13) of Pavia and Romero (2021a) are not included in the model.
- **full:** This value accounts for a scenario with two elections elapsed at least some months, where: (i) the column $J-1$ of `votes_election1` totals new young electors that have the right to vote for the first time; (ii) the column J of `votes_election1` measures new immigrants that have the right to vote; and (iii) the column K of `votes_election2` corresponds to total exits of the census lists (due to death or emigration). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree and constraints (8) and (9) of Romero et al. (2020) are imposed.
- **gold:** This value accounts for a scenario similar to full, where total exits are separated out between exits due to emigration (column $K-1$ of `votes_election2`) and death (column K of `votes_election2`). In this scenario, the sum by rows of `votes_election1` and `votes_election2` must agree. The same restrictions as in the above scenario apply but for both columns $K-1$ and K of the vote transition probability matrix

Value

A list with the following components

| | |
|--------------|--|
| VTM | A matrix of order $J \times K$ with the estimated percentages of row-standardized vote transitions from election 1 to election 2. |
| VTM.votes | A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2. |
| OTM | A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2. |
| HETe | The estimated heterogeneity index as defined in equation (15) of Pavia and Romero (2021). |
| VTM.complete | A matrix of order $J' \times K'$ with the estimated proportions of row-standardized vote transitions from election 1 to election 2, including in regular and raw scenarios |

- the row and the column corresponding to `net_entries` and `net_exits` even when they are really small, less than 1% in all units.
- `VTM.complete.votes` A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2, including in `regular` and `raw` scenarios the row and the column corresponding to `net_entries` and `net_exits` even when they are really small, less than 1% in all units.
- `VTM.prop.units` An array of order $J \times K \times I$ with the estimated proportions of vote transitions from election 1 to election 2 attained for each unit after adjusting the `lphom()` initial estimate.
- `VTM.votes.units` An array of order $J \times K \times I$ with the estimated matrix of vote transitions from election 1 to election 2 attained for each unit after adjusting the `lphom()` initial estimate.
- `zeros` A list of vectors of length two, indicating the election options for which no transfer of votes are allowed between election 1 and election 2.
- `inputs` A list containing all the objects with the values used as arguments by the function.
- `origin` A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections.
- `destination` A matrix with the final data used as votes of the origin election after taking into account the level of information available regarding to new entries and exits of the election censuses between the two elections.
- `EHet` A matrix of order $I \times K$ measuring in each spatial unit a distance to the homogeneity hypothesis, that is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results with the solution in each territorial unit for each option of election 2.
- `solution_init` A list with the main outputs produced by `lphom()`.
- `VTM_init`: A matrix of order $J \times K$ with the estimated percentages of vote transitions from election 1 to election 2 initially obtained by `lphom()`.
 - `VTM.votes_init`: A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2 initially obtained by `lphom()`.
 - `OTM_init`: A matrix of order $K \times J$ with the estimated percentages of the origin of the votes obtained for the different options of election 2 initially obtained by `lphom()`.
 - `HETe_init`: The estimated heterogeneity index defined in equation (10) of Romero et al. (2020).
 - `EHet_init`: A matrix of order $I \times K$ measuring in each spatial unit the distance to the homogeneity hypothesis, that is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results, using the `lphom()` solution, in each territorial unit for each option of election 2.
 - `VTM.complete_init`: A matrix of order $J \times K$ with the estimated proportions of vote transitions from election 1 to election 2 initially obtained by `lphom()`, including in `regular` and `raw` scenarios the row and the column corresponding to `net_entries` and `net_exits` even when they are really small, less than 1% in all units.

- VTM.complete.votes_init: A matrix of order $J \times K$ with the estimated vote transitions from election 1 to election 2 initially obtained by **lphom()**, including in regular and raw scenarios the row and the column corresponding to net_entries and net_exits even when they are really small, less than 1% in all units.

Author(s)

Jose M. Pavia, <pavia@uv.es>

Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM, and Romero, R (2021). Improving estimates accuracy of voter transitions. Two new algorithms for ecological inference based on linear programming. doi: [10.31124/advance.14716638.v1](https://doi.org/10.31124/advance.14716638.v1).

See Also

[lphom](#) [nslphom](#) [lclphom](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom_joint\(\)](#)

Examples

```
mt.ts <- tslphom(France2017P[, 1:8] , France2017P[, 9:12], new_and_exit_voters= "raw")
mt.ts$VTM
mt.ts$HETe
mt.ts$solution_init$HETe_init
```

tslphom_dual

Implements the tslphom_dual algorithm

Description

Estimates $R \times C$ vote transfer matrices (ecological contingency tables) with `tslphom_dual`

Usage

```
tslphom_dual(
  votes_election1,
  votes_election2,
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  ...
)
```

Arguments

| | |
|------------------------------|--|
| <code>votes_election1</code> | data.frame (or matrix) of order $I \times J$ with the counts to be initially mapped to rows. When estimating vote transfer matrices, the votes gained by the J political options competing on election 1 (or origin) in the I territorial units considered. The sum by rows of <code>votes_election1</code> and <code>votes_election2</code> must coincide. |
| <code>votes_election2</code> | data.frame (or matrix) of order $I \times K$ with the counts to be initially mapped to columns. When estimating vote transfer matrices, the votes gained by the K political options competing on election 2 (or destination) in the I territorial units considered. In general, The sum by rows of <code>votes_election1</code> and <code>votes_election2</code> must coincide. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in both iterations: zero (lphom) and final (including unit) solutions. If TRUE, the LP matrices are approximated to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Value

A list with the following components

| | |
|--------------------------------|---|
| <code>VTM.votes.w</code> | The matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
| <code>VTM.votes.units.w</code> | The array of order $J \times K \times I$ with the local estimated cross-distributions of votes of elections 1 and 2 by unit, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
| <code>VTM.votes.a</code> | The matrix of order $J \times K$ with the estimated cross-distribution of votes of elections 1 and 2, attained simple averaging the two dual solutions. |
| <code>VTM.votes.units.a</code> | The matrix of order $J \times K \times I$ with the estimated cross-distributions of votes of elections 1 and 2 by unit, attained weighting the two dual solutions using as weights the corresponding HTEe estimates. |
| <code>HTEe.w</code> | Estimated heterogeneity index associated to the <code>VTM.votes.w</code> solution. |
| <code>HTEe.a</code> | Estimated heterogeneity index associated to the <code>VTM.votes.a</code> solution. |

| | |
|-------------------|---|
| VTM12.w | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the VTM.votes.w solution. |
| VTM21.w | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the VTM.votes.w solution. |
| VTM12.a | The matrix of order $J \times K$ with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the VTM.votes.a solution. |
| VTM21.a | The matrix of order $K \times J$ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the VTM.votes.a solution. |
| tslphom.object.12 | The output of the <code>tslphom</code> function attained solving the problem $X \rightarrow Y$, that is, mapping <code>votes_election1</code> to rows and <code>votes_election2</code> to columns. |
| tslphom.object.21 | The output of the <code>tslphom</code> function attained solving the problem $Y \rightarrow X$, that is, mapping <code>votes_election2</code> to rows and <code>votes_election1</code> to columns. |
| inputs | A list containing all the objects with the values used as arguments by the function. |

Author(s)

Jose M. Pavia, <pavia@uv.es>
 Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM and Romero, R (2021). Symmetry estimating $R \times C$ vote transfer matrices from aggregate data, mimeo.

See Also

[tslphom](#) [lphom_dual](#) [nslphom_dual](#) [lphom_joint](#) [tslphom_joint](#) [nslphom_joint](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_joint\(\)](#), [tslphom\(\)](#)

Examples

```
x <- France2017P[, 1:8]
y <- France2017P[, 9:12]
y[,1] <- y[,1] - (rowSums(y) - rowSums(x))
mt <- tslphom_dual(x, y)
mt$VTM.votes.w
mt$HETe.w
```

| | |
|---------------|---|
| tslphom_joint | <i>Implements the tslphom_joint algorithm</i> |
|---------------|---|

Description

Estimates RxC vote transfer matrices (ecological contingency tables) with `tslphom_joint`

Usage

```
tslphom_joint(
  votes_election1,
  votes_election2,
  integers = FALSE,
  solver = "lp_solve",
  integers.solver = "symphony",
  ...
)
```

Arguments

| | |
|------------------------------|--|
| <code>votes_election1</code> | data.frame (or matrix) of order IxJ with the counts to be initially mapped to rows. When estimating vote transfer matrices, the votes gained by the <i>J</i> political options competing on election 1 (or origin) in the <i>I</i> territorial units considered. The sum by rows of <code>votes_election1</code> and <code>votes_election2</code> must coincide. |
| <code>votes_election2</code> | data.frame (or matrix) of order IxK with the counts to be initially mapped to columns. When estimating vote transfer matrices, the votes gained by the <i>K</i> political options competing on election 2 (or destination) in the <i>I</i> territorial units considered. In general, The sum by rows of <code>votes_election1</code> and <code>votes_election2</code> must coincide. |
| <code>integers</code> | A TRUE/FALSE value that indicates whether the problem is solved in integer values in both iterations: zero (<code>lphom</code>) and final (including unit) solutions. If TRUE, the LP matrices are approximated to the closest integer solution solving the corresponding Integer Linear Program. Default, FALSE. |
| <code>solver</code> | A character string indicating the linear programming solver to be used, only <code>lp_solve</code> and <code>symphony</code> are allowed. By default, <code>lp_solve</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. |
| <code>integers.solver</code> | A character string indicating the linear programming solver to be used to approximate to the closest integer solution, only <code>symphony</code> and <code>lp_solve</code> are allowed. By default, <code>symphony</code> . The package <code>Rsymphony</code> needs to be installed for the option <code>symphony</code> to be used. Only used when <code>integers = TRUE</code> . |
| <code>...</code> | Other arguments to be passed to the function. Not currently used. |

Value

A list with the following components

| | |
|-----------------|---|
| VTM.votes | A matrix of order JxK with the estimated cross-distribution of votes of elections 1 and 2. |
| HETe | The estimated heterogeneity index associated to the VTM.votes solution. |
| VTM12 | The matrix of order JxK with the estimated row-standardized proportions of vote transitions from election 1 to election 2 associated to the VTM.votes solution. |
| VTM21 | The matrix of order KxJ with the estimated row-standardized proportions of vote transitions from election 2 to election 1 associated to the VTM.votes solution. |
| VTM.votes.units | An array of order JxKxI with the estimated matrix of cross-distributions of votes of elections 1 and 2 attained for each unit after congruently adjusting the lphom_joint() initial estimate. |
| EHet12 | A matrix of order IxK measuring in each unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election two. The matrix Eik. |
| EHet21 | A matrix of order IxJ measuring in each unit a distance to the homogeneity hypothesis. That is, the differences under the homogeneity hypothesis between the actual recorded results and the expected results in each territorial unit for each option of election one. The matrix Eij. |
| inputs | A list containing all the objects with the values used as arguments by the function. |
| solution_init | A list with the main outputs produced by lphom_joint() . |

Author(s)

Jose M. Pavia, <pavia@uv.es>

Rafael Romero <rromero@eio.upv.es>

References

Pavia, JM and Romero, R (2021). Symmetry estimating RxC vote transfer matrices from aggregate data, mimeo.

See Also

[tslphom](#) [lphom_dual](#) [tslphom_dual](#) [nslphom_dual](#) [lphom_joint](#) [nslphom_joint](#)

Other linear programming ecological inference functions: [lclphom\(\)](#), [lp_apriori\(\)](#), [lphom_dual\(\)](#), [lphom_joint\(\)](#), [lphom\(\)](#), [nslphom_dual\(\)](#), [nslphom_joint\(\)](#), [nslphom\(\)](#), [tslphom_dual\(\)](#), [tslphom\(\)](#)

Examples

```
x <- France2017P[, 1:8]
y <- France2017P[, 9:12]
y[,1] <- y[,1] - (rowSums(y) - rowSums(x))
mt <- tslphom_joint(x, y)
mt$VTM.votes
mt$HETe
```

Index

- * **datasets**
 - France2017D, 6
 - France2017P, 7
- * **linear programming ecological inference functions**
 - lclphom, 8
 - lp_apriori, 20
 - lphom, 13
 - lphom_dual, 16
 - lphom_joint, 18
 - ns_lphom, 24
 - ns_lphom_dual, 29
 - ns_lphom_joint, 32
 - ts_lphom, 38
 - ts_lphom_dual, 42
 - ts_lphom_joint, 45
- adjust2integers, 2
- confidence_intervals_pjk, 3, 5
- error_lphom, 4, 4
- France2017D, 6
- France2017P, 7
- lclphom, 8, 16, 18, 20, 24, 29, 31, 34, 42, 44, 46
- lp_apriori, 12, 16, 18, 20, 20, 29, 31, 34, 42, 44, 46
- lphom, 4, 5, 12, 13, 17, 18, 20, 24, 29, 31, 34, 42, 44, 46
- lphom_dual, 12, 16, 16, 20, 24, 29, 31, 34, 42, 44, 46
- lphom_joint, 12, 16, 18, 18, 24, 29, 31, 34, 42, 44, 46
- ns_lphom, 12, 16, 18, 20, 24, 24, 31, 34, 42, 44, 46
- ns_lphom_dual, 12, 16, 18, 20, 24, 29, 29, 34, 42, 44, 46
- ns_lphom_joint, 12, 16, 18, 20, 24, 29, 31, 32, 42, 44, 46
- plot.lphom, 34
- print.lphom, 36
- print.summary.lphom, 37
- summary.lphom, 37
- ts_lphom, 12, 16, 18, 20, 24, 29, 31, 34, 38, 44, 46
- ts_lphom_dual, 12, 16, 18, 20, 24, 29, 31, 34, 42, 42, 46
- ts_lphom_joint, 12, 16, 18, 20, 24, 29, 31, 34, 42, 44, 45