Package 'stagsynth'

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Type Package

Title Staggered Synthetic Control Estimation and Inference

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Description Implements the Staggered Synthetic Control (SSC) method for estimating treatment effects in panel data with staggered adoption, as proposed by Cao, Lu, and Wu (2020) <doi:10.48550/arXiv.1912.06320>. Constructs synthetic control weights via constrained quadratic programming, estimates heterogeneous treatment effects and event-time average treatment effects on the treated (ATT), and provides placebo-in-time confidence intervals and p-values.

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`stagsynth-package` *stagsynth: Staggered Synthetic Control Estimation and Inference*

Description

Implements the Staggered Synthetic Control (SSC) method of Cao, Lu, and Wu (2020) for estimating treatment effects in panel data with staggered adoption.

Main function

`ssc`: Estimate event-time ATT, overall ATT, and placebo-in-time confidence intervals.

Utilities

- `panel_to_matrices`: Convert long-format panel data to the $N \times T$ matrices expected by `ssc()`.
- `ssc_min_eigenvalue`: Check the design matrix invertibility condition.
- `synthetic_control`: Estimate SC weights for a single treated unit.
- `synthetic_control_batch`: Estimate SC weights for all units.

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`panel_to_matrices` *Convert Long-Format Panel Data to Matrices*

Description

Transform a data frame in long format (one row per unit-period) into the $N \times T$ matrices `Y` and `D` expected by `ssc`.

Usage

```
panel_to_matrices(data, unit, time, outcome, treatment)
```

Arguments

`data`	A data frame.
`unit`	Character: name of the unit identifier column.
`time`	Character: name of the time period column.
`outcome`	Character: name of the outcome variable column.
`treatment`	Character: name of the treatment indicator column (must be 0/1).

Value

A list with components

Y Numeric $N \times T$ outcome matrix.

D Numeric $N \times T$ treatment matrix.

units Sorted vector of unique unit identifiers.

times Sorted vector of unique time periods.

Examples

```
df <- data.frame(
  id   = rep(1:4, each = 6),
  time = rep(1:6, times = 4),
  Y    = rnorm(24),
  D    = c(rep(0, 12), rep(c(0,0,0,1,1,1), 2))
)
mat <- panel_to_matrices(df, unit = "id", time = "time",
                         outcome = "Y", treatment = "D")
```

`plot.ssc` *Plot Event-Time ATT from SSC Estimation*

Description

Plot Event-Time ATT from SSC Estimation

Usage

```
## S3 method for class 'ssc'
plot(
  x,
  main = "Event-time ATT (SSC)",
  xlab = "Event time",
  ylab = "ATT estimate",
  ci = !anyNA(x$ci_lower_event),
  ...
)
```

Arguments

x	An object of class "ssc".
main	Title string.
xlab, ylab	Axis labels.
ci	Logical: draw the confidence band? Default TRUE if inference is available.
...	Additional arguments (currently unused).

Value

A ggplot object (invisibly) if **ggplot2** is available; otherwise a base-R plot is drawn and NULL is returned invisibly.

Examples

```
set.seed(1)
N <- 10; Ttot <- 8
Y <- matrix(rnorm(N * Ttot), N, Ttot)
D <- matrix(0L, N, Ttot)
D[1:3, 5:Ttot] <- 1L   # units 1-3 treated from period 5
fit <- ssc(Y, D, S = 2, alpha = 0.05)
plot(fit)
```

---

print.ssc *Print an ssc Object*

Description

Compact one-line summary of a "ssc" estimation result.

Usage

```
## S3 method for class 'ssc'
print(x, ...)
```

Arguments

x	An object of class "ssc", as returned by ssc.
...	Currently unused.

Value

x, invisibly.

ssc *Staggered Synthetic Control Estimation*

Description

Estimate treatment effects in a panel with staggered adoption using the Staggered Synthetic Control (SSC) method of Cao, Lu, and Wu (2020). Returns event-time ATT, overall ATT, heterogeneous treatment effects, and placebo-in-time confidence intervals.

Usage

```
ssc(Y, D, S = NULL, alpha = 0.05)
```

Arguments

`Y`	Numeric matrix ($N \times T_{total}$) of outcomes. Rows are units, columns are time periods (pre- and post-treatment).
`D`	Binary matrix ($N \times T_{total}$) of treatment indicators. `D[i,t] = 1` if unit i is treated at time t. Treatment must be absorbing (once treated, always treated).
`S`	Integer or `NULL`. Number of post-treatment periods to use. If `NULL` (default), all available post-treatment periods are used.
`alpha`	Significance level for confidence intervals (default 0.05).

Details

The SSC method proceeds in four steps:

1. **SC weights.** For every unit, estimate synthetic control weights from pre-treatment data.
2. **Treatment structure.** Build the treatment assignment matrices A_s that map heterogeneous effects γ to unit-level outcomes at each post-treatment period.
3. **Estimation.** Solve a GLS-type system to recover $\hat{\gamma}$, then aggregate to event-time or overall ATT via a linear map L.
4. **Inference.** Construct a null distribution by applying the same estimator to rolling windows of pre-treatment residuals (placebo-in-time). Confidence intervals are the $\alpha/2$ and $1-\alpha/2$ quantiles of this distribution, shifted by the point estimate.

Value

An object of class `"ssc"`, a list containing:

att_event Numeric vector of length S: event-time ATT estimates (averaged across units at each event time).

ci_lower_event, ci_upper_event Numeric vectors of length S: lower and upper bounds of $(1-\alpha)$ placebo-in-time confidence intervals. `NA` when $T < S$ (too few pre-treatment periods).

att_overall Scalar: overall ATT (simple average of all heterogeneous effects).

ci_lower_overall, ci_upper_overall Scalar CI bounds for the overall ATT. NA when $T < S$.

p_value Two-sided p-value for $H_0 : ATT = 0$ based on the placebo distribution. NA when $T < S$.

gamma_hat Numeric vector of length K: heterogeneous treatment effects for every treated (unit, post-period) pair.

te_mat_hat Numeric $N \times S$ matrix of unit-level treatment effects at each post-treatment period.

B_hat Numeric $N \times N$ SC weight matrix.

a_hat Numeric vector of length N: SC intercepts.

u_hat Numeric $N \times T$ matrix of pre-treatment SC residuals.

min_eigenvalue Smallest eigenvalue of the sample analogue of the design matrix $\sum_s A_s' \hat{M} A_s$. Must be positive for the estimator to be well-defined.

index_mat Integer $K \times 3$ matrix. Each row (s, i, e) records the post-treatment period s, unit i, and event time e for one element of $\hat{\gamma}$.

N, T, S, K Panel dimensions.

alpha Significance level used.

References

Cao, J., Lu, C., and Wu, Y. (2020). "Synthetic Control Inference for Staggered Adoption."

Examples

```
set.seed(1)
N <- 5; Ttot <- 15
Y <- matrix(rnorm(N * Ttot), N, Ttot)
D <- matrix(0L, N, Ttot)
D[1, 8:15] <- 1L
D[2, 10:15] <- 1L
result <- ssc(Y, D)
print(result)
summary(result)
```

`ssc_min_eigenvalue` *Compute Smallest Eigenvalue of the SSC Design Matrix*

Description

A diagnostic function that builds the SSC design matrix $\sum_s A_s' \hat{M} A_s$ and returns its smallest eigenvalue. This matrix must be positive definite for SSC estimates to exist.

Usage

```
ssc_min_eigenvalue(Y, D, S = NULL)
```

Arguments

Y	Numeric matrix ($N \times T_{total}$) of outcomes.
D	Binary matrix ($N \times T_{total}$) of treatment indicators.
S	Number of post-treatment periods (or NULL for all).

Details

A positive value means the SSC estimator is well-defined; a value near zero warns that identification is weak.

Value

A scalar: the smallest eigenvalue.

Examples

```
set.seed(1)
N <- 10; Ttot <- 8
Y <- matrix(rnorm(N * Ttot), N, Ttot)
D <- matrix(0L, N, Ttot)
D[1:3, 5:Ttot] <- 1L   # units 1-3 treated from period 5
ssc_min_eigenvalue(Y, D, S = 2)
```

---

summary.ssc *Summarise an ssc Object*

Description

Prints a detailed summary of a "ssc" estimation result, including design diagnostics, the overall ATT with confidence interval and p-value, and a table of event-time ATT estimates.

Usage

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

Arguments

object	An object of class "ssc", as returned by ssc.
...	Currently unused.

Value

object, invisibly.

`synthetic_control` *Synthetic Control Weights for a Single Treated Unit*

Description

Estimate synthetic control weights by solving a constrained quadratic program on demeaned pre-treatment outcomes: minimise $\|\tilde{Y}_1 - \tilde{X}b\|^2$ subject to $\sum b_j = 1,\ b_j \geq 0$, where $\tilde{Y}_1$ and $\tilde{X}$ are time-demeaned series for the treated unit and controls.

Usage

```
synthetic_control(Y)
```

Arguments

`Y`	Numeric matrix ($N \times T$). The first row is the treated unit; remaining rows are donor (control) units. Each column is a pre-treatment time period.

Details

The QP is solved by `solve.QP`. A small ridge term ($10^{-6}I$) is added to the Hessian for numerical stability when T is close to or smaller than $N - 1$.

Value

A list with components

a_hat Scalar intercept $\hat{a} = \bar{Y}_1 - \bar{X}'\hat{b}$.

b_hat Numeric vector of length N. Entry 1 is 0 (the treated unit's self-weight); entries $2, \ldots, N$ are the non-negative weights summing to 1.

Examples

```
set.seed(1)
Y <- matrix(rnorm(5 * 20), 5, 20)  # 5 units, 20 pre-treatment periods
res <- synthetic_control(Y)
res$b_hat   # SC weights for unit 1
```

`synthetic_control_batch` *Synthetic Control Weights for All Units (Batch)*

Description

For each unit in turn, treat that unit as the "treated" unit and estimate SC weights from the remaining units. This produces an $N \times N$ weight matrix $\hat{B}$ with zeros on the diagonal.

Usage

```
synthetic_control_batch(Y)
```

Arguments

`Y`	Numeric matrix ($N \times T$) of pre-treatment outcomes. Rows are units, columns are time periods.

Value

A list with components

a_hat Numeric vector of length N: unit-level intercepts.

B_hat Numeric $N \times N$ matrix of SC weights. Row i contains the weights used to construct the synthetic control for unit i; $B_{ii} = 0$.

Examples

```
set.seed(1)
Y <- matrix(rnorm(5 * 20), 5, 20)
res <- synthetic_control_batch(Y)
res$B_hat   # N x N weight matrix
```

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