

# Package ‘balnet’

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**Title** Pathwise Estimation of Covariate Balancing Propensity Scores

**Version** 0.0.1

**Description** Provides pathwise estimation of regularized logistic propensity score models using covariate balancing loss functions rather than maximum likelihood. Regularization paths are fit via the 'adelie' elastic-net solver with a 'glmnet'-like interface and objectives that directly target covariate balance for the ATE and ATT.  
For details, see Sverdrup & Hastie (2026) <[doi:10.48550/arXiv.2602.18577](https://doi.org/10.48550/arXiv.2602.18577)>.

**License** MIT + file LICENSE

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**SystemRequirements** C++17

**Imports** Rcpp, Matrix, methods

**Suggests** testthat (>= 3.0.0), knitr, rmarkdown

**URL** <https://github.com/erikcs/balnet>

**BugReports** <https://github.com/erikcs/balnet/issues>

**VignetteBuilder** knitr

**NeedsCompilation** yes

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balnet	<i>Pathwise estimation of covariate balancing propensity scores.</i>
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## Description

Fits regularized logistic regression models using covariate balancing loss functions, targeting the ATE, ATT, or treated/control means.

## Usage

```
balnet(
  X,
  W,
  target = c("ATE", "ATT", "treated", "control"),
  sample.weights = NULL,
  max.imbalance = NULL,
  nlambda = 100L,
  lambda.min.ratio = 0.01,
  lambda = NULL,
  penalty.factor = NULL,
  groups = NULL,
  alpha = 1,
  standardize = TRUE,
  tol = 1e-07,
  maxit = as.integer(1e+05),
  verbose = FALSE,
  num.threads = 1L,
  ...
)
```

**Arguments**

<code>X</code>	A numeric matrix or data frame with pre-treatment covariates.
<code>W</code>	Treatment vector (0 = control, 1 = treated).
<code>target</code>	The target estimand. Default is "ATE".
<code>sample.weights</code>	Optional sample weights. If NULL (default), each unit receives the same weight.
<code>max.imbalance</code>	Optional upper bound on the standardized covariate imbalance. For lasso penalization ( <code>alpha = 1</code> ), there is a one-to-one correspondence between the penalty parameter $\lambda$ and the maximum allowable covariate imbalance. When supplied, <code>max.imbalance</code> is used to adjust the lambda sequence (via <code>lambda.min.ratio</code> ) so that the generated sequence ends at the specified imbalance level.
<code>nlambda</code>	Number of values for lambda if generated automatically. Default is 100.
<code>lambda.min.ratio</code>	Ratio of smallest to largest lambda. Default is 1e-2.
<code>lambda</code>	Optional lambda sequence. By default, it is constructed automatically using <code>nlambda</code> and <code>lambda.min.ratio</code> (or <code>max.imbalance</code> , if specified).
<code>penalty.factor</code>	Penalty factor per feature. Default is 1 (i.e., each feature receives the same penalty).
<code>groups</code>	Optional list of group indices for group penalization.
<code>alpha</code>	Elastic net mixing parameter. Default is 1 (lasso), 0 corresponds to ridge.
<code>standardize</code>	Whether to standardize the input matrix. Should only be FALSE if X already has zero-mean columns with unit variance. For <code>target = "ATT"</code> , standardization should be based on the treated group.
<code>tol</code>	Coordinate descent convergence tolerance. Default is 1e-7.
<code>maxit</code>	Maximum number of coordinate descent iterations. Default is 1e5.
<code>verbose</code>	Whether to display information during fitting. Default is FALSE.
<code>num.threads</code>	Number of threads to use. Default is 1.
<code>...</code>	Additional internal arguments passed to the solver.

**Details**

This function aims to find balancing weights  $\hat{\gamma}_i$ , using logistic propensity scores, that balance covariate means to a target vector, i.e.,

$$\frac{1}{n} \sum_{i=1}^n \hat{\gamma}_i X_i = \bar{X}_{\text{target}}.$$

With lasso regularization (`alpha = 1`), imbalance is controlled in the  $\ell_\infty$  sense, allowing absolute slack of at most  $\lambda$  per covariate.

For `target = "ATE"`, two logistic models are fit, one per arm, with

$$\hat{\gamma}_i^{(1)} = \frac{W_i}{\hat{e}^{(1)}(X_i)}, \quad \hat{\gamma}_i^{(0)} = \frac{1 - W_i}{1 - \hat{e}^{(0)}(X_i)}, \quad \bar{X}_{\text{target}} = \frac{1}{n} \sum_{i=1}^n X_i.$$

$\hat{e}^{(w)}(X_i)$  is the fitted propensity score for arm  $w$ . For `target = "ATT"`, weights balance the control means:

$$\hat{\gamma}_i = (1 - W_i) \frac{\hat{e}^{(0)}(X_i)}{1 - \hat{e}^{(0)}(X_i)}, \quad \bar{X}_{\text{target}} = \frac{1}{\sum W_i} \sum_{i=1}^n W_i X_i.$$

**Value**

A fit balnet object.

**References**

Sverdrup, Erik and Trevor Hastie. "balnet: Pathwise Estimation of Covariate Balancing Propensity Scores". arXiv preprint, arXiv:2602.18577, 2026.

**Examples**

```
# Simulate data with confounding.
n <- 2000
p <- 10
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1.5 + exp(X[, 2] + X[, 3])))
Y <- W + 2 * log(1 + exp(X[, 1] + X[, 2] + X[, 3])) + rnorm(n)

# Fit model targeting the ATE = E[Y(1)] - E[Y(0)].
# Two logistic models are fit: one for treated, one for control.
fit <- balnet(X, W, target = "ATE")

# Print path summary.
print(fit)

# Visualize the path.
plot(fit)

# Plot the standardized covariate imbalance at given lambda.
# Note: lambda = 0 selects the final lambda in the sequence. Scalar values
# are applied to both arms.
plot(fit, lambda = 0)

# Predict propensity scores at end of lambda path.
W.hat <- predict(fit, X, lambda = 0)

# Get balancing weights at end of lambda path.
ipw.weights <- balweights(fit, lambda = 0)

# Estimate ATE using balancing weights.
mean(Y * (ipw.weights$treated - ipw.weights$control))
```

---

balweights

*Extract balancing weights from a balnet object.*

---

**Description**

Retrieves the estimated balancing weights  $\hat{\gamma}$ . Under unconfoundedness, these correspond to inverse probability weights (IPW) for standard treatment effect estimands.

**Usage**

```
balweights(object, lambda = NULL, ...)

## S3 method for class 'balnet'
balweights(object, lambda = NULL, ...)

## S3 method for class 'cv.balnet'
balweights(object, lambda = "lambda.min", ...)
```

**Arguments**

object	A balnet object.
lambda	Value(s) of the penalty parameter lambda at which weights are required. <ul style="list-style-type: none"> <li>• If NULL (default), the full lambda path from the fit is used.</li> <li>• If new values are supplied, linear interpolation is performed. For dual-arm fits (target = "ATE"), lambda can be a list or two-column matrix: the first element/column corresponds to the control arm and the second to the treatment.</li> </ul>
...	Additional arguments (currently ignored).

**Value**

Estimated balancing weights (for contrast fits, target = "ATE" or "ATT", returns a list with entries for each arm).

**Examples**

```
n <- 100
p <- 25
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
fit <- balnet(X, W, target = "ATT")

# Extract balancing weights.
wts <- balweights(fit, lambda = 0)
```

---

coef.balnet

*Extract coefficients from a balnet object.*


---

**Description**

Extract coefficients from a balnet object.

**Usage**

```
## S3 method for class 'balnet'
coef(object, lambda = NULL, ...)
```

**Arguments**

object	A balnet object.
lambda	Value(s) of the penalty parameter lambda at which coefficients are required. <ul style="list-style-type: none"> <li>• If NULL (default), the full lambda path from the fit is used.</li> <li>• If new values are supplied, linear interpolation is performed. For dual-arm fits (target = "ATE"), lambda can be a list or two-column matrix: the first element/column corresponds to the control arm and the second to the treatment.</li> </ul>
...	Additional arguments (currently ignored).

**Value**

Estimated logistic coefficients (for dual-arm fits, returns a list with entries for each arm).

**Examples**

```
n <- 100
p <- 25
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
fit <- balnet(X, W, target = "ATT")

# Extract coefficients.
coefs <- coef(fit)
```

---

coef.cv.balnet	<i>Extract coefficients from a cv.balnet object.</i>
----------------	--

---

**Description**

Extract coefficients from a cv.balnet object.

**Usage**

```
## S3 method for class 'cv.balnet'
coef(object, lambda = "lambda.min", ...)
```

**Arguments**

object            A cv.balnet object.  
 lambda           The lambda to use. Defaults to the cross-validated lambda.  
 ...               Additional arguments (currently ignored).

**Value**

Estimated logistic coefficients (for dual-arm fits, returns a list with entries for each arm).

**Examples**

```
n <- 100
p <- 15
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
cv.fit <- cv.balnet(X, W, target = "ATT")

# Extract coefficients at cross-validated lambda.
coefs <- coef(cv.fit)
```

---

cv.balnet                            *Cross-validation for balnet.*

---

**Description**

Cross-validation for balnet.

**Usage**

```
cv.balnet(
  X,
  W,
  type.measure = c("balance.loss"),
  nfolds = 10,
  foldid = NULL,
  ...
)
```

**Arguments**

X                            A numeric matrix or data frame with pre-treatment covariates.  
 W                            Treatment vector (0: control, 1: treated).  
 type.measure               The loss to minimize for cross-validation. Default is balance loss.

**nfolds**            The number of folds used for cross-validation, default is 10.  
**foldid**            An optional n-vector specifying which fold 1 to nfold a sample belongs to. If NULL, this defaults to `sample(rep(seq(nfolds), length.out = nrow(X)))`.  
**...**                Arguments for `balnet`.

### Value

A fit `cv.balnet` object.

### Examples

```

n <- 100
p <- 15
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATE model.
cv.fit <- cv.balnet(X, W)

# Print CV summary.
print(cv.fit)

# Plot at cross-validated lambda.
plot(cv.fit)

# Predict at cross-validated lambda.
W.hat <- predict(cv.fit, X)

```

---

plot.balnet

*Plot diagnostics for a balnet object.*

---

### Description

Shows effective sample size (ESS) and percent bias reduction (PBR; reduction in mean absolute imbalance) along the regularization path, computed from balancing weights and normalized to percentages. The right-hand axis maps these values to the coefficient of variation (CV) of the weights. Supplying the `lambda` argument displays the standardized covariate imbalance  $(\bar{X}_{\text{weighted}} - \bar{X}_{\text{target}}) / \sigma_{\text{target}}$ , computed using the balancing weights at the specified `lambda`.

### Usage

```

## S3 method for class 'balnet'
plot(x, lambda = NULL, groups = NULL, max = NULL, ...)

```

**Arguments**

x	A balnet object.
lambda	If NULL (default) diagnostics over the lambda path is shown. Otherwise, covariate balance at provided lambda value is shown (if target = "ATE", lambda can be a 2-vector, arm 0 and arm 1.)
groups	Optional named list of contiguous covariate index ranges to aggregate into a single variable before computing covariate imbalance (e.g., list(demographics = 4:12)).
max	The number of covariates to display in covariate balance plot. Defaults to all covariates.
...	Additional arguments.

**Value**

Invisibly returns the information underlying the plot.

**Examples**

```
n <- 100
p <- 25
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
fit <- balnet(X, W, target = "ATT")

# Plot the five covariates with the largest unweighted imbalance
plot(fit, lambda = 0, max = 5)
```

---

plot.cv.balnet      *Plot diagnostics for a cv.balnet object.*

---

**Description**

Plot diagnostics for a cv.balnet object.

**Usage**

```
## S3 method for class 'cv.balnet'
plot(x, lambda = "lambda.min", ...)
```

**Arguments**

x	A cv.balnet object.
lambda	The lambda to use. Defaults to the cross-validated lambda.
...	Additional arguments.

**Value**

Invisibly returns the information underlying the plot.

**Examples**

```
n <- 100
p <- 15
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
cv.fit <- cv.balnet(X, W, target = "ATT")

# Plot at cross-validated lambda.
plot(cv.fit)
```

---

predict.balnet      *Predict using a balnet object.*

---

**Description**

Predict using a balnet object.

**Usage**

```
## S3 method for class 'balnet'
predict(object, newdata, lambda = NULL, type = c("response"), ...)
```

**Arguments**

object	A balnet object.
newdata	A numeric matrix.
lambda	Value(s) of the penalty parameter lambda at which coefficients are required. <ul style="list-style-type: none"> <li>• If NULL (default), the full lambda path from the fit is used.</li> <li>• If new values are supplied, linear interpolation is performed. For dual-arm fits (target = "ATE"), lambda can be a list or two-column matrix: the first element/column corresponds to the control arm and the second to the treatment.</li> </ul>
type	The type of predictions. Default is "response" (propensity scores).
...	Additional arguments (currently ignored).

**Value**

Estimated predictions (for dual-arm fits, returns a list with entries for each arm).

**Examples**

```

n <- 100
p <- 25
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
fit <- balnet(X, W, target = "ATT")

# Predict propensity scores.
W.hat <- predict(fit, X)

```

---

predict.cv.balnet      *Predict using a cv.balnet object.*

---

**Description**

Predict using a cv.balnet object.

**Usage**

```

## S3 method for class 'cv.balnet'
predict(object, newdata, lambda = "lambda.min", type = c("response"), ...)

```

**Arguments**

object	A cv.balnet object.
newdata	A numeric matrix.
lambda	The lambda to use. Defaults to the cross-validated lambda.
type	The type of predictions. Default is "response" (propensity scores).
...	Additional arguments (currently ignored).

**Value**

Estimated predictions (for dual-arm fits, returns a list with entries for each arm).

**Examples**

```

n <- 100
p <- 15
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
cv.fit <- cv.balnet(X, W, target = "ATT")

```

```
# Predict propensity scores at cross-validated lambda.
W.hat <- predict(cv.fit, X)
```

---

print.balnet            *Print a balnet object.*

---

### Description

Print a balnet object.

### Usage

```
## S3 method for class 'balnet'
print(x, digits = max(3L, getOption("digits") - 3L), max = 3, ...)
```

### Arguments

x	A balnet object.
digits	Number of digits to print.
max	Total number of rows to show from the beginning and end of the path
...	Additional print arguments.

### Value

Invisibly returns the printed information.

### Examples

```
n <- 100
p <- 25
X <- matrix(rnorm(n * p), n, p)
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))

# Fit an ATT model.
fit <- balnet(X, W, target = "ATT")

# Print path summary.
print(fit)
```

---

print.cv.balnet	<i>Print a cv.balnet object.</i>
-----------------	----------------------------------

---

**Description**

Print a cv.balnet object.

**Usage**

```
## S3 method for class 'cv.balnet'  
print(x, digits = max(3L, getOption("digits") - 3L), ...)
```

**Arguments**

x	A cv.balnet object.
digits	Number of digits to print.
...	Additional print arguments.

**Value**

Invisibly returns the printed information.

**Examples**

```
n <- 100  
p <- 15  
X <- matrix(rnorm(n * p), n, p)  
W <- rbinom(n, 1, 1 / (1 + exp(1 - X[, 1])))  
  
# Fit an ATT model.  
cv.fit <- cv.balnet(X, W, target = "ATT")  
  
# Print CV summary.  
print(cv.fit)
```

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