Package: hspm (via r-universe)

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Type Package

Title Heterogeneous Spatial Models

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Description Spatial heterogeneity can be specified in various ways. 'hspm' is an ambitious project that aims at implementing various methodologies to control for heterogeneity in spatial models. The current version of 'hspm' deals with spatial and (non-spatial) regimes models. In particular, the package allows to estimate a general spatial regimes model with additional endogenous variables, specified in terms of a spatial lag of the dependent variable, the spatially lagged regressors, and, potentially, a spatially autocorrelated error term. Spatial regime models are estimated by instrumental variables and generalized methods of moments (see Arraiz et al., (2010) <doi:10.1111/j.1467-9787.2009.00618.x>, Bivand and Piras, (2015) <doi:10.18637/jss.v063.i18>, Drukker et al., (2013) <doi:10.1080/07474938.2013.741020>, Kelejian and Prucha, (2010) <doi:10.1016/j.jeconom.2009.10.025>).

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Depends R (>= 4.0)

Imports Formula, sphet, stats, spdep, Matrix, stringr, maxLik, methods, plm, spldv

Suggests splm

License GPL (>= 2)

URL https://github.com/gpiras/hspm

BugReports https://github.com/gpiras/hspm/issues

Repository https://gpiras.r-universe.dev

RemoteUrl https://github.com/gpiras/hspm

RemoteRef HEAD

RemoteSha ba46eb679e9f69476b75c42a6074b14038da27c3

Contents

`baltim` *Baltimore house sales prices and hedonics*

Description

A dataset containing the prices and other attributes of 211 dwelling in Baltimore, MD

Usage

```
baltim
```

Format

A data frame with 211 rows and 17 variables:

STATION ID variable

PRICE sales price, in 1,000 US dollars (MLS)

NROOM number of rooms

DWELL 1 if detached unit, 0 otherwise

NBATH number of bathrooms

PATIO 1 if patio, 0 otherwise

FIREPL 1 if fireplace, 0 otherwise

AC 1 if air conditioning, 0 otherwise

BMENT 1 if basement, 0 otherwise

NSTOR number of stores

GAR number of car space in garage, (0 = no garage)

AGE age of dwellings in years

CITCOU 1 if dwelling is in Baltimore County, 0 otherwise

LOTSZ lot size in hundreds of square feet

SQFT interior living space in hundreds of square feet

X X coordinate on the Maryland grid

Y Y coordinate on the Maryland grid

Source

https://geodacenter.github.io/data-and-lab/

`hsar2sls` *Estimation of HSAR models by 2SLS*

Description

Estimation of HSAR models by 2SLS

Usage

```
hsar2sls(formula, data, listw = NULL, index = NULL, nins = 2, ...)

## S3 method for class 'hsar2sls'
summary(object, MG = TRUE, ...)

## S3 method for class 'summary.hsar2sls'
print(x, digits = max(5, getOption("digits") - 3), ...)
```

Arguments

`formula`	a symbolic description of the model.
`data`	the data of class `pdata.frame`.
`listw`	object. An object of class `listw`, `matrix`, or `Matrix`.
`index`	index.
`nins`	numeric. Number of instrument. `nins` = 2 as default.
`...`	additional arguments passed to `maxLik`
`MG`	logical. If `TRUE`, the Mean Group estimator is returned
`x, object`	an object of class `hsar2sls`
`digits`	the number of digits

hsarML *Estimation of HSAR models by Quasi-Maximum Likelihood*

Description

Estimation of HSAR models by Quasi-Maximum Likelihood

Usage

```
hsarML(
  formula,
  data,
  listw = NULL,
  index = NULL,
  gradient = TRUE,
  average = FALSE,
  init.values = NULL,
  print.init = FALSE,
  otype = c("maxLik", "optim"),
  ...
)

## S3 method for class 'hsarML'
coef(object, ...)

## S3 method for class 'hsarML'
summary(object, MG = TRUE, ...)

## S3 method for class 'summary.hsarML'
print(x, digits = max(5, getOption("digits") - 3), ...)
```

Arguments

`formula`	a symbolic description of the model.
`data`	the data of class `pdata.frame`.
`listw`	object. An object of class `listw`, `matrix`, or `Matrix`.
`index`	index.
`gradient`	logical. Only for testing procedures. Should the analytic gradient be used in the ML optimization procedure? `TRUE` as default. If `FALSE`, then the numerical gradient is used.
`average`	logical. Should the sample log-likelihood function be divided by N?
`init.values`	if not `NULL`, the user must provide a vector of initial parameters for the optimization procedure.
`print.init`	logical. If `TRUE` the initial parameters used in the optimization of the first step are printed.

`otype`	string. A string indicating whether package `maxLik` or `optim` is used in for the numerical optimization.
`...`	additional arguments passed to `maxLik`
`MG`	logical. If `TRUE`, the Mean Group estimator is returned
`x, object`	an object of class `hsarML`
`digits`	the number of digits

`ivregimes` *Estimation of regime models with endogenous variables*

Description

The function `ivregimes` deals with the estimation of regime models. Most of the times the variable identifying the regimes reveals some spatial aspects of the data (e.g., administrative boundaries). The model includes exogenous as well as endogenous variables among the regressors.

Usage

```
ivregimes(formula, data, rgv = NULL, vc = c("homoskedastic", "robust", "OGMM"))
```

Arguments

`formula`	a symbolic description of the model of the form `y ~ x_f | x_v | h_f | h_v` where `y` is the dependent variable, `x_f` are the regressors that do not vary by regimes, `x_v` are the regressors that vary by regimes, `h_f` are the fixed instruments and `h_v` are the instruments that vary by regimes.
`data`	the data of class `data.frame`.
`rgv`	an object of class `formula` to identify the regime variables
`vc`	one of `c("homoskedastic", "robust", "OGMM")`. If `"OGMM"` an optimal weighted GMM is used to estimate the VC matrix.

Details

The basic (non spatial) model with endogenous variables can be written in a general way as:

$$y = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + X\beta + \begin{bmatrix} Y_1 & 0 \\ 0 & Y_2 \end{bmatrix} \begin{bmatrix} \pi_1 \\ \pi_2 \end{bmatrix} + Y\pi + \varepsilon$$

where $y = [y_1', y_2']'$, and the $n_1 \times 1$ vector y_1 contains the observations on the dependent variable for the first regime, and the $n_2 \times 1$ vector y_2 (with $n_1 + n_2 = n$) contains the observations on the dependent variable for the second regime. The $n_1 \times k$ matrix X_1 and the $n_2 \times k$ matrix X_2 are blocks of a block diagonal matrix, the vectors of parameters β_1 and β_2 have dimension $k_1 \times 1$ and $k_2 \times 1$, respectively, X is the $n \times p$ matrix of regressors that do not vary by regime, β is a $p \times 1$ vector of parameters. The three matrices Y_1 $(n_1 \times q)$, Y_2 $(n_2 \times q)$ and Y $(n \times r)$ with corresponding vectors of parameters π_1, π_2 and π, contain the endogenous variables. Finally, $\varepsilon = [\varepsilon_1', \varepsilon_2']'$ is the $n \times 1$ vector of innovations. The model is estimated by two stage least square. In particular:

- If vc = "homoskedastic", the variance-covariance matrix is estimated by $\sigma^2(\hat{Z}'\hat{Z})^{-1}$, where $\hat{Z} = PZ$, $P = H(H'H)^{-1}H'$, H is the matrix of instruments, and Z is the matrix of all exogenous and endogenous variables in the model.
- If vc = "robust", the variance-covariance matrix is estimated by $(\hat{Z}'\hat{Z})^{-1}(\hat{Z}'\hat{\Sigma}\hat{Z})(\hat{Z}'\hat{Z})^{-1}$, where $\hat{\Sigma}$ is a diagonal matrix with diagonal elements $\hat{\sigma}_i$, for $i = 1, ..., n$.
- Finally, if vc = "OGMM", the model is estimated in two steps. In the first step, the model is estimated by 2SLS yielding the residuals $\hat{\varepsilon}$. With the residuals, the diagonal matrix $\hat{\Sigma}$ is estimated and is used to construct the matrix $\hat{S} = H'\hat{\Sigma}H$. Then $\eta_{OWGMM} = (Z'H\hat{S}^{-1}H'Z)^{-1}Z'H\hat{S}^{-1}H'y$, where η_{OWGMM} is the vector of all the parameters in the model, The variance-covariance matrix is: $n(Z'H\hat{S}^{-1}H'Z)^{-1}$.

Value

An object of class ivregimes. A list of five elements. The first element of the list contains the estimation results. The other elements are needed for printing the results.

Author(s)

Gianfranco Piras and Mauricio Sarrias

Examples

```
data("natreg")
form  <- HR90  ~ 0 | MA90 + PS90 + RD90 + UE90 | 0 | MA90 + PS90 + RD90 + FH90 + FP89 + GI89
split  <- ~ REGIONS
mod <- ivregimes(formula = form, data = natreg, rgv = split, vc = "robust")
summary(mod)
mod1 <- ivregimes(formula = form, data = natreg, rgv = split, vc = "OGMM")
summary(mod1)
form1  <- HR90  ~ MA90 + PS90 |  RD90 + UE90 -1 | MA90 + PS90 | RD90 + FH90 + FP89 + GI89 -1
mod2 <- ivregimes(formula = form1, data = natreg, rgv = split, vc = "homoskedastic")
summary(mod2)
```

---

natreg *US Counties Homicides data*

Description

Continental U.S. counties data for homicides and selected socio-economic characteristics. Data for four decennial census years: 1960, 1970, 1980 and 1990.

Usage

```
natreg
```

Format

A data frame with 3085 rows and 73 variables

REGIONS Regions of the US

NOSOUTH Counties not in the south

POLY_ID Poligon id

NAME Counties names

STATE_NAME State name

STATE_FIPS FIPS code for the state

CNTY_FIPS FIPS code for the county

FIPS state and county FIPS code

STFIPS FIPS code for the state

COFIPS FIPS code for the county

FIPSNO state + county FIPS code

SOUTH dummy indicator: 1 if the county is in the southern US

HR60 homicide rate per 100,000 in 1960

HR70 homicide rate per 100,000 in 1970

HR80 homicide rate per 100,000 in 1980

HR90 homicide rate per 100,000 in 1990

HC60 homicide count, three year average centered on 1960

HC70 homicide count, three year average centered on 1970

HC80 homicide count, three year average centered on 1980

HC90 homicide count, three year average centered on 1990

PO60 county population in 1960

PO70 county population in 1970

PO80 county population in 1980

PO90 county population in 1990

RD60 resource deprivation in 1960

RD70 resource deprivation in 1970

RD80 resource deprivation in 1980

RD90 resource deprivation in 1990

PS60 population structure in 1960

PS70 population structure in 1970

PS80 population structure in 1980

PS90 population structure in 1990

UE60 unemployment rate in 1960

UE70 unemployment rate in 1970

UE80 unemployment rate in 1980

UE90 unemployment rate in 1990
DV60 divorce rate in 1960: pct. males over 14 divorced
DV70 divorce rate in 1970: pct. males over 14 divorced
DV80 divorce rate in 1980: pct. males over 14 divorced
DV90 divorce rate in 1990: pct. males over 14 divorced
MA60 median age in 1960
MA70 median age in 1970
MA80 median age in 1980
MA90 median age in 1990
POL60 log of population in 1960
POL70 log of population in 1970
POL80 log of population in 1980
POL90 log of population in 1990
DNL60 log of population density in 1960
DNL70 log of population density in 1970
DNL80 log of population density in 1980
DNL90 log of population density in 1990
MFIL59 log of median family income in 1959
MFIL69 log of median family income in 1969
MFIL79 log of median family income in 1979
MFIL89 log of median family income in 1989
FP59 pct. families below poverty in 1959
FP69 pct. families below poverty in 1969
FP79 pct. families below poverty in 1979
FP89 pct. families below poverty in 1989
BLK60 pct. black in 1960
BLK70 pct. black in 1970
BLK80 pct. black in 1980
BLK90 pct. black in 1990
GI59 Gini index of family income inequality in 1959
GI69 Gini index of family income inequality in 1969
GI79 Gini index of family income inequality in 1979
GI89 Gini index of family income inequality in 1989
FH60 pct. female headed households in 1960
FH70 pct. female headed households in 1970
FH80 pct. female headed households in 1980
FH90 pct. female headed households in 1990
West West regional dummy

Source

https://geodacenter.github.io/data-and-lab/

`regimes` *Estimation of regimes models*

Description

The function `regimes` deals with the estimation of regime models. Most of the times the variable identifying the regimes reveals some spatial aspects of the data (e.g., administrative boundaries).

Usage

```
regimes(formula, data, rgv = NULL, vc = c("homoskedastic", "groupwise"))
```

Arguments

`formula`	a symbolic description of the model of the form `y ~ x_f	x_v` where `y` is the dependent variable, `x_f` are the regressors that do not vary by regimes and `x_v` are the regressors that vary by regimes
`data`	the data of class `data.frame`.
`rgv`	an object of class `formula` to identify the regime variables
`vc`	one of `c("homoskedastic", "groupwise")`. If `groupwise`, the model VC matrix is estimated by weighted least square.

Details

For convenience and without loss of generality, we assume the presence of only two regimes. In this case, the basic (non-spatial) is:

$$y = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + X\beta + \varepsilon$$

where $y = [y_1', y_2']'$, and the $n_1 \times 1$ vector y_1 contains the observations on the dependent variable for the first regime, and the $n_2 \times 1$ vector y_2 (with $n_1 + n_2 = n$) contains the observations on the dependent variable for the second regime. The $n_1 \times k$ matrix X_1 and the $n_2 \times k$ matrix X_2 are blocks of a block diagonal matrix, the vectors of parameters β_1 and β_2 have dimension $k_1 \times 1$ and $k_2 \times 1$, respectively, X is the $n \times p$ matrix of regressors that do not vary by regime, β is a $p \times 1$ vector of parameters and $\varepsilon = [\varepsilon_1', \varepsilon_2']'$ is the $n \times 1$ vector of innovations.

- If `vc = "homoskedastic"`, the model is estimated by OLS.
- If `vc = "groupwise"`, the model is estimated in two steps. In the first step, the model is estimated by OLS. In the second step, the inverse of the (groupwise) residuals from the first step are employed as weights in a weighted least square procedure.

Value

An object of class `lm` and `spregimes`.

Author(s)

Gianfranco Piras and Mauricio Sarrias

Examples

```
data("baltim")
form   <- PRICE  ~ NROOM + NBATH + PATIO + FIREPL + AC + GAR + AGE + LOTSZ + SQFT
split  <- ~ CITCOU
mod <- regimes(formula = form, data = baltim, rgv = split, vc = "groupwise")
summary(mod)
form <- PRICE  ~ AC + AGE + NROOM + PATIO + FIREPL + SQFT | NBATH + GAR + LOTSZ - 1
mod <- regimes(form, baltim, split, vc = "homoskedastic")
summary(mod)
```

---

spregimes — *Estimation of spatial regimes models*

Description

The function spregimes deals with the estimation of spatial regimes models. This is a general function that allows the estimation of various spatial specifications, including the spatial lag regimes model, the spatial error regimes model, and the spatial SARAR regimes model. Since the estimation is based on generalized method of moments (GMM), endogenous variables can be included. For further information on estimation, see details.

Usage

```
spregimes(
  formula,
  data = list(),
  model = c("sarar", "lag", "error", "ols"),
  listw,
  wy_rg = FALSE,
  weps_rg = FALSE,
  initial.value = NULL,
  rgv = NULL,
  het = FALSE,
  verbose = FALSE,
  control = list()
)

## S3 method for class 'spregimes'
coef(object, ...)

## S3 method for class 'spregimes'
```

```
vcov(object, ...)

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

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

## S3 method for class 'summary.spregimes'
print(x, digits = max(5, getOption("digits") - 3), ...)

## S3 method for class 'spregimes'
residuals(object, ...)

## S3 method for class 'spregimes'
fitted(object, ...)
```

Arguments

formula	a symbolic description of the model of the form y ~ x_f | x_v | wx | h_f | h_v | wh where y is the dependent variable, x_f are the regressors that do not vary by regimes, x_v are the regressors that vary by regimes, wx are the spatially lagged regressors, h_f are the instruments that do not vary by regimes, h_v are the instruments that vary by regimes, wh are the spatially lagged instruments.
data	the data of class data.frame.
model	should be one of c("sarar", "lag", "error", "ols")
listw	a spatial weighting matrix of class listw, matrix or Matrix
wy_rg	default wy_rg = FALSE, the lagged dependent variable does not vary by regime (see details)
weps_rg	default weps_rg = FALSE, if TRUE the spatial error term varies by regimes (see details)
initial.value	initial value for the spatial error parameter
rgv	an object of class formula to identify the regime variables
het	heteroskedastic variance-covariance matrix
verbose	print a trace of the optimization
control	select arguments for the optimization
object	an object of class spregimes
...	additional arguments
x	an object of class spregimes
digits	number of digits

Details

The function `spregimes` is a wrapper that allows the estimation of a general spatial regimes model. For convenience and without loss of generality, we assume the presence of only two regimes. In this case the general model can be written as:

$$y = W \begin{bmatrix} y_1 & 0 \\ 0 & y_2 \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix} + \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + X\beta + \begin{bmatrix} Y_1 & 0 \\ 0 & Y_2 \end{bmatrix} \begin{bmatrix} \pi_1 \\ \pi_2 \end{bmatrix} + Y\pi +$$
$$W \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} + WX\delta + W \begin{bmatrix} Y_1 & 0 \\ 0 & Y_2 \end{bmatrix} \begin{bmatrix} \theta_1 \\ \theta_2 \end{bmatrix} + WY\theta + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix}$$

where

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} = W \begin{bmatrix} \varepsilon_1 & 0 \\ 0 & \varepsilon_2 \end{bmatrix} \begin{bmatrix} \rho_1 \\ \rho_2 \end{bmatrix} + u$$

The model includes the spatial lag of the dependent variable, the spatial lag of the regressors, the spatial lag of the errors and, possibly, additional endogenous variables. The function `spregimes` estimates all of the nested specifications deriving from this model. There are, however, some restrictions. For example, if `weps_rg` is set to TRUE, all the regressors in the model should also vary by regimes. The estimation of the different models relies heavily on code available from the package **sphet**.

1. For the spatial lag (or Durbin) regimes model (i.e, when ρ_1 and ρ_2 are zero), an instrumental variable procedure is adopted, where the matrix of instruments is formed by the spatial lags of the exogenous variables and the additional instruments included in the `formula`. A robust estimation of the variance-covariance matrix can be obtained by setting `het = TRUE`.
2. For the spatial error regime models (i.e, when λ_1 and λ_2 are zero), the spatial coefficient(s) are estimated with the GMM procedure described in Kelejian and Prucha (2010) and Drukker et al., (2013). The difference between Kelejian and Prucha (2010) and Drukker et al., (2013), is that the former assume heteroskedastic innovations (`het = TRUE`), while the latter does not (`het = FALSE`).
3. For the SARAR regimes model, the estimation procedure alternates a series of IV and GMM steps. The variance-covariance can be estimated assuming that the innovations are homoskedastic (`het = FALSE`) as well as heteroskedastic (`het = TRUE`).

Value

An object of class “`spregimes`”

Author(s)

Gianfranco Piras and Mauricio Sarrias

References

Arraiz, I. and Drukker, M.D. and Kelejian, H.H. and Prucha, I.R. (2010) A spatial Cliff-Ord-type Model with Heteroskedastic Innovations: Small and Large Sample Results, *Journal of Regional Sciences*, **50**, pages 592–614.

Drukker, D.M. and Egger, P. and Prucha, I.R. (2013) On Two-step Estimation of a Spatial Auto regressive Model with Autoregressive Disturbances and Endogenous Regressors, *Econometric Review*, **32**, pages 686–733.

Kelejian, H.H. and Prucha, I.R. (2010) Specification and Estimation of Spatial Autoregressive Models with Autoregressive and Heteroskedastic Disturbances, *Journal of Econometrics*, **157**, pages 53–67.

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Gianfranco Piras, Paolo Postiglione (2022). A deeper look at impacts in spatial Durbin model with sphet. *Geographical Analysis*, 54(3), 664-684.

Luc Anselin, Sergio J. Rey (2014). *Modern Spatial Econometrics in Practice: A Guide to GeoDa, GeoDaSpace and PySal.* GeoDa Press LLC.

Examples

```
data("natreg")
data("ws_6")

form <-  HR90  ~ 0 | MA90 + PS90 +
RD90 + UE90 | 0 | 0 | MA90 + PS90 +
RD90 + FH90 + FP89 + GI89 | 0

form1 <-  HR90  ~ MA90 -1 |  PS90 +
RD90 + UE90 | 0 | MA90 -1 |  PS90 +
RD90 + FH90 + FP89 + GI89 | 0

form2 <-  HR90  ~ MA90 -1 |  PS90 +
RD90 + UE90 | MA90 | MA90 -1 |  PS90 +
RD90 + FH90 + FP89 + GI89 | 0

form3 <-  HR90  ~ MA90 -1 |  PS90 +
RD90 + UE90 | MA90 | MA90 -1 |  PS90 +
RD90 + FH90 + FP89 + GI89 | GI89

form4 <-  HR90  ~ MA90 -1 |  PS90 +
RD90 + UE90 | MA90 + RD90 | MA90 -1 |  PS90 +
RD90 + FH90 + FP89 + GI89 | GI89


split  <- ~ REGIONS

####################################################
# Linear model with regimes and lagged regressors #
####################################################
mod <- spregimes(formula = form2, data = natreg,
rgv = split, listw = ws_6, model = "ols")
summary(mod)

mod1 <- spregimes(formula = form3, data = natreg,
rgv = split, listw = ws_6, model = "ols")
summary(mod1)
```

```
mod2 <- spregimes(formula = form4, data = natreg,
rgv = split, listw = ws_6, model = "ols")
summary(mod2)


################################
# Spatial Error regimes model #
################################
mod <- spregimes(formula = form, data = natreg,
rgv = split, listw = ws_6, model = "error", het = TRUE)
summary(mod)
mod1 <- spregimes(formula = form, data = natreg,
rgv = split, listw = ws_6, model = "error",
weps_rg = TRUE, het = TRUE)
summary(mod1)
mod2 <- spregimes(formula = form1, data = natreg,
rgv = split, listw = ws_6, model = "error", het = TRUE)
summary(mod2)

################################
#  Spatial Lag regimes model  #
################################
mod4 <- spregimes(formula = form, data = natreg,
rgv = split, listw = ws_6, model = "lag",
het = TRUE, wy_rg = TRUE)
summary(mod4)
mod5 <- spregimes(formula = form1, data = natreg,
rgv = split, listw = ws_6, model = "lag",
het = TRUE, wy_rg = TRUE)
summary(mod5)

################################
# Spatial SARAR regimes model #
################################
mod6 <- spregimes(formula = form, data = natreg,
rgv = split, listw = ws_6, model = "sarar",
het = TRUE, wy_rg = TRUE, weps_rg = TRUE)
summary(mod6)
mod7 <- spregimes(formula = form, data = natreg,
rgv = split, listw = ws_6, model = "sarar",
het = TRUE, wy_rg = FALSE, weps_rg = FALSE)
summary(mod7)
mod8 <- spregimes(formula = form1, data = natreg,
rgv = split, listw = ws_6, model = "sarar",
het = TRUE, wy_rg = TRUE, weps_rg = FALSE)
summary(mod8)
```

---

ws_6 *Spatial weighting matrix for the US Counties Homicides data*

Description

ws_6 is a spatial weights matrix based on the 6 nearest neighbors for the Continental U.S. counties data for homicides

Usage

```
ws_6
```

Format

A spatial weighting matrix of class `Matrix`

Source

https://geodacenter.github.io/data-and-lab/

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