

```

# Spatial Econometrics in R
# Copyright 2013 by Ani Katchova

# install.packages("spdep")
library(spdep)

data(columbus)

mydata <- columbus
attach(mydata)
Y <- cbind(CRIME)
X <- cbind(INC, HOVAL)
xy <- cbind(mydata$X, mydata$Y)
neighbors <- col.gal.nb
coords <- coords

# Neighbors summary
summary(neighbors)
plot(neighbors, coords)

# Descriptive statistics
summary(Y)
summary(X)

# OLS regression
olsreg <- lm(Y ~ X)
summary(olsreg)

## SPATIAL ANALYSIS BASED ON CONTIGUITY

# Spatial weight matrix based on contiguity
listw <- nb2listw(neighbors)
summary(listw)

# Moran's I test
moran.test(CRIME, listw)
moran.plot(CRIME, listw)

# Lagrange multiplier test for spatial lag and spatial error dependencies
lm.LMtests(olsreg, listw, test=c("LMlag", "LMerr"))

# Spatial lag model
spatial.lag <- lagsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)
summary(spatial.lag)

# Spatial error model
spatial.error <- errorsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)
summary(spatial.error)

## SPATIAL ANALYSIS BASED ON DISTANCE WEIGHT MATRIX

# Spatial weight matrix based on distance (with lower and upper bounds for distance,
d1 and d2)
nb <- dnearneigh(xy, d1=0, d2=10)

```

```
listw <- nb2listw(nb, style="W")
summary(listw)

# Moran's I test
moran.test(CRIME, listw)
moran.plot(CRIME, listw)

# Lagrange multiplier test for spatial lag and spatial error dependencies
lm.LMtests(olsreg, listw, test=c("LMlag", "LMerr"))

# Spatial lag model
spatial.lag1 <- lagsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)
summary(spatial.lag1)

# Spatial error model
spatial.error1 <- errorsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)
summary(spatial.error1)
```

```

> # Spatial Econometrics in R
> # Copyright 2013 by Ani Katchova
>
> # install.packages("spdep")
> library(spdep)
Loading required package: sp
Loading required package: boot
Loading required package: Matrix
Loading required package: lattice

Attaching package: 'lattice'

The following object(s) are masked from 'package:boot':

    melanoma

Loading required package: MASS
Loading required package: nlme
Loading required package: maptools
Loading required package: foreign
Loading required package: grid
Checking rgeos availability: FALSE
    Note: when rgeos is not available, polygon geometry computations in maptools
depend on gpclib,
    which has a restricted licence. It is disabled by default;
    to enable gpclib, type gpclibPermit()
Loading required package: deldir
deldir 0.0-21
Loading required package: coda
Loading required package: splines
>
> data(columbus)
>
> mydata <- columbus
> attach(mydata)
> Y <- cbind(CRIME)
> X <- cbind(INC, HOVAL)
> xy <- cbind(mydata$X, mydata$Y)
> neighbors <- col.gal.nb
> coords <- coords
>
> # Neighbors summary
> summary(neighbors)
Neighbour list object:
Number of regions: 49
Number of nonzero links: 230
Percentage nonzero weights: 9.579342
Average number of links: 4.693878
Link number distribution:

  2  3  4  5  6  7  8  9 10
  7  7 13  4  9  6  1  1  1
7 least connected regions:
1005 1008 1045 1047 1049 1048 1015 with 2 links
1 most connected region:

```

```

1017 with 10 links
> plot(neighbors, coords)
>
> # Descriptive statistics
> summary(Y)
      CRIME
Min.   : 0.1783
1st Qu.:20.0485
Median :34.0008
Mean   :35.1288
3rd Qu.:48.5855
Max.   :68.8920
> summary(X)
      INC      HOVAL
Min.   : 4.477   Min.   :17.90
1st Qu.: 9.963   1st Qu.:25.70
Median :13.380   Median :33.50
Mean   :14.375   Mean   :38.44
3rd Qu.:18.324   3rd Qu.:43.30
Max.   :31.070   Max.   :96.40
>
> # OLS regression
> olsreg <- lm(Y ~ X)
> summary(olsreg)

Call:
lm(formula = Y ~ X)

Residuals:
    Min       1Q   Median       3Q      Max
-34.418  -6.388  -1.580   9.052  28.649

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  68.6190     4.7355  14.490 < 2e-16 ***
XINC         -1.5973     0.3341  -4.780 1.83e-05 ***
XHOVAL       -0.2739     0.1032  -2.654  0.0109 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 11.43 on 46 degrees of freedom
Multiple R-squared:  0.5524,    Adjusted R-squared:  0.5329
F-statistic: 28.39 on 2 and 46 DF,  p-value: 9.341e-09

>
> ## SPATIAL ANALYSIS BASED ON CONTIGUITY
>
> # Spatial weight matrix based on contiguity
> listw <- nb2listw(neighbors)
> summary(listw)
Characteristics of weights list object:
Neighbour list object:
Number of regions: 49
Number of nonzero links: 230
Percentage nonzero weights: 9.579342

```

Average number of links: 4.693878

Link number distribution:

```
  2  3  4  5  6  7  8  9 10
  7  7 13  4  9  6  1  1  1
7 least connected regions:
1005 1008 1045 1047 1049 1048 1015 with 2 links
1 most connected region:
1017 with 10 links
```

Weights style: W

Weights constants summary:

```
      n  nn S0      S1      S2
W 49 2401 49 23.48489 204.6687
```

>

> # Moran's I test

> moran.test(CRIME, listw)

Moran's I test under randomisation

data: CRIME

weights: listw

Moran I statistic standard deviate = 5.3427, p-value = 4.578e-08

alternative hypothesis: greater

sample estimates:

Moran I statistic	Expectation	Variance
0.485770914	-0.020833333	0.008991121

> moran.plot(CRIME, listw)

>

> # Lagrange multiplier test for spatial lag and spatial error dependencies

> lm.LMtests(olsreg, listw, test=c("LMlag", "LMerr"))

Lagrange multiplier diagnostics for spatial dependence

data:

model: lm(formula = Y ~ X)

weights: listw

LMlag = 7.8557, df = 1, p-value = 0.005066

Lagrange multiplier diagnostics for spatial dependence

data:

model: lm(formula = Y ~ X)

weights: listw

LMerr = 4.6111, df = 1, p-value = 0.03177

>

> # Spatial lag model

> spatial.lag <- lagsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)

> summary(spatial.lag)

```
Call:lagsarlm(formula = CRIME ~ INC + HOVAL, data = mydata, listw = listw)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-37.4497093	-5.4565567	0.0016387	6.7159553	24.7107978

Type: lag

Coefficients: (asymptotic standard errors)

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	46.851431	7.314754	6.4051	1.503e-10
INC	-1.073533	0.310872	-3.4533	0.0005538
HOVAL	-0.269997	0.090128	-2.9957	0.0027381

Rho: 0.40389, LR test value: 8.4179, p-value: 0.0037154

Asymptotic standard error: 0.12071

z-value: 3.3459, p-value: 0.00082027

Wald statistic: 11.195, p-value: 0.00082027

Log likelihood: -183.1683 for lag model

ML residual variance (sigma squared): 99.164, (sigma: 9.9581)

Number of observations: 49

Number of parameters estimated: 5

AIC: 376.34, (AIC for lm: 382.75)

LM test for residual autocorrelation

test value: 0.19184, p-value: 0.66139

>

> # Spatial error model

> spatial.error <- errorsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)

> summary(spatial.error)

```
Call:errorsarlm(formula = CRIME ~ INC + HOVAL, data = mydata, listw = listw)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-34.45950	-6.21730	-0.69775	7.65256	24.23631

Type: error

Coefficients: (asymptotic standard errors)

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	61.053618	5.314875	11.4873	< 2.2e-16
INC	-0.995473	0.337025	-2.9537	0.0031398
HOVAL	-0.307979	0.092584	-3.3265	0.0008794

Lambda: 0.52089, LR test value: 6.4441, p-value: 0.011132

Asymptotic standard error: 0.14129

z-value: 3.6868, p-value: 0.00022713

Wald statistic: 13.592, p-value: 0.00022713

Log likelihood: -184.1552 for error model

ML residual variance (sigma squared): 99.98, (sigma: 9.999)

Number of observations: 49

Number of parameters estimated: 5

AIC: 378.31, (AIC for lm: 382.75)

```

>
>
> ## SPATIAL ANALYSIS BASED ON DISTANCE WEIGHT MATRIX
>
> # Spatial weight matrix based on distance (with lower and upper bounds for distance,
d1 and d2)
> nb <- dnearneigh(xy, d1=0, d2=10)
> listw <- nb2listw(nb, style="W")
> summary(listw)
Characteristics of weights list object:
Neighbour list object:
Number of regions: 49
Number of nonzero links: 1234
Percentage nonzero weights: 51.39525
Average number of links: 25.18367
Link number distribution:

  5  6  8 10 12 13 14 15 16 18 19 20 21 24 26 28 29 30 31 32 33 34 35 36 38
  1  2  1  1  1  1  1  1  1  1  2  2  4  3  1  2  2  2  3  3  2  6  2  2  2
1 least connected region:
39 with 5 links
2 most connected regions:
22 26 with 38 links

Weights style: W
Weights constants summary:
      n   nn S0      S1      S2
W 49 2401 49 4.763862 199.3227
>
> # Moran's I test
> moran.test(CRIME, listw)

Moran's I test under randomisation

data: CRIME
weights: listw

Moran I statistic standard deviate = 5.6185, p-value = 9.629e-09
alternative hypothesis: greater
sample estimates:
Moran I statistic      Expectation      Variance
      0.167361950      -0.020833333      0.001121945

> moran.plot(CRIME, listw)
>
> # Lagrange multiplier test for spatial lag and spatial error dependencies
> lm.LMtests(olsreg, listw, test=c("LMlag", "LMerr"))

Lagrange multiplier diagnostics for spatial dependence

data:
model: lm(formula = Y ~ X)
weights: listw

```

LMlag = 2.8736, df = 1, p-value = 0.09004

Lagrange multiplier diagnostics for spatial dependence

data:

model: lm(formula = Y ~ X)

weights: listw

LMerr = 0.1284, df = 1, p-value = 0.7201

>

> # Spatial lag model

> spatial.lag1 <- lagsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)

> summary(spatial.lag1)

Call:lagsarlm(formula = CRIME ~ INC + HOVAL, data = mydata, listw = listw)

Residuals:

	Min	1Q	Median	3Q	Max
	-35.68762	-7.01341	-0.83503	8.40003	27.44614

Type: lag

Coefficients: (asymptotic standard errors)

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	51.627459	11.817848	4.3686	1.250e-05
INC	-1.384654	0.334827	-4.1354	3.543e-05
HOVAL	-0.281171	0.098167	-2.8642	0.004181

Rho: 0.37541, LR test value: 1.9423, p-value: 0.16342

Asymptotic standard error: 0.26881

z-value: 1.3966, p-value: 0.16254

Wald statistic: 1.9504, p-value: 0.16254

Log likelihood: -186.4061 for lag model

ML residual variance (sigma squared): 117.06, (sigma: 10.82)

Number of observations: 49

Number of parameters estimated: 5

AIC: 382.81, (AIC for lm: 382.75)

LM test for residual autocorrelation

test value: 1.4922, p-value: 0.22187

>

> # Spatial error model

> spatial.error1 <- errorsarlm(CRIME ~ INC + HOVAL, data = mydata, listw)

> summary(spatial.error1)

Call:errorsarlm(formula = CRIME ~ INC + HOVAL, data = mydata, listw = listw)

Residuals:

	Min	1Q	Median	3Q	Max
	-34.85406	-6.71581	-0.46122	8.91963	28.71276

Type: error

Coefficients: (asymptotic standard errors)

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	67.311097	4.836926	13.9161	< 2.2e-16
INC	-1.538356	0.330112	-4.6601	3.161e-06
HOVAL	-0.268478	0.098726	-2.7194	0.006539

Lambda: 0.18231, LR test value: 0.14824, p-value: 0.70022

Asymptotic standard error: 0.4012

z-value: 0.45442, p-value: 0.64953

Wald statistic: 0.20649, p-value: 0.64953

Log likelihood: -187.3031 for error model

ML residual variance (sigma squared): 122.18, (sigma: 11.054)

Number of observations: 49

Number of parameters estimated: 5

AIC: 384.61, (AIC for lm: 382.75)



