

Package ‘EconGeo’

August 9, 2016

Title Computing Key Indicators of the Spatial Distribution of Economic Activities

Version 1.2

Author Pierre-Alexandre Balland <p.balland@uu.nl>

Maintainer Pierre-Alexandre Balland <p.balland@uu.nl>

Description Functions to compute a series of indices commonly used in economic geography & urban economics to describe the location, distribution, spatial organization, and complexity of economic activities. Most of the functions use matrix calculus and are based on bipartite (incidence) matrices consisting of region - industry pairs.

URL <https://github.com/PABalland/EconGeo>

Depends R (>= 3.3.1)

Imports Matrix

License GPL-2 | GPL-3 [expanded from: GPL]

Encoding UTF-8

LazyData true

RoxygenNote 5.0.1.9000

BugReports <http://github.com/PABalland/EconGeo/issues>

R topics documented:

co.occurrence	2
diversity	3
ease.recombination	4
entropy	5
entry.list	6
entry.mat	7
exit.list	8
exit.mat	10
expy	11
get.list	12
get.matrix	12
Gini	13
growth.ind	14
growth.list	15
growth.list.ind	16

growth.list.reg	17
growth.mat	19
growth.reg	20
Hachman	21
Herfindahl	22
Hoover.curve	23
Hoover.Gini	23
inv.norm.ubiquity	24
KCI	25
Krugman.index	26
location.quotient	27
location.quotient.avg	28
match.mat	29
modular.complexity	30
modular.complexity.avg	31
MORc	32
MORt	33
norm.ubiquity	35
prody	36
RCA	37
relatedness	38
relatedness.density	39
relatedness.density.ext	40
relatedness.density.ext.avg	41
relatedness.density.int	42
relatedness.density.int.avg	43
TCI	45
ubiquity	46
weighted.avg	47

Index 49

co.occurrence	<i>Compute the number of co-occurrences between industry pairs from an incidence (industry - event) matrix</i>
---------------	--

Description

This function computes the number of co-occurrences between industry pairs from an incidence (industry - event) matrix

Usage

```
co.occurrence(mat, diagonal = FALSE, list = FALSE)
```

Arguments

mat	An incidence matrix with industries in rows and events in columns
diagonal	Logical; shall the values in the diagonal of the co-occurrence matrix be included in the output? Defaults to FALSE (values in the diagonal are set to 0), but can be set to TRUE (values in the diagonal reflects in how many events a single industry can be found)

`list` Logical; is the input a list? Defaults to FALSE (input = adjacency matrix), but can be set to TRUE if the input is an edge list

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

See Also

[relatedness](#), [relatedness.density](#)

Examples

```
## generate a region - events matrix
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 5)
rownames(mat) <- c("I1", "I2", "I3", "I4")
colnames(mat) <- c("US1", "US2", "US3", "US4", "US5")

## run the function
co.occurrence (mat)
co.occurrence (mat, diagonal = TRUE)

## generate a regular data frame (list)
list <- get.list (mat)

## run the function
co.occurrence (list, list = TRUE)
co.occurrence (list, list = TRUE, diagonal = TRUE)
```

diversity

Compute a simple measure of diversity of regions

Description

This function computes a simple measure of diversity of regions by counting the number of industries in which a region has a relative comparative advantage (location quotient > 1) from regions - industries (incidence) matrices

Usage

```
diversity(mat, RCA = FALSE)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
RCA	Logical; should the index of relative comparative advantage (RCA - also referred to as location quotient) first be computed? Defaults to FALSE (a binary matrix - 0/1 - is expected as an input), but can be set to TRUE if the index of relative comparative advantage first needs to be computed

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, forthcoming

See Also

[ubiquity](#), [location.quotient](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
diversity(mat, RCA = TRUE)

## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
diversity(mat)
```

ease.recombination	<i>Compute the ease of recombination of a given technological class</i>
--------------------	---

Description

This function computes the ease of recombination of a given technological class from technological classes - patents (incidence) matrices

Usage

```
ease.recombination(mat, sparse = FALSE)
```

Arguments

mat	A bipartite adjacency matrix (can be a sparse matrix)
sparse	Logical; is the input matrix a sparse matrix? Defaults to FALSE, but can be set to TRUE if the input matrix is a sparse matrix

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Fleming, L. and Sorenson, O. (2001) Technology as a complex adaptive system: evidence from patent data, *Research Policy* **30**: 1019-1039

See Also

[modular.complexity](#), [TCI](#), [MORt](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:1,30,replace=T), ncol = 5)
rownames(mat) <- c("T1", "T2", "T3", "T4", "T5", "T6")
colnames(mat) <- c("US1", "US2", "US3", "US4", "US5")

## generate a region - industry sparse matrix
library(Matrix)
smat <- Matrix(mat,sparse=TRUE)

## run the function
modular.complexity(mat)
modular.complexity(smat, sparse = TRUE)
```

entropy

Compute the Shannon entropy index from regions - industries matrices

Description

This function computes the Shannon entropy index from regions - industries matrices from (incidence) regions - industries matrices

Usage

```
entropy(mat)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
-----	--

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Shannon, C.E., Weaver, W. (1949) *The Mathematical Theory of Communication*. Univ of Illinois Press.

Frenken, K., Van Oort, F. and Verburg, T. (2007) Related variety, unrelated variety and regional economic growth, *Regional studies* **41** (5): 685-697.

See Also

[diversity](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
entropy(mat)
```

entry.list	<i>Generate a data frame of entry events from multiple regions - industries matrices (same matrix composition for the different periods)</i>
------------	--

Description

This function generates a data frame of entry events from multiple regions - industries matrices (same matrix composition for the different periods). In this function, the maximum number of periods is limited to 20.

Usage

```
entry.list(mat1, mat2, mat3, mat4, mat5, mat6, mat7, mat8, mat9, mat10, mat11,
  mat12, mat13, mat14, mat15, mat16, mat17, mat18, mat19, mat20)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1 - mandatory)
mat2	An incidence matrix with regions in rows and industries in columns (period 2 - mandatory)
mat...	An incidence matrix with regions in rows and industries in columns (period ... - optional)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[entry](#), [exit](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix in which cells represent the presence/absence
## of a RCA (period 1)
set.seed(31)
mat1 <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")

## generate a second region - industry matrix in which cells represent the presence/absence
## of a RCA (period 2)
mat2 <- mat1
mat2[3,1] <- 1

## run the function
entry.list (mat1, mat2)

## generate a third region - industry matrix in which cells represent the presence/absence
## of a RCA (period 3)
mat3 <- mat2
mat3[5,2] <- 1

## run the function
entry.list (mat1, mat2, mat3)

## generate a fourth region - industry matrix in which cells represent the presence/absence
## of a RCA (period 4)
mat4 <- mat3
mat4[5,4] <- 1

## run the function
entry.list (mat1, mat2, mat3, mat4)
```

entry.mat

Generate a matrix of entry events from two regions - industries matrices (same matrix composition from two different periods)

Description

This function generates a matrix of entry events from two regions - industries matrices (same matrix composition from two different periods)

Usage

```
entry.mat(mat1, mat2)
```

Arguments

mat1 An incidence matrix with regions in rows and industries in columns (period 1)
mat2 An incidence matrix with regions in rows and industries in columns (period 2)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[exit](#), [entry.list](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix in which cells represent the presence/absence
## of a RCA (period 1)
set.seed(31)
mat1 <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")

## generate a second region - industry matrix in which cells represent the presence/absence
## of a RCA (period 2)
mat2 <- mat1
mat2[3,1] <- 1

## run the function
entry.mat (mat1, mat2)
```

exit.list	<i>Generate a data frame of exit events from multiple regions - industries matrices (same matrix composition for the different periods)</i>
-----------	---

Description

This function generates a data frame of exit events from multiple regions - industries matrices (same matrix composition for the different periods). In this function, the maximum number of periods is limited to 20.

Usage

```
exit.list(mat1, mat2, mat3, mat4, mat5, mat6, mat7, mat8, mat9, mat10, mat11,
          mat12, mat13, mat14, mat15, mat16, mat17, mat18, mat19, mat20)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1 - mandatory)
mat2	An incidence matrix with regions in rows and industries in columns (period 2 - mandatory)
mat...	An incidence matrix with regions in rows and industries in columns (period ... - optional)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[entry](#), [exit](#), [entry.list](#)

Examples

```
## generate a first region - industry matrix in which cells represent the presence/absence
## of a RCA (period 1)
set.seed(31)
mat1 <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat1) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c("I1", "I2", "I3", "I4")

## generate a second region - industry matrix in which cells represent the presence/absence
## of a RCA (period 2)
mat2 <- mat1
mat2[2,1] <- 0

## run the function
exit.list(mat1, mat2)

## generate a third region - industry matrix in which cells represent the presence/absence
## of a RCA (period 3)
mat3 <- mat2
mat3[5,1] <- 0

## run the function
exit.list(mat1, mat2, mat3)
```

```
## generate a fourth region - industry matrix in which cells represent the presence/absence
## of a RCA (period 4)
mat4 <- mat3
mat4[5,3] <- 0

## run the function
exit.list (mat1, mat2, mat3, mat4)
```

exit.mat	<i>Generate a matrix of exit events from two regions - industries matrices (same matrix composition from two different periods)</i>
----------	---

Description

This function generates a matrix of exit events from two regions - industries matrices (same matrix composition from two different periods)

Usage

```
exit.mat(mat1, mat2)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1)
mat2	An incidence matrix with regions in rows and industries in columns (period 2)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[entry](#), [exit.list](#), [entry.list](#)

Examples

```
## generate a first region - industry matrix in which cells represent the presence/absence
## of a RCA (period 1)
set.seed(31)
mat1 <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")
```

```
## generate a second region - industry matrix in which cells represent the presence/absence
## of a RCA (period 2)
mat2 <- mat1
mat2[2,1] <- 0

## run the function
exit.mat (mat1, mat2)
```

expy

Compute the expy index of regions from regions - industries matrices

Description

This function computes the expy index of regions from (incidence) regions - industries matrices, as proposed by Hausmann, Hwang & Rodrik (2007). The index is a measure of the productivity level associated with a region's specialization pattern.

Usage

```
expy(mat, vec)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
vec	A vector that gives GDP, R&D, education or any other relevant regional attribute that will be used to compute the weighted average for each industry

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balassa, B. (1965) Trade Liberalization and Revealed Comparative Advantage, *The Manchester School* **33**: 99-123

Hausmann, R., Hwang, J. & Rodrik, D. (2007) What you export matters, *Journal of economic growth* **12**: 1-25.

See Also

[location.quotient](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## a vector of GDP of regions
```

```
vec <- c (5, 10, 15, 25, 50)
## run the function
expy (mat, vec)
```

get.list

Create regular data frames from regions - industries matrices

Description

This function creates regular data frames with three columns (regions, industries, count) from (incidence) matrices (wide to long format) using the reshape2 package

Usage

```
get.list (data)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns (or the other way around)
-----	--

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

See Also

[get.matrix](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
get.list (mat)
```

get.matrix

Create regions - industries matrices from regular data frames

Description

This function creates regions - industries (incidence) matrices from regular data frames (long to wide format) using the reshape2 package or the Matrix package

Usage

```
get.matrix (data)
```

Arguments

<code>data</code>	is a data frame with three columns (regions, industries, count)
<code>sparse</code>	Logical; shall the returned output be a sparse matrix? Defaults to FALSE, but can be set to TRUE if the dataset is very large

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

See Also

[get.list](#)

Examples

```
## generate a region - industry data frame
set.seed(31)
region <- c("R1", "R1", "R1", "R1", "R2", "R2", "R3", "R4", "R5")
industry <- c("I1", "I2", "I3", "I4", "I1", "I2", "I1", "I1", "I3")
data <- data.frame (region, industry)
data$count <- 1

## run the function
get.matrix (data)
get.matrix (data, sparse = TRUE)
```

Gini

Compute the Gini coefficient from regional industrial counts

Description

This function computes the Gini coefficient from regional industrial count. This index gives an indication of the unequal distribution of an industry accross regions.

Usage

```
Gini(ind)
```

Arguments

<code>ind</code>	A vector of industrial regional count
------------------	---------------------------------------

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Gini, C. (1921) Measurement of Inequality of Incomes, *The Economic Journal* **31**: 124-126

See Also

[Hoover.curve](#)

Examples

```
## generate vectors of industrial count
ind <- c(0, 10, 10, 30, 50)

## run the function
Gini (ind)
```

growth.ind	<i>Generate a matrix of industrial growth by industries from two regions - industries matrices (same matrix composition from two different periods)</i>
------------	---

Description

This function generates a matrix of industrial growth by industries from two regions - industries matrices (same matrix composition from two different periods)

Usage

```
growth.ind(mat1, mat2)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1)
mat2	An incidence matrix with regions in rows and industries in columns (period 2)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[exit](#), [entry.list](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix with full count (period 1)
set.seed(31)
mat1 <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")

## generate a second region - industry matrix with full count (period 2)
```

```
mat2 <- mat1
mat2[3,1] <- 8

## run the function
growth.ind (mat1, mat2)
```

growth.list	<i>Generate a data frame of industrial growth in regions from multiple regions - industries matrices (same matrix composition for the different periods)</i>
-------------	--

Description

This function generates a data frame of industrial growth in regions from multiple regions - industries matrices (same matrix composition for the different periods). In this function, the maximum number of periods is limited to 20.

Usage

```
growth.list(mat1, mat2, mat3, mat4, mat5, mat6, mat7, mat8, mat9, mat10, mat11,
  mat12, mat13, mat14, mat15, mat16, mat17, mat18, mat19, mat20)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1 - mandatory)
mat2	An incidence matrix with regions in rows and industries in columns (period 2 - mandatory)
mat...	An incidence matrix with regions in rows and industries in columns (period ... - optional)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[growth](#), [exit](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix with full count (period 1)
set.seed(31)
mat1 <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat1) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c("I1", "I2", "I3", "I4")

## generate a second region - industry matrix with full count (period 2)
mat2 <- mat1
mat2[3,1] <- 8

## run the function
growth.list(mat1, mat2)

## generate a third region - industry matrix with full count (period 3)
mat3 <- mat2
mat3[5,2] <- 1

## run the function
growth.list(mat1, mat2, mat3)

## generate a fourth region - industry matrix with full count (period 4)
mat4 <- mat3
mat4[5,4] <- 1

## run the function
growth.list(mat1, mat2, mat3, mat4)
```

growth.list.ind	<i>Generate a data frame of industrial growth in regions from multiple regions - industries matrices (same matrix composition for the different periods)</i>
-----------------	--

Description

This function generates a data frame of industrial growth in regions from multiple regions - industries matrices (same matrix composition for the different periods). In this function, the maximum number of periods is limited to 20.

Usage

```
growth.list.ind(mat1, mat2, mat3, mat4, mat5, mat6, mat7, mat8, mat9, mat10,
  mat11, mat12, mat13, mat14, mat15, mat16, mat17, mat18, mat19, mat20)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1 - mandatory)
mat2	An incidence matrix with regions in rows and industries in columns (period 2 - mandatory)
mat...	An incidence matrix with regions in rows and industries in columns (period ... - optional)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[growth](#), [exit](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix with full count (period 1)
set.seed(31)
mat1 <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat1) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c("I1", "I2", "I3", "I4")

## generate a second region - industry matrix with full count (period 2)
mat2 <- mat1
mat2[3,1] <- 8

## run the function
growth.list.ind(mat1, mat2)

## generate a third region - industry matrix with full count (period 3)
mat3 <- mat2
mat3[5,2] <- 1

## run the function
growth.list.ind(mat1, mat2, mat3)

## generate a fourth region - industry matrix with full count (period 4)
mat4 <- mat3
mat4[5,4] <- 1

## run the function
growth.list.ind(mat1, mat2, mat3, mat4)
```

growth.list.reg

Generate a data frame of region growth from multiple regions - industries matrices (same matrix composition for the different periods)

Description

This function generates a data frame of industrial growth in regions from multiple regions - industries matrices (same matrix composition for the different periods). In this function, the maximum number of periods is limited to 20.

Usage

```
growth.list.reg(mat1, mat2, mat3, mat4, mat5, mat6, mat7, mat8, mat9, mat10,
  mat11, mat12, mat13, mat14, mat15, mat16, mat17, mat18, mat19, mat20)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1 - mandatory)
mat2	An incidence matrix with regions in rows and industries in columns (period 2 - mandatory)
mat...	An incidence matrix with regions in rows and industries in columns (period ... - optional)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[growth](#), [exit](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix with full count (period 1)
set.seed(31)
mat1 <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat1) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c("I1", "I2", "I3", "I4")

## generate a second region - industry matrix with full count (period 2)
mat2 <- mat1
mat2[3,1] <- 8

## run the function
growth.list.reg(mat1, mat2)

## generate a third region - industry matrix with full count (period 3)
mat3 <- mat2
mat3[5,2] <- 1

## run the function
growth.list.reg(mat1, mat2, mat3)

## generate a fourth region - industry matrix with full count (period 4)
mat4 <- mat3
```

```
mat4[5,4] <- 1

## run the function
growth.list.reg (mat1, mat2, mat3, mat4)
```

growth.mat	<i>Generate a matrix of industrial growth in regions from two regions - industries matrices (same matrix composition from two different periods)</i>
------------	--

Description

This function generates a matrix of industrial growth in regions from two regions - industries matrices (same matrix composition from two different periods)

Usage

```
growth.mat(mat1, mat2)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1)
mat2	An incidence matrix with regions in rows and industries in columns (period 2)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[exit](#), [entry.list](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix with full count (period 1)
set.seed(31)
mat1 <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")

## generate a second region - industry matrix with full count (period 2)
mat2 <- mat1
mat2[3,1] <- 8
```

```
## run the function
growth.mat (mat1, mat2)
```

growth.reg	<i>Generate a matrix of industrial growth by regions from two regions - industries matrices (same matrix composition from two different periods)</i>
------------	--

Description

This function generates a matrix of industrial growth by regions from two regions - industries matrices (same matrix composition from two different periods)

Usage

```
growth.reg(mat1, mat2)
```

Arguments

mat1	An incidence matrix with regions in rows and industries in columns (period 1)
mat2	An incidence matrix with regions in rows and industries in columns (period 2)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[exit](#), [entry.list](#), [exit.list](#)

Examples

```
## generate a first region - industry matrix with full count (period 1)
set.seed(31)
mat1 <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")

## generate a second region - industry matrix with full count (period 2)
mat2 <- mat1
mat2[3,1] <- 8
```

```
## run the function  
growth.reg (mat1, mat2)
```

Hachman*Compute the Hachman index from regions - industries matrices*

Description

This function computes the Hachman index from regions - industries matrices. The Hachman index indicates how closely the industrial distribution of a region resembles the one of a more global economy (nation, world). The index varies between 0 (extreme dissimilarity between the region and the more global economy) and 1 (extreme similarity between the region and the more global economy)

Usage

```
Hachman(mat)
```

Arguments

mat An incidence matrix with regions in rows and industries in columns

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

See Also

[average.location.quotient](#)

Examples

```
## generate a region - industry matrix  
set.seed(31)  
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)  
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")  
colnames(mat) <- c ("I1", "I2", "I3", "I4")  
  
## run the function  
Hachman (mat)
```

Herfindahl*Compute the Herfindahl index from regions - industries matrices*

Description

This function computes the Herfindahl index from regions - industries matrices from (incidence) regions - industries matrices. This index is also known as the Herfindahl-Hirschman index.

Usage

```
Herfindahl(mat)
```

Arguments

mat An incidence matrix with regions in rows and industries in columns

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Herfindahl, O.C. (1959) *Copper Costs and Prices: 1870-1957*. Baltimore: The Johns Hopkins Press.

Hirschman, A.O. (1945) *National Power and the Structure of Foreign Trade*, Berkeley and Los Angeles: University of California Press.

See Also

[Krugman.index](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
Herfindahl(mat)
```

Hoover.curve	<i>Compute the Hoover curve from regional counts in population and industry</i>
--------------	---

Description

This function computes the Hoover curve (locational Lorenz curve) from regional shares in population and industry

Usage

```
Hoover.curve(ind, pop)
```

Arguments

ind	A vector of industrial regional count
pop	A vector of population regional count

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hoover, E.M. (1936) The Measurement of Industrial Localization, *The Review of Economics and Statistics* **18** (1): 162-171

See Also

[location.quotient](#), [locational.Gini](#)

Examples

```
## generate vectors of industrial and population count
ind <- c(0, 10, 10, 30, 50)
pop <- c(5, 10, 10, 25, 30)

## run the function
Hoover.curve (ind, pop)
```

Hoover.Gini	<i>Compute the Hoover Gini from regional counts in population and industry</i>
-------------	--

Description

This function computes the Hoover Gini from regional shares in population and industry

Usage

```
Hoover.Gini(ind, pop)
```

Arguments

ind A vector of industrial regional count
 pop A vector of population regional count

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hoover, E.M. (1936) The Measurement of Industrial Localization, *The Review of Economics and Statistics* **18** (1): 162-171

See Also

[location.quotient](#), [locational.Gini](#)

Examples

```
## generate vectors of industrial and population count
ind <- c(0, 10, 10, 30, 50)
pop <- c(5, 10, 10, 25, 30)

## run the function
Hoover.Gini(ind, pop)
```

inv.norm.ubiquity	<i>Compute a measure of complexity from the inverse of the normalized ubiquity of industries</i>
-------------------	--

Description

This function computes a measure of complexity from the inverse of the normalized ubiquity of industries. We divide the logarithm of the total count (employment, number of firms, number of patents, ...) in an industry by its ubiquity. Ubiquity is given by the number of regions in which an industry can be found (location quotient > 1) from regions - industries (incidence) matrices

Usage

```
inv.norm.ubiquity(mat)
```

Arguments

mat An incidence matrix with regions in rows and industries in columns

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, *forthcoming*

See Also

[diversity](#), [location.quotient](#), [ubiquity](#), [TCI](#), [MORt](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
inv.norm.ubiquity (mat)
```

KCI	<i>Compute an index of knowledge complexity of regions using the eigenvector method</i>
-----	---

Description

This function computes an index of knowledge complexity of regions using the eigenvector method from regions - industries (incidence) matrices. Technically, the function returns the eigenvector associated with the second largest eigenvalue of the projected region - region matrix.

Usage

```
KCI(mat, RCA = FALSE)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
RCA	Logical; should the index of relative comparative advantage (RCA - also referred to as location quotient) first be computed? Defaults to FALSE (a binary matrix - 0/1 - is expected as an input), but can be set to TRUE if the index of relative comparative advantage first needs to be computed

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hidalgo, C. and Hausmann, R. (2009) The building blocks of economic complexity, *Proceedings of the National Academy of Sciences* **106**: 10570 - 10575.

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, *forthcoming*

See Also

[location.quotient](#), [ubiquity](#), [diversity](#), [MORc](#), [TCI](#), [MORt](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
KCI (mat, RCA = TRUE)

## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
KCI (mat)

## generate the simple network of Hidalgo and Hausmann (2009) presented p.11 (Fig. S4)
countries <- c("C1", "C1", "C1", "C1", "C2", "C3", "C3", "C4")
products <- c("P1", "P2", "P3", "P4", "P2", "P3", "P4", "P4")
data <- data.frame(countries, products)
data$freq <- 1
mat <- get.matrix (data)

## run the function
KCI (mat)
```

Krugman.index

Compute the Krugman index from regions - industries matrices

Description

This function computes the Krugman index from regions - industries matrices. This index is often referred to as the Krugman specialisation index and measures the distance between the distributions of industry shares in a region and at a more aggregated level (country for instance).

Usage

```
Krugman.index(mat)
```

Arguments

mat An incidence matrix with regions in rows and industries in columns

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Krugman P. (1991) *Geography and Trade*, MIT Press, Cambridge

See Also[average.location.quotient](#)**Examples**

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
Krugman.index (mat)
```

location.quotient	<i>Compute location quotients from regions - industries matrices</i>
-------------------	--

Description

This function computes location quotients from (incidence) regions - industries matrices. The numerator is the share of a given industry in a given region. The denominator is the share of a this industry in a larger economy (overall country for instance). This index is also referred to as the index of Revealed Comparative Advantage (RCA) following Ballasa (1965), or the Hoover-Balassa index.

Usage

```
location.quotient(mat, binary = FALSE)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
binary	Logical; shall the returned output be a dichotomized version (0/1) of the location quotient? Defaults to FALSE (the full values of the location quotient will be returned), but can be set to TRUE (location quotient values above 1 will be set to 1 & location quotient values below 1 will be set to 0)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balassa, B. (1965) Trade Liberalization and Revealed Comparative Advantage, *The Manchester School* **33**: 99-123.

See Also[RCA](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
location.quotient (mat)
location.quotient (mat, binary = TRUE)
```

location.quotient.avg *Compute average location quotients of regions from regions - industries matrices*

Description

This function computes the average location quotients of regions from (incidence) regions - industries matrices. This index is also referred to as the *coefficient of specialization* (Hoover and Giarratani, 1985).

Usage

```
location.quotient.avg(mat)
```

Arguments

mat An incidence matrix with regions in rows and industries in columns

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hoover, E.M. and Giarratani, F. (1985) *An Introduction to Regional Economics*. 3rd edition. New York: Alfred A. Knopf

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

See Also

[location.quotient](#), [Hachman](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
location.quotient.avg (mat)
```

match.mat	<i>Re-arrange the dimension of a matrix based on the dimension of another matrix</i>
-----------	--

Description

This function e-arranges the dimension of a matrix based on the dimension of another matrix

Usage

```
match.mat(fill = mat1, dim = mat2, missing = T)
```

Arguments

fill	A matrix that will be used to populate the matrix output
dim	A matrix that will be used to determine the dimensions of the matrix output
missing	Logical; Shall the cells of the non matching rows/columns set to NA? Default to TRUE but can be set to FALSE to set the cells of the non matching rows/columns to 0 instead.

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

See Also

[location.quotient](#)

Examples

```
## generate a first region - industry matrix
set.seed(31)
mat1 <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat1) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat1) <- c ("I1", "I2", "I3", "I4")

## generate a second region - industry matrix
set.seed(31)
mat2 <- matrix(sample(0:1,16,replace=T), ncol = 4)
rownames(mat2) <- c ("R1", "R2", "R3", "R5")
colnames(mat2) <- c ("I1", "I2", "I3", "I4")

## run the function
```

```

match.mat (fill = mat1, dim = mat2)
match.mat (fill = mat2, dim = mat1)
match.mat (fill = mat2, dim = mat1, missing = F)

```

modular.complexity	<i>Compute a measure of modular complexity of patent documents</i>
--------------------	--

Description

This function computes a measure of modular complexity of patent documents from technological classes - patents (incidence) matrices

Usage

```
modular.complexity(mat, sparse = FALSE, list = FALSE)
```

Arguments

mat	A bipartite adjacency matrix (can be a sparse matrix)
sparse	Logical; is the input matrix a sparse matrix? Defaults to FALSE, but can be set to TRUE if the input matrix is a sparse matrix
list	Logical; is the input a list? Defaults to FALSE (input = adjacency matrix), but can be set to TRUE if the input is an edge list

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Fleming, L. and Sorenson, O. (2001) Technology as a complex adaptive system: evidence from patent data, *Research Policy* **30**: 1019-1039

See Also

[ease.recombination](#), [TCI](#), [MORt](#)

Examples

```

## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:1,30,replace=T), ncol = 5)
rownames(mat) <- c ("T1", "T2", "T3", "T4", "T5", "T6")
colnames(mat) <- c ("US1", "US2", "US3", "US4", "US5")

## run the function
modular.complexity (mat)

## generate a region - industry sparse matrix
library (Matrix)

## run the function
smat <- Matrix(mat,sparse=TRUE)

```

```
modular.complexity (smat, sparse = TRUE)
## generate a regular data frame (list)
list <- get.list (mat)

## run the function
modular.complexity (list, list = TRUE)
```

modular.complexity.avg

Compute a measure of average modular complexity of technologies

Description

This function computes a measure of average modular complexity of technologies (average complexity of patent documents in a given technological class) from technological classes - patents (incidence) matrices

Usage

```
modular.complexity.avg(mat, sparse = FALSE, list = FALSE)
```

Arguments

mat	A bipartite adjacency matrix (can be a sparse matrix)
sparse	Logical; is the input matrix a sparse matrix? Defaults to FALSE, but can be set to TRUE if the input matrix is a sparse matrix
list	Logical; is the input a list? Defaults to FALSE (input = adjacency matrix), but can be set to TRUE if the input is an edge list

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Fleming, L. and Sorenson, O. (2001) Technology as a complex adaptive system: evidence from patent data, *Research Policy* **30**: 1019-1039

See Also

[ease.recombination](#), [TCI](#), [MORT](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:1,30,replace=T), ncol = 5)
rownames(mat) <- c ("T1", "T2", "T3", "T4", "T5", "T6")
colnames(mat) <- c ("US1", "US2", "US3", "US4", "US5")

## run the function
```

```

modular.complexity.avg (mat)

## generate a region - industry sparse matrix
library (Matrix)

## run the function
smat <- Matrix(mat,sparse=TRUE)

modular.complexity.avg (smat, sparse = TRUE)
## generate a regular data frame (list)
list <- get.list (mat)

## run the function
modular.complexity.avg (list, list = TRUE)

```

MORc

Compute an index of knowledge complexity of regions using the method of reflection

Description

This function computes an index of knowledge complexity of regions using the method of reflection from regions - industries (incidence) matrices. The index has been developed by Hidalgo and Hausmann (2009) for country - product matrices and adapted by Balland and Rigby (2016) to city - technology matrices.

Usage

```
MORc(mat, RCA = FALSE, steps = 20)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
RCA	Logical; should the index of relative comparative advantage (RCA - also referred to as location quotient) first be computed? Defaults to FALSE (a binary matrix - 0/1 - is expected as an input), but can be set to TRUE if the index of relative comparative advantage first needs to be computed
steps	Number of iteration steps. Defaults to 20, but can be set to 0 to give diversity (number of industry in which a region has a RCA), to 1 to give the average ubiquity of the industries in which a region has a RCA, to 2 to give the average diversity of regions that have similar industrial structures, or to any other number of steps < or = 22. Note that above steps = 2 the index will be rescaled from 0 (minimum relative complexity) to 100 (maximum relative complexity).

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hidalgo, C. and Hausmann, R. (2009) The building blocks of economic complexity, *Proceedings of the National Academy of Sciences* **106**: 10570 - 10575.

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, *forthcoming*

See Also

[location.quotient](#), [ubiquity](#), [diversity](#), [KCI](#), [TCI](#), [MORt](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
MORc(mat, RCA = TRUE)
MORc(mat, RCA = TRUE, steps = 0)
MORc(mat, RCA = TRUE, steps = 1)
MORc(mat, RCA = TRUE, steps = 2)

## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(32)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
MORc(mat)
MORc(mat, steps = 0)
MORc(mat, steps = 1)
MORc(mat, steps = 2)

## generate the simple network of Hidalgo and Hausmann (2009) presented p.11 (Fig. S4)
countries <- c("C1", "C1", "C1", "C1", "C2", "C3", "C3", "C4")
products <- c("P1", "P2", "P3", "P4", "P2", "P3", "P4", "P4")
data <- data.frame(countries, products)
data$freq <- 1
mat <- get.matrix(data)

## run the function
MORc(mat)
MORc(mat, steps = 0)
MORc(mat, steps = 1)
MORc(mat, steps = 2)
```

Description

This function computes an index of knowledge complexity of industries using the method of reflection from regions - industries (incidence) matrices. The index has been developed by Hidalgo and Hausmann (2009) for country - product matrices and adapted by Balland and Rigby (2016) to city - technology matrices.

Usage

```
MORt(mat, RCA = FALSE, steps = 19)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
RCA	Logical; should the index of relative comparative advantage (RCA - also referred to as location quotient) first be computed? Defaults to FALSE (a binary matrix - 0/1 - is expected as an input), but can be set to TRUE if the index of relative comparative advantage first needs to be computed
steps	Number of iteration steps. Defaults to 19, but can be set to 0 to give ubiquity (number of regions that have a RCA in a industry), to 1 to give the average diversity of the regions that have a RCA in this industry, to 2 to give the average ubiquity of technologies developed in the same regions, or to any other number of steps < or = to 21. Note that above steps = 2 the index will be rescaled from 0 (minimum relative complexity) to 100 (maximum relative complexity).

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hidalgo, C. and Hausmann, R. (2009) The building blocks of economic complexity, *Proceedings of the National Academy of Sciences* **106**: 10570 - 10575.

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, forthcoming

See Also

[location.quotient](#), [ubiquity](#), [diversity](#), [KCI](#), [TCI](#), [MORc](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
MORt(mat, RCA = TRUE)
MORt(mat, RCA = TRUE, steps = 0)
MORt(mat, RCA = TRUE, steps = 1)
MORt(mat, RCA = TRUE, steps = 2)
```

```
## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(32)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
MORT (mat)
MORT (mat, steps = 0)
MORT (mat, steps = 1)
MORT (mat, steps = 2)

## generate the simple network of Hidalgo and Hausmann (2009) presented p.11 (Fig. S4)
countries <- c("C1", "C1", "C1", "C1", "C2", "C3", "C3", "C4")
products <- c("P1", "P2", "P3", "P4", "P2", "P3", "P4", "P4")
data <- data.frame(countries, products)
data$freq <- 1
mat <- get.matrix (data)

## run the function
MORT (mat)
MORT (mat, steps = 0)
MORT (mat, steps = 1)
MORT (mat, steps = 2)
```

norm.ubiquity	<i>Compute a measure of complexity by normalizing ubiquity of industries</i>
---------------	--

Description

This function computes a measure of complexity by normalizing ubiquity of industries. We divide the share of the total count (employment, number of firms, number of patents, ...) in an industry by its share of ubiquity. Ubiquity is given by the number of regions in which an industry can be found (location quotient > 1) from regions - industries (incidence) matrices

Usage

```
norm.ubiquity(mat)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
-----	--

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, forthcoming

See Also

[diversity](#), [location.quotient](#), [ubiquity](#), [TCI](#), [MORt](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
norm.ubiquity(mat)
```

prody	<i>Compute the prody index of industries from regions - industries matrices</i>
-------	---

Description

This function computes the prody index of industries from (incidence) regions - industries matrices, as proposed by Hausmann, Hwang & Rodrik (2007). The index gives an associated income level for each industry. It represents a weighted average of per-capita GDPs (but GDP can be replaced by R&D, education...), where the weights correspond to the revealed comparative advantage of each region in a given industry (or sector, technology, ...).

Usage

```
prody(mat, vec)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
vec	A vector that gives GDP, R&D, education or any other relevant regional attribute that will be used to compute the weighted average for each industry

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balassa, B. (1965) Trade Liberalization and Revealed Comparative Advantage, *The Manchester School* **33**: 99-123

Hausmann, R., Hwang, J. & Rodrik, D. (2007) What you export matters, *Journal of economic growth* **12**: 1-25.

See Also

[location.quotient](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## a vector of GDP of regions
vec <- c(5, 10, 15, 25, 50)
## run the function
prody(mat, vec)
```

RCA

Compute an index of revealed comparative advantage (RCA) from regions - industries matrices

Description

This function computes an index of revealed comparative advantage (RCA) from (incidence) regions - industries matrices. The numerator is the share of a given industry in a given region. The denominator is the share of a this industry in a larger economy (overall country for instance). This index is also referred to as a location quotient, or the Hoover-Balassa index.

Usage

```
RCA(mat, binary = FALSE)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
binary	Logical; shall the returned output be a dichotomized version (0/1) of the RCA? Defaults to FALSE (the full values of the RCA will be returned), but can be set to TRUE (RCA above 1 will be set to 1 & RCA values below 1 will be set to 0)

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balassa, B. (1965) Trade Liberalization and Revealed Comparative Advantage, *The Manchester School* **33**: 99-123.

See Also

[location.quotient](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
RCA(mat)
RCA(mat, binary = TRUE)
```

relatedness	<i>Compute the relatedness between entities (industries, technologies, ...) from their co-occurrence matrix</i>
-------------	---

Description

This function computes the relatedness between entities (industries, technologies, ...) from their co-occurrence (adjacency) matrix. Different normalization procedures are proposed following van Eck and Waltman (2009): association strength, cosine, Jaccard, and an adapted version of the association strength that we refer to as probability index.

Usage

```
relatedness(mat, method = "prob")
```

Arguments

mat	An adjacency matrix of co-occurrences between entities (industries, technologies, cities...)
method	Which normalization method should be used to compute relatedness? Defaults to "prob", but it can be "association", "cosine" or "Jaccard"

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>
 Joan Crespo <J.Crespo@uu.nl>
 Mathieu Steijn <M.P.A.Steijn@uu.nl>

References

- van Eck, N.J. and Waltman, L. (2009) How to normalize cooccurrence data? An analysis of some well-known similarity measures, *Journal of the American Society for Information Science and Technology* **60** (8): 1635-1651
- Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114
- Steijn, M.P.A. (2016) Improvement on the association strength: implementing a probabilistic measure based on combinations without repetition, *Working Paper, Utrecht University*

See Also

[relatedness.density](#), [co.occurrence](#)

Examples

```
## generate an industry - industry matrix in which cells give the number of co-occurrences
## between two industries
set.seed(31)
mat <- matrix(sample(0:10,36,replace=T), ncol = 6)
mat[lower.tri(mat, diag = TRUE)] <- t(mat)[lower.tri(t(mat), diag = TRUE)]
rownames(mat) <- c ("I1", "I2", "I3", "I4", "I5", "I6")
colnames(mat) <- c ("I1", "I2", "I3", "I4", "I5", "I6")

## run the function
relatedness (mat)
relatedness (mat, method = "association")
relatedness (mat, method = "cosine")
relatedness (mat, method = "Jaccard")
```

<code>relatedness.density</code>	<i>Compute the relatedness density between regions and industries from regions - industries matrices and industries - industries matrices</i>
----------------------------------	---

Description

This function computes the relatedness density between regions and industries from regions - industries (incidence) matrices and industries - industries (adjacency) matrices

Usage

```
relatedness.density(mat, relatedness)
```

Arguments

<code>mat</code>	An incidence matrix with regions in rows and industries in columns
<code>relatedness</code>	An adjacency industry - industry matrix indicating the degree of relatedness between industries

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[relatedness, co.occurence](#)

Examples

```
## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## generate an industry - industry matrix in which cells indicate if two industries are
## related (1) or not (0)
relatedness <- matrix(sample(0:1,16,replace=T), ncol = 4)
relatedness[lower.tri(relatedness, diag = TRUE)] <- t(relatedness)[lower.tri(t(relatedness),
diag = TRUE)]
rownames(relatedness) <- c ("I1", "I2", "I3", "I4")
colnames(relatedness) <- c ("I1", "I2", "I3", "I4")

## run the function
relatedness.density (mat, relatedness)
```

relatedness.density.ext

Compute the relatedness density between regions and industries that are not part of the regional portfolio from regions - industries matrices and industries - industries matrices

Description

This function computes the relatedness density between regions and industries that are not part of the regional portfolio from regions - industries (incidence) matrices and industries - industries (adjacency) matrices

Usage

```
relatedness.density.ext(mat, relatedness)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
relatedness	An adjacency industry - industry matrix indicating the degree of relatedness between industries

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[relatedness](#), [co.occurence](#)

Examples

```
## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## generate an industry - industry matrix in which cells indicate if two industries are
## related (1) or not (0)
relatedness <- matrix(sample(0:1,16,replace=T), ncol = 4)
relatedness[lower.tri(relatedness, diag = TRUE)] <- t(relatedness)[lower.tri(t(relatedness),
diag = TRUE)]
rownames(relatedness) <- c ("I1", "I2", "I3", "I4")
colnames(relatedness) <- c ("I1", "I2", "I3", "I4")

## run the function
relatedness.density.ext (mat, relatedness)
```

relatedness.density.ext.avg

Compute the average relatedness density of regions to industries that are not part of the regional portfolio from regions - industries matrices and industries - industries matrices

Description

This function computes the average relatedness density of regions to industries that are not part of the regional portfolio from regions - industries (incidence) matrices and industries - industries (adjacency) matrices. This is the technological flexibility indicator proposed by Balland et al. (2015).

Usage

```
relatedness.density.ext.avg(mat, relatedness)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
relatedness	An adjacency industry - industry matrix indicating the degree of relatedness between industries

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Balland P.A., Rigby, D., and Boschma, R. (2015) The Technological Resilience of U.S. Cities, *Cambridge Journal of Regions, Economy and Society*, **8** (2): 167-184

See Also

[relatedness](#), [relatedness.density](#), [relatedness.density.ext](#), [relatedness.density.int](#), [avg.relatedness.density.int](#)

Examples

```
## generate a region - industry matrix in which cells represent the presence/absence
## of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## generate an industry - industry matrix in which cells indicate if two industries are
## related (1) or not (0)
relatedness <- matrix(sample(0:1,16,replace=T), ncol = 4)
relatedness[lower.tri(relatedness, diag = TRUE)] <- t(relatedness)[lower.tri(t(relatedness),
diag = TRUE)]
rownames(relatedness) <- c ("I1", "I2", "I3", "I4")
colnames(relatedness) <- c ("I1", "I2", "I3", "I4")

## run the function
relatedness.density.ext.avg (mat, relatedness)
```

relatedness.density.int

Compute the relatedness density between regions and industries that are part of the regional portfolio from regions - industries matrices and industries - industries matrices

Description

This function computes the relatedness density between regions and industries that are part of the regional portfolio from regions - industries (incidence) matrices and industries - industries (adjacency) matrices

Usage

```
relatedness.density.int(mat, relatedness)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
relatedness	An adjacency industry - industry matrix indicating the degree of relatedness between industries

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Boschma, R., Heimeriks, G. and Balland, P.A. (2014) Scientific Knowledge Dynamics and Relatedness in Bio-Tech Cities, *Research Policy* **43** (1): 107-114

See Also

[relatedness](#), [co.occurence](#)

Examples

```
## generate a region - industry matrix in which cells represent the presence/absence
## of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## generate an industry - industry matrix in which cells indicate if two industries are
## related (1) or not (0)
relatedness <- matrix(sample(0:1,16,replace=T), ncol = 4)
relatedness[lower.tri(relatedness, diag = TRUE)] <- t(relatedness)[lower.tri(t(relatedness),
diag = TRUE)]
rownames(relatedness) <- c ("I1", "I2", "I3", "I4")
colnames(relatedness) <- c ("I1", "I2", "I3", "I4")

## run the function
relatedness.density.int (mat, relatedness)
```

relatedness.density.int.avg

*Compute the average relatedness density within the regional portfolio
from regions - industries matrices and industries - industries matrices*

Description

This function computes the average relatedness density within the regional portfolio from regions - industries (incidence) matrices and industries - industries (adjacency) matrices. This is a measure of the technological coherence of the regional industrial structure.

Usage

```
relatedness.density.int.avg(mat, relatedness)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
relatedness	An adjacency industry - industry matrix indicating the degree of relatedness between industries

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Boschma, R., Balland, P.A. and Kogler, D. (2015) Relatedness and Technological Change in Cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010, *Industrial and Corporate Change* **24** (1): 223-250

Balland P.A., Rigby, D., and Boschma, R. (2015) The Technological Resilience of U.S. Cities, *Cambridge Journal of Regions, Economy and Society*, **8** (2): 167-184

See Also

[relatedness](#), [relatedness.density](#), [relatedness.density.ext](#), [relatedness.density.int](#), [avg.relatedness.density.ext](#)

Examples

```
## generate a region - industry matrix in which cells represent the presence/absence
## of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## generate an industry - industry matrix in which cells indicate if two industries are
## related (1) or not (0)
relatedness <- matrix(sample(0:1,16,replace=T), ncol = 4)
relatedness[lower.tri(relatedness, diag = TRUE)] <- t(relatedness)[lower.tri(t(relatedness),
diag = TRUE)]
rownames(relatedness) <- c ("I1", "I2", "I3", "I4")
colnames(relatedness) <- c ("I1", "I2", "I3", "I4")

## run the function
relatedness.density.int.avg (mat, relatedness)
```

TCI	<i>Compute an index of knowledge complexity of industries using the eigenvector method</i>
-----	--

Description

This function computes an index of knowledge complexity of industries using the eigenvector method from regions - industries (incidence) matrices. Technically, the function returns the eigenvector associated with the second largest eigenvalue of the projected industry - industry matrix.

Usage

```
TCI(mat, RCA = FALSE)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
RCA	Logical; should the index of relative comparative advantage (RCA - also referred to as location quotient) first be computed? Defaults to FALSE (a binary matrix - 0/1 - is expected as an input), but can be set to TRUE if the index of relative comparative advantage first needs to be computed

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Hidalgo, C. and Hausmann, R. (2009) The building blocks of economic complexity, *Proceedings of the National Academy of Sciences* **106**: 10570 - 10575.

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, forthcoming

See Also

[location.quotient](#), [ubiquity](#), [diversity](#), [MORc](#), [KCI](#), [MORt](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c("I1", "I2", "I3", "I4")

## run the function
TCI (mat, RCA = TRUE)

## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
```

```

rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
TCI (mat)

## generate the simple network of Hidalgo and Hausmann (2009) presented p.11 (Fig. S4)
countries <- c("C1", "C1", "C1", "C1", "C2", "C3", "C3", "C4")
products <- c("P1", "P2", "P3", "P4", "P2", "P3", "P4", "P4")
data <- data.frame(countries, products)
data$freq <- 1
mat <- get.matrix (data)

## run the function
TCI (mat)

```

ubiquity

Compute a simple measure of ubiquity of industries

Description

This function computes a simple measure of ubiquity of industries by counting the number of regions in which an industry can be found (location quotient > 1) from regions - industries (incidence) matrices

Usage

```
ubiquity(mat, RCA = FALSE)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
RCA	Logical; should the index of relative comparative advantage (RCA - also referred to as location quotient) first be computed? Defaults to FALSE (a binary matrix - 0/1 - is expected as an input), but can be set to TRUE if the index of relative comparative advantage first needs to be computed

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

References

Balland, P.A. and Rigby, D. (2016) The geography of complex knowledge, *Economic Geography*, forthcoming

See Also

[diversity location.quotient](#)

Examples

```
## generate a region - industry matrix with full count
set.seed(31)
mat <- matrix(sample(0:10,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
ubiquity (mat, RCA = TRUE)

## generate a region - industry matrix in which cells represent the presence/absence of a RCA
set.seed(31)
mat <- matrix(sample(0:1,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## run the function
ubiquity (mat)
```

weighted.avg	<i>Compute a weighted average of regions or industries from regions - industries matrices</i>
--------------	---

Description

This function computes a weighted average of regions or industries from (incidence) regions - industries matrices.

Usage

```
weighted.avg(mat, vec, reg = T)
```

Arguments

mat	An incidence matrix with regions in rows and industries in columns
vec	A vector that will be used to compute the weighted average for each industry/region
reg	Logical; Shall the weighted average for regions be returned? Default to TRUE (requires a vector of industry value) but can be set to FALSE (requires a vector of region value) if the weighted average for industries should be returned

Author(s)

Pierre-Alexandre Balland <p.balland@uu.nl>

See Also

[location.quotient](#)

Examples

```
## generate a region - industry matrix
set.seed(31)
mat <- matrix(sample(0:100,20,replace=T), ncol = 4)
rownames(mat) <- c ("R1", "R2", "R3", "R4", "R5")
colnames(mat) <- c ("I1", "I2", "I3", "I4")

## a vector for regions will be used to computed the weighted average of industries
vec <- c (5, 10, 15, 25, 50)
## run the function
weighted.avg (mat, vec, reg = F)

## a vector for industries will be used to computed the weighted average of regions
vec <- c (5, 10, 15, 25)
## run the function
weighted.avg (mat, vec, reg = T)
```


Index

- *Topic **complexity**
 - ease.recombination, 4
 - KCI, 25
 - modular.complexity, 30
 - modular.complexity.avg, 31
 - MORc, 32
 - MORt, 33
 - norm.ubiquity, 35
 - prody, 36
 - TCI, 45
 - *Topic **concentration**
 - Gini, 13
 - Herfindahl, 22
 - Hoover.curve, 23
 - Hoover.Gini, 23
 - location.quotient, 27
 - location.quotient.avg, 28
 - prody, 36
 - *Topic **data.management**
 - get.list, 12
 - get.matrix, 12
 - match.mat, 29
 - *Topic **diversification**
 - entry.list, 6
 - entry.mat, 7
 - exit.list, 8
 - exit.mat, 10
 - *Topic **diversity**
 - diversity, 3
 - entropy, 5
 - expy, 11
 - relatedness.density.ext.avg, 41
 - weighted.avg, 47
 - *Topic **growth**
 - growth.ind, 14
 - growth.list, 15
 - growth.list.ind, 16
 - growth.list.reg, 17
 - growth.mat, 19
 - growth.reg, 20
 - *Topic **inequality**
 - Gini, 13
 - Hoover.curve, 23
 - Hoover.Gini, 23
 - *Topic **relatedness**
 - co.occurrence, 2
 - relatedness, 38
 - relatedness.density, 39
 - relatedness.density.ext, 40
 - relatedness.density.ext.avg, 41
 - relatedness.density.int, 42
 - relatedness.density.int.avg, 43
 - *Topic **specialization**
 - expy, 11
 - Hachman, 21
 - Herfindahl, 22
 - Krugman.index, 26
 - location.quotient, 27
 - location.quotient.avg, 28
 - RCA, 37
 - relatedness.density.int.avg, 43
 - weighted.avg, 47
 - *Topic **ubiquity**
 - inv.norm.ubiquity, 24
 - norm.ubiquity, 35
 - ubiquity, 46
- average.location.quotient, 21, 27
- avg.relatedness.density.ext, 44
- avg.relatedness.density.int, 42
- co.occurrence, 2, 39–41, 43
- diversity, 3, 6, 25, 33, 34, 36, 45, 46
- ease.recombination, 4, 30, 31
- entropy, 5
- entry, 7, 9, 10
- entry.list, 6, 8–10, 14, 19, 20
- entry.mat, 7
- exit, 7–9, 14, 15, 17–20
- exit.list, 7, 8, 8, 10, 14, 15, 17–20
- exit.mat, 10
- expy, 11
- get.list, 12, 13
- get.matrix, 12, 12
- Gini, 13

growth, [15](#), [17](#), [18](#)
growth.ind, [14](#)
growth.list, [15](#)
growth.list.ind, [16](#)
growth.list.reg, [17](#)
growth.mat, [19](#)
growth.reg, [20](#)

Hachman, [21](#), [28](#)
Herfindahl, [22](#)
Hoover.curve, [13](#), [23](#)
Hoover.Gini, [23](#)

inv.norm.ubiquity, [24](#)

KCI, [25](#), [33](#), [34](#), [45](#)
Krugman.index, [22](#), [26](#)

location.quotient, [4](#), [11](#), [23–25](#), [27](#), [28](#), [29](#),
 [33](#), [34](#), [36](#), [37](#), [45–47](#)
location.quotient.avg, [28](#)
locational.Gini, [23](#), [24](#)

match.mat, [29](#)
modular.complexity, [5](#), [30](#)
modular.complexity.avg, [31](#)
MORc, [25](#), [32](#), [34](#), [45](#)
MORt, [5](#), [25](#), [30](#), [31](#), [33](#), [33](#), [36](#), [45](#)

norm.ubiquity, [35](#)

prody, [36](#)

RCA, [27](#), [37](#)
relatedness, [3](#), [38](#), [40–44](#)
relatedness.density, [3](#), [39](#), [39](#), [42](#), [44](#)
relatedness.density.ext, [40](#), [42](#), [44](#)
relatedness.density.ext.avg, [41](#)
relatedness.density.int, [42](#), [42](#), [44](#)
relatedness.density.int.avg, [43](#)

TCI, [5](#), [25](#), [30](#), [31](#), [33](#), [34](#), [36](#), [45](#)

ubiquity, [4](#), [25](#), [33](#), [34](#), [36](#), [45](#), [46](#)

weighted.avg, [47](#)