



Il PIL degli Stati africani

Dario Comanducci

Tesina per il Corso di Geospatial Data Analysis

Master in Data Science and Statistical Learning
Università degli Studi di Firenze

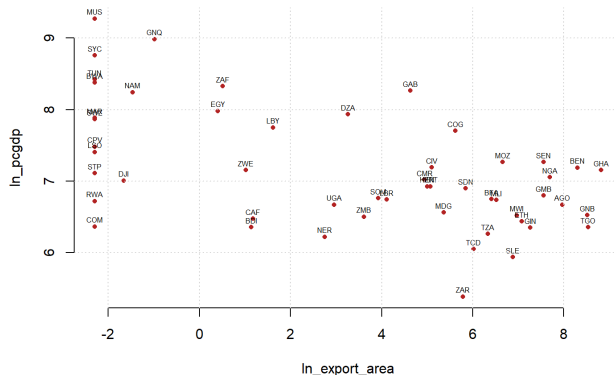
31 Gennaio 2025

La tratta degli schiavi ha influito sul PIL degli Stati africani?

Solo correlazione o causalità?



N. Nunn. "The Long-Term Effects of Africa's Slave Trades".
Quarterly Journal of Economics, 123(1):139-176, 2008.



ln_pcgdp: PIL procapite (log)

ln_export_area: tot. schiavi deportati / superficie terrestre (log)

isocode	Paese	isocode	Paese
AGO	Angola	MDG	Madagascar
BDI	Burundi	MLI	Mali
BEN	Benin	MOZ	Mozambique
BFA	Burkina Faso	MRT	Mauritania
BWA	Botswana	MUS	Mauritius
CAF	Central Afr. Rep.	MWI	Malawi
CIV	Ivory Coast	NAM	Namibia
CMR	Cameroon	NER	Niger
COG	Congo	NGA	Nigeria
COM	Comoros	RWA	Rwanda
CPV	Cape Verde Isl.	SDN	Sudan
DJI	Djibouti	SEN	Senegal
DZA	Algeria	SLE	Sierra Leone
EGY	Egypt	SOM	Somalia
ETH	Ethiopia	STP	S. Tome & Principe
GAB	Gabon	SWZ	Swaziland
GHA	Ghana	SYC	Seychelles
GIN	Guinea	TCD	Chad
GMB	Gambia	TGO	Togo
GNB	Guinea-Bissau	TUN	Tunisia
GNQ	Eq. Guinea	TZA	Tanzania
KEN	Kenya	UGA	Uganda
LBR	Liberia	ZAF	South Africa
LBY	Libya	ZAR	Dem. Rep. Congo
LSO	Lesotho	ZMB	Zambia
MAR	Morocco	ZWE	Zimbabwe

Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

II dataset

N. Nunn. "The Long-Term Effects of Africa's Slave Trades"



Variabili continue

ln_pcgdp	GDP per capita (log)
ln_export_area	slave exports / land area (log)
rain_min	min monthly avg rainfall (mm)
humid_max	max monthly avg humidity (%)
low_temp	min monthly avg low temp (C)
ln_coast_area	ocean proximity (log)
abs_latitude	dist. from Equator
longitude	longitude
ln_gold_pop	gold avg prod. p.c. (log)
ln_oil_pop	oil avg prod. p.c. (log)
ln_diamonds_pop	diamond avg prod. p.c. (log)
islam	percent islamic pop.
atlantic_dist_min	min atlantic distance (10^3 km)
indian_dist_min	min indian distance (10^3 km)
saharan_dist_min	min saharan distance (10^3 km)
red_sea_dist_min	min Red Sea distance (10^3 km)

Variabili binarie

region_n	North Africa indicator
island_dum	small island indicator
colony0	No colony
colony1	GB
colony2	FR
colony3	PT
colony4	BE
colony5	ES
colony6	UN
colony7	IT
legor_fr	Legal origin indicator: FR
legor_uk	Legal origin indicator: GB

Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Geodetic CRS: WGS 84



ZWE Zimbabwe	LBR Liberia
ZMB Zambia	LSO Lesotho
UGA Uganda	KEN Kenya
TUN Tunisia	GNB Guinea-Bissau
TGO Togo	GIN Guinea
TZA Tanzania	GHA Ghana
SWZ eSwatini	GMB Gambia
SSD S. Sudan	GAB Gabon
SDN Sudan	ETH Ethiopia
ZAF South Africa	ERI Eritrea
SOM Somalia	GNQ Eq. Guinea
-99 Somaliland	EGY Egypt
SLE Sierra Leone	DJI Djibouti
SEN Senegal	CIV Côte d'Ivoire
STP São Tomé and Príncipe	COD Dem. Rep. Congo
RWA Rwanda	COG Congo
NGA Nigeria	COM Comoros
NER Niger	CDI Chad
NAM Namibia	CAF Central African Rep.
MZM Mozambique	CPV Cabo Verde
MOR Morocco	CMR Cameroon
ESH W. Sahara	BFI Burundi
MRT Mauritania	BFA Burkina Faso
MU Malawi	BWA Botswana
MDG Madagascar	BNB Benin
LBY Libya	AGO Angola
	DZA Algeria

A map of the African continent with each country labeled with its three-letter ISO 3166-1 alpha-3 code. The labels are: TUN (Tunisia), MAR (Morocco), DZA (Algeria), LBY (Libya), EGY (Egypt), MRT (Mali), MUJ (Mauritania), NER (Niger), TCD (Chad), SDN (Sudan), DJI (Djibouti), SEN (Senegal), GNB (Guinea-Bissau), GIN (Guinea), SLE (Sierra Leone), LBR (Liberia), CIV (Ivory Coast), BFA (Burkina Faso), BEN (Benin), GHA (Ghana), TOG (Togo), NGA (Nigeria), CMR (Cameroon), CAF (Cape Verde), ETH (Ethiopia), SOM (Somalia), UGA (Uganda), KEN (Kenya), ZAR (Zambia), BDI (Burundi), RWA (Rwanda), TZA (Tanzania), AGO (Angola), ZMB (Zimbabwe), MWI (Malawi), NAM (Namibia), BWA (Botswana), ZWE (Zimbabwe), MOZ (Mozambique), SWZ (Swaziland), ZAF (South Africa), and LSO (Lesotho).

Geospatial Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spazialeModelli
spaziali

Lo shapefile

Proiezione in metri



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali



EPSG:2312 Garoua - UTM zone 33N

[https://spatialreference.org/
ref/epsg/2312/](https://spatialreference.org/ref/epsg/2312/)

Original Projection



EPSG:2312 Projection

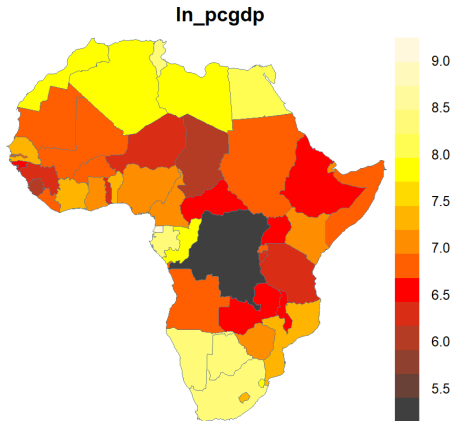
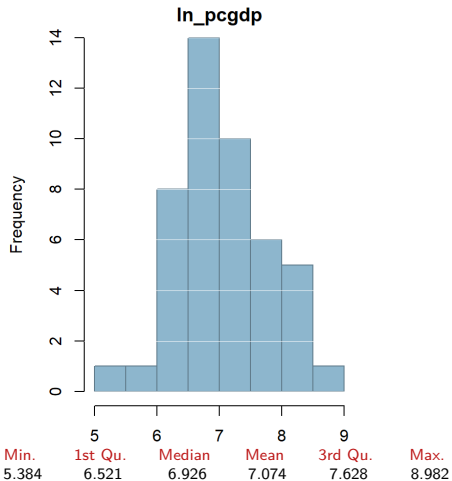


Ispezione dei dati

Variabili continue



ln_pcgdp



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

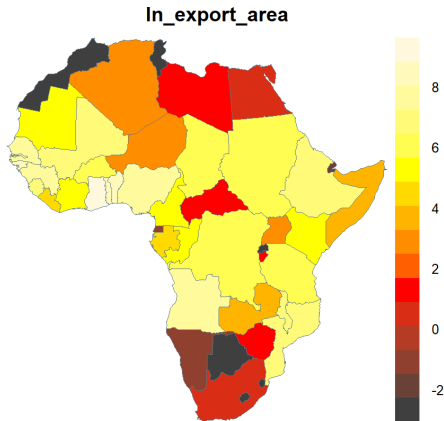
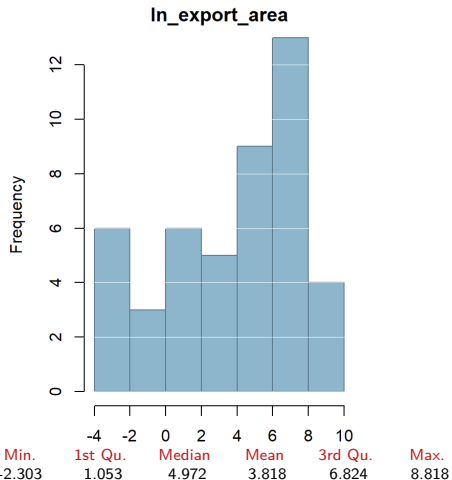
Modelli
spaziali

Ispezione dei dati

Variabili continue



ln_export_area



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

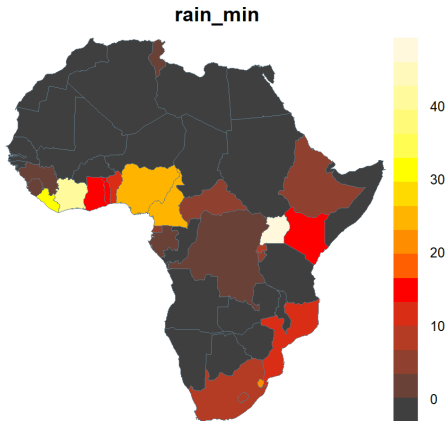
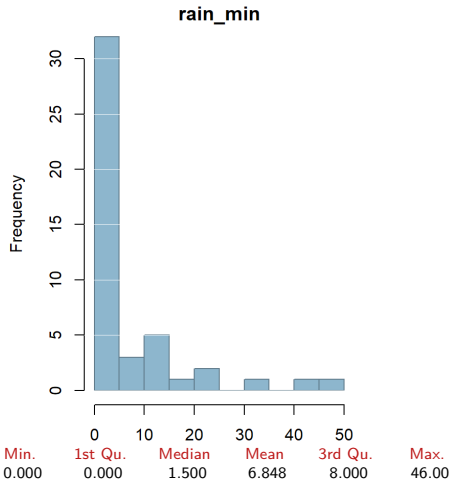
Modelli
spaziali

Ispezione dei dati

Variabili continue



rain_min



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

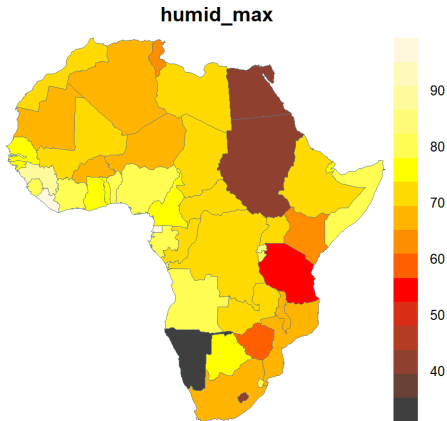
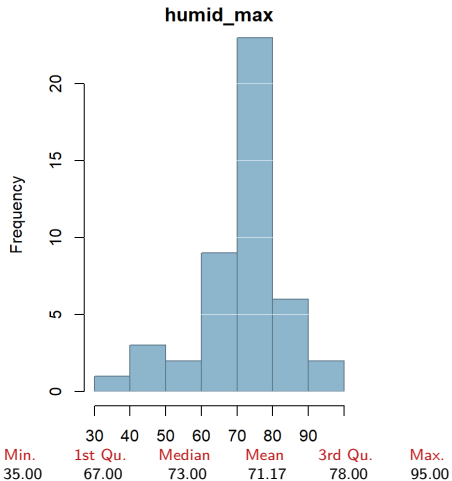
Modelli
spaziali

Ispezione dei dati

Variabili continue



humid_max



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Data Analysis

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Introduzione

Analisi dei dati

Analisi
spaziale

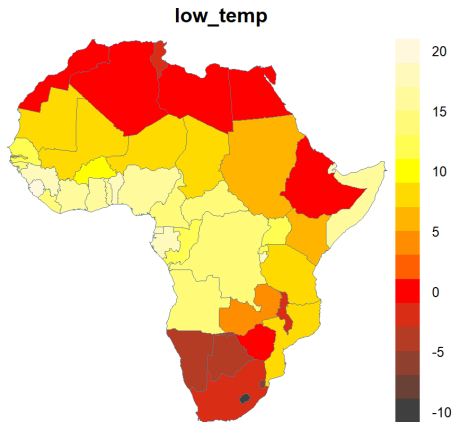
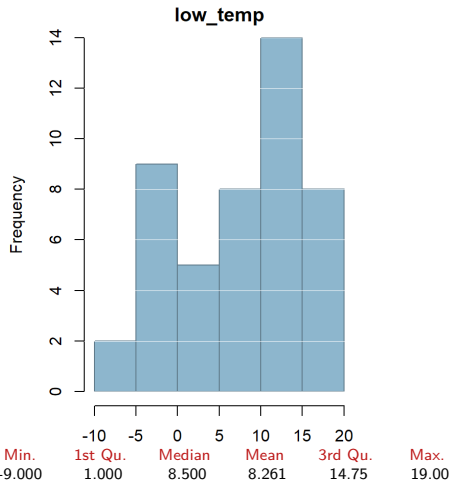
Modelli
spaziali

Ispezione dei dati

Variabili continue



low_temp



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Data Analysis

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Introduzione

Analisi dei dati

Analisi
spaziale

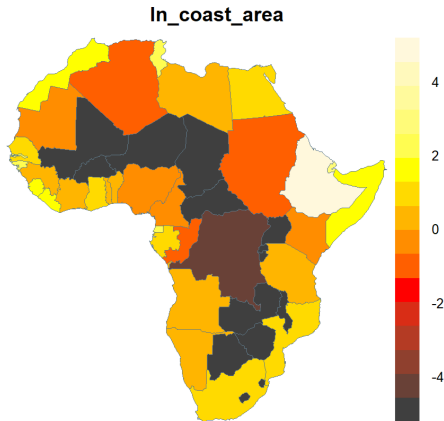
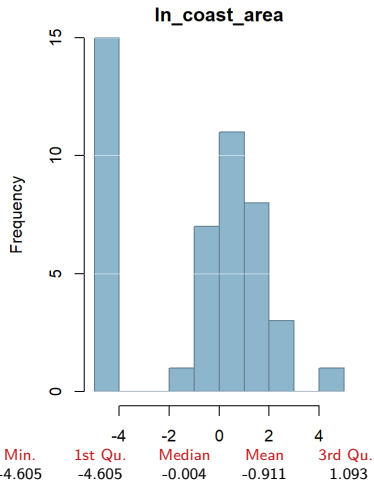
Modelli
spaziali

Ispezione dei dati

Variabili continue



ln_coast_area



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

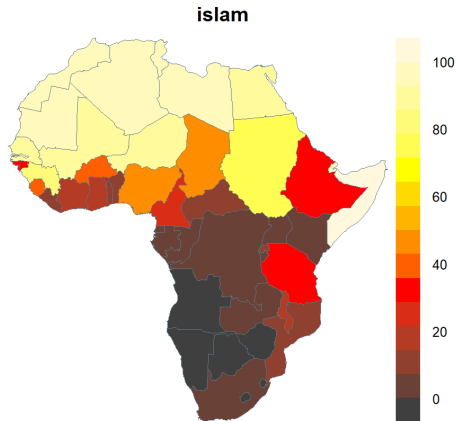
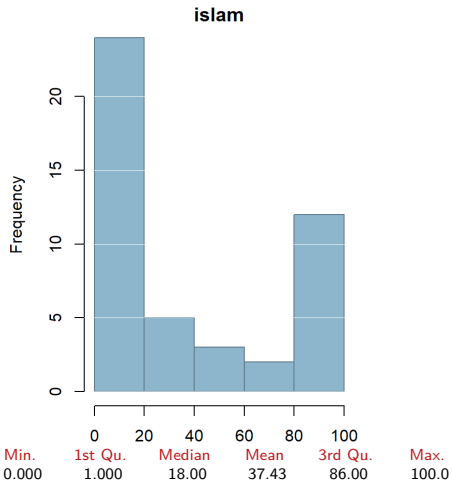
Modelli
spaziali

Ispezione dei dati

Variabili continue



islam



Geospatial
Data Analysis

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Introduzione

Analisi dei dati

Analisi
spaziale

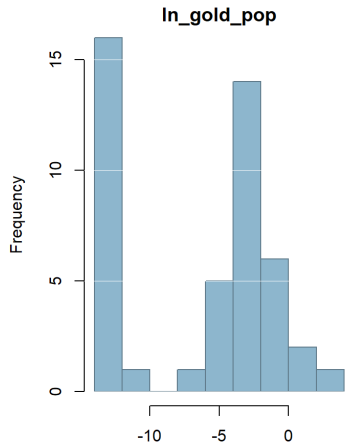
Modelli
spaziali

Ispezione dei dati

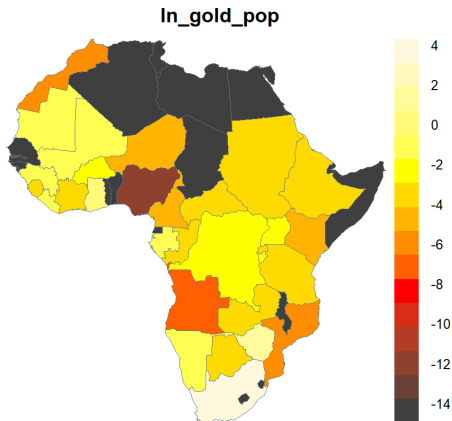
Variabili continue



ln_gold_pop



Min. -13.82 1st Qu. -13.82 Median -4.132 Mean -6.795 3rd Qu. -2.695 Max. 3.084



Geospatial
Data Analysis

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Introduzione

Analisi dei dati

Analisi
spaziale

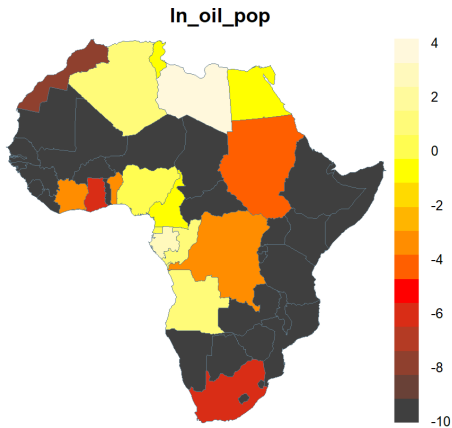
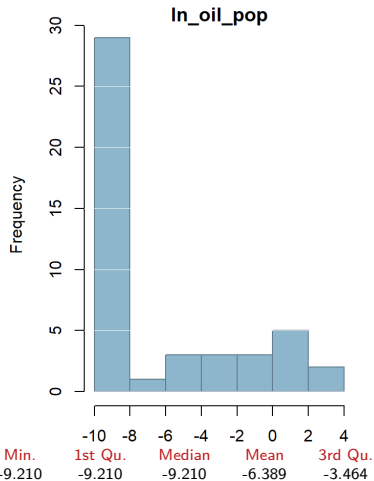
Modelli
spaziali

Ispezione dei dati

Variabili continue



ln_oil_pop



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Ispezione dei dati

Variabili continue



Geospatial
Data Analysis

D. Comanducci

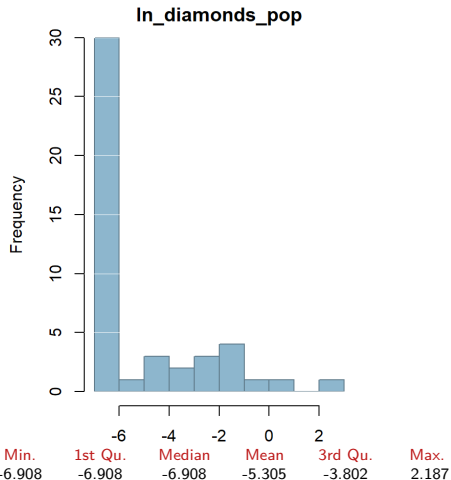
Introduzione

Analisi dei dati

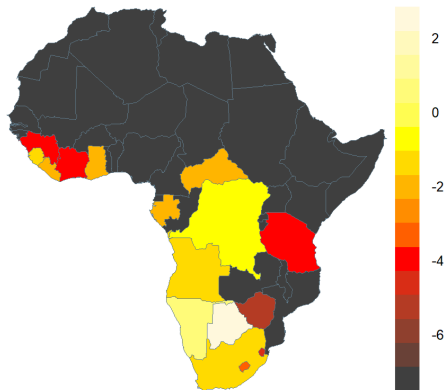
Analisi
spaziale

Modelli
spaziali

ln_diamonds_pop



ln_diamonds_pop



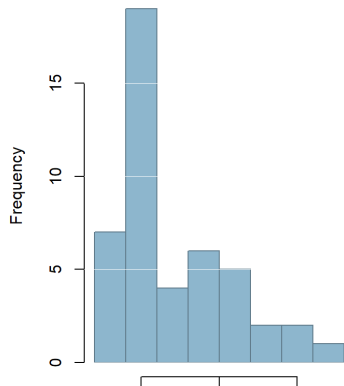
Ispezione dei dati

Variabili continue



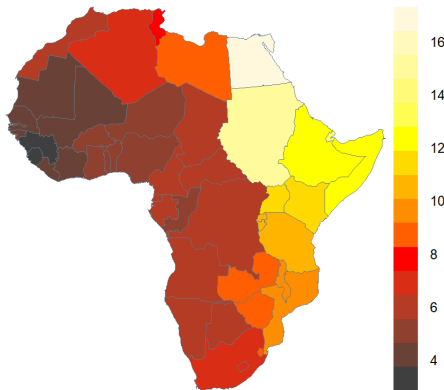
atlantic_dist_min

atlantic_dist_min



Min. 3.705 1st Qu. 4.975 Median 5.685 Mean 7.247 3rd Qu. 9.205 Max. 16.39

atlantic_dist_min



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

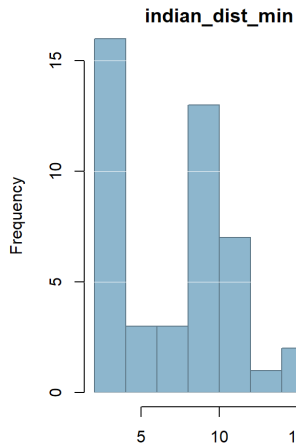
Modelli
spaziali

Ispezione dei dati

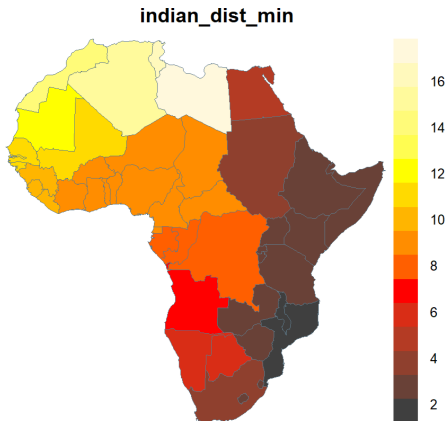
Variabili continue



indian_dist_min



Min. 2.183 1st Qu. 2.705 Median 8.461 Mean 7.306 3rd Qu. 9.697 Max. 16.78



Geospatial
Data Analysis

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Introduzione

Analisi dei dati

Analisi
spaziale

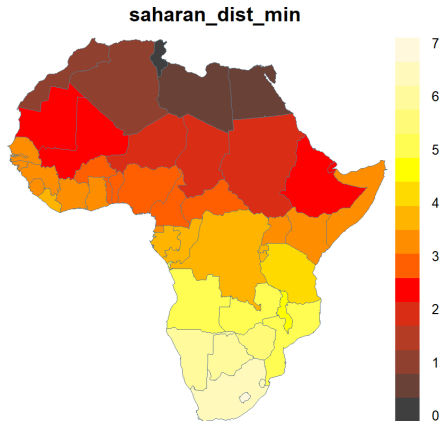
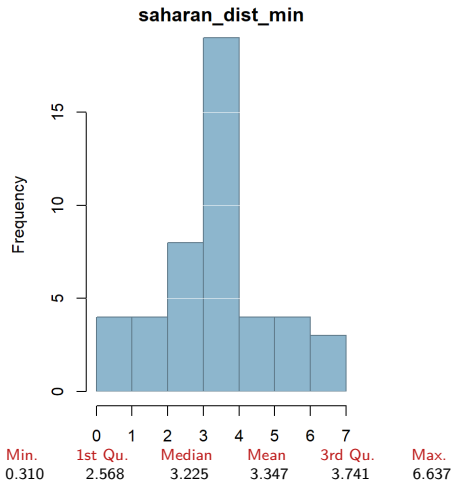
Modelli
spaziali

Ispezione dei dati

Variabili continue



saharan_dist_min



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

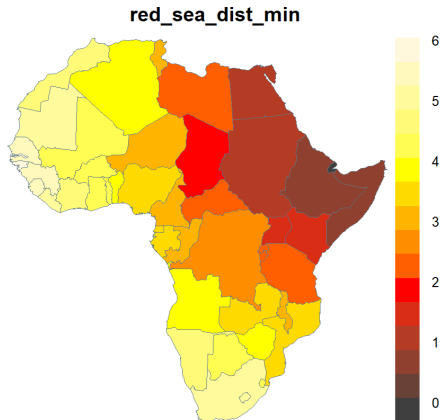
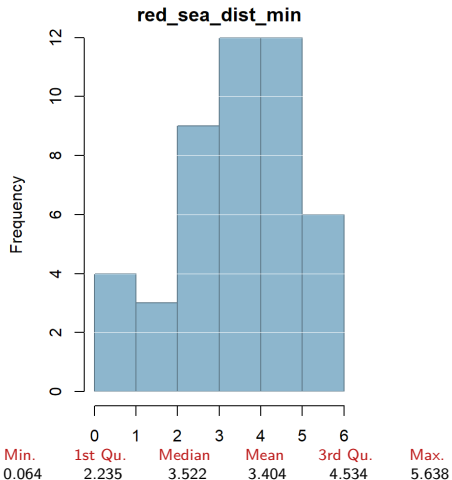
Modelli
spaziali

Ispezione dei dati

Variabili continue



red_sea_dist_min



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

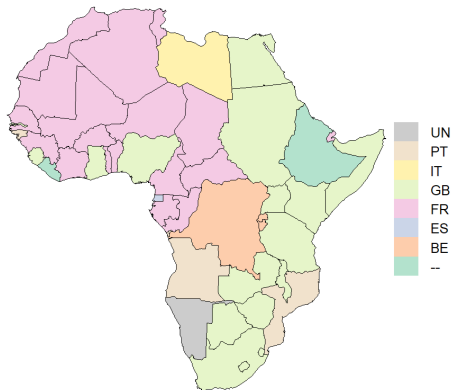
Modelli
spaziali

Ispezione dei dati

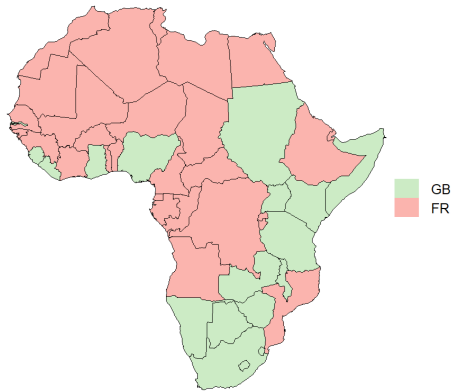
Variabili discrete



colony0 ... colony7
colonizers



legor_fr & legor_uk
legislative origin



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Data Analysis

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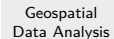
Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

(V. binarie)



Introduzione

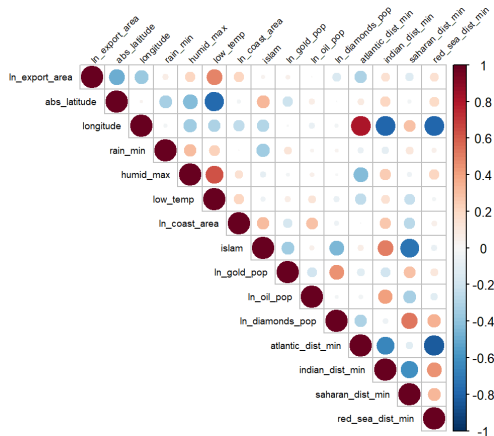
Analisi dei dati

Analisi
spazialeModelli
spaziali

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Indici di correlazione

(Variabili continue)



v_1	v_2	$\text{cor}(v_1, v_2)$
abs_latitude	low_temp	-0.77686
longitude	atlantic_dist_min	0.81459
longitude	indian_dist_min	-0.79186
longitude	red_sea_dist_min	-0.78283
islam	saharan_dist_min	-0.73502
atlantic_dist_min	red_sea_dist_min	-0.83068

Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Matrice di prossimità

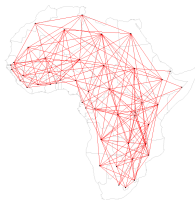
Vicini con confini comuni



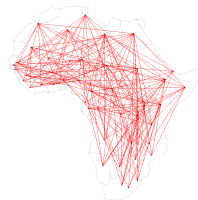
prox. lag 1



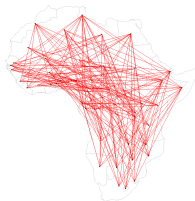
prox. lag 2



prox. lag 3



prox. lag 4



prox. lag 5



```
slaveTrade.nb = poly2nb(slaveTrade)
slaveTrade.lw = nb2listw(slaveTrade.nb, style = "W")
```

Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

**Analisi
spaziale**

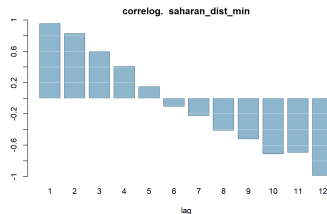
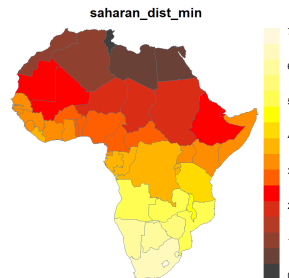
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



	<i>I</i>	<i>p</i> -value	<i>C</i>	<i>p</i> -value
saharan_dist_min	0.872	6.07e-19	0.097	1.04e-15
red_sea_dist_min	0.871	1.06e-18	0.105	2.73e-16
indian_dist_min	0.803	3.45e-16	0.205	2.38e-13
atlantic_dist_min	0.726	6.49e-14	0.242	3.79e-11
islam	0.705	7.97e-13	0.287	8.79e-12
low_temp	0.570	3.87e-09	0.326	2.62e-10
ln_oil_pop	0.467	7.96e-07	0.522	8.62e-06
ln_pcgdp	0.423	5.85e-06	0.563	5.55e-05
ln_diamonds_pop	0.314	4.28e-04	0.674	2.75e-03
ln_export_area	0.306	7.08e-04	0.551	1.47e-05
humid_max	0.274	1.46e-03	0.647	2.18e-03
ln_coast_area	0.242	5.11e-03	0.683	1.45e-03
ln_gold_pop	0.174	2.84e-03	0.802	2.91e-04
rain_min	0.164	2.71e-02	0.799	6.87e-02



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

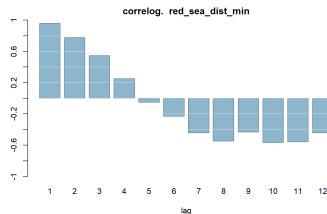
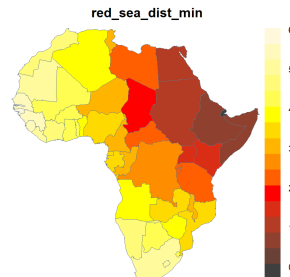
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



	<i>I</i>	<i>p</i> -value	<i>C</i>	<i>p</i> -value
saharan_dist_min	0.872	6.07e-19	0.097	1.04e-15
red_sea_dist_min	0.871	1.06e-18	0.105	2.73e-16
indian_dist_min	0.803	3.45e-16	0.205	2.38e-13
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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

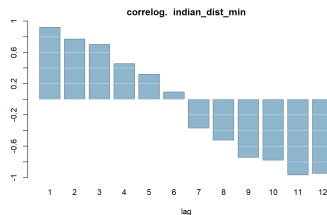
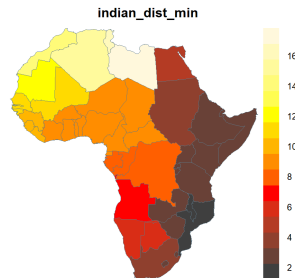
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



	<i>I</i>	<i>p</i> -value	<i>C</i>	<i>p</i> -value
saharan_dist_min	0.872	6.07e-19	0.097	1.04e-15
red_sea_dist_min	0.871	1.06e-18	0.105	2.73e-16
indian_dist_min	0.803	3.45e-16	0.205	2.38e-13
atlantic_dist_min	0.726	6.49e-14	0.242	3.79e-11
islam	0.705	7.97e-13	0.287	8.79e-12
low_temp	0.570	3.87e-09	0.326	2.62e-10
ln_oil_pop	0.467	7.96e-07	0.522	8.62e-06
ln_pcgdp	0.423	5.85e-06	0.563	5.55e-05
ln_diamonds_pop	0.314	4.28e-04	0.674	2.75e-03
ln_export_area	0.306	7.08e-04	0.551	1.47e-05
humid_max	0.274	1.46e-03	0.647	2.18e-03
ln_coast_area	0.242	5.11e-03	0.683	1.45e-03
ln_gold_pop	0.174	2.84e-03	0.802	2.91e-04
rain_min	0.164	2.71e-02	0.799	6.87e-02



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

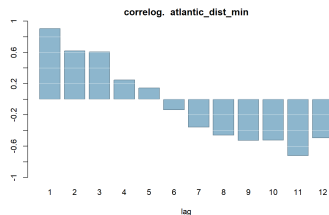
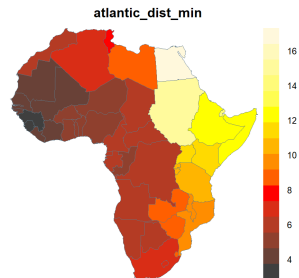
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



	<i>I</i>	<i>p</i> -value	<i>C</i>	<i>p</i> -value
saharan_dist_min	0.872	6.07e-19	0.097	1.04e-15
red_sea_dist_min	0.871	1.06e-18	0.105	2.73e-16
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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

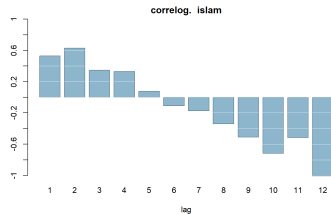
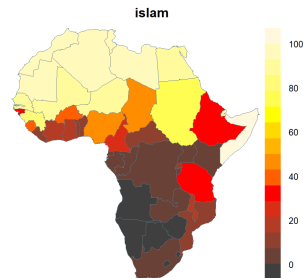
Modelli
spaziali

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

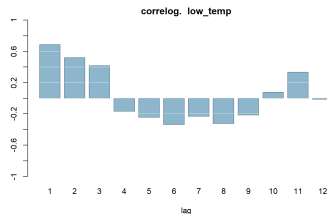
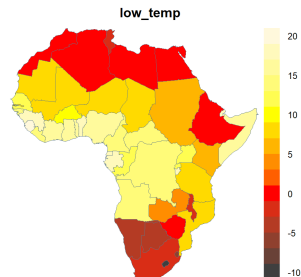
Modelli
spaziali

Test di Moran globale

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

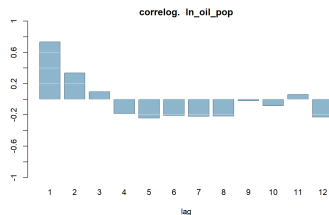
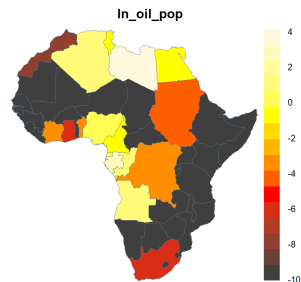
Modelli
spaziali

Test di Moran globale

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

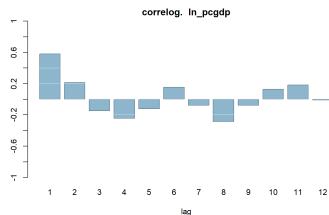
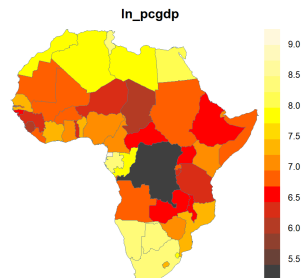
Modelli
spaziali

Test di Moran globale

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

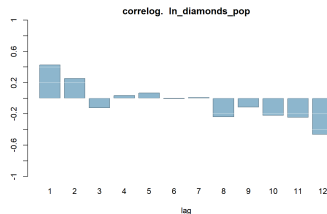
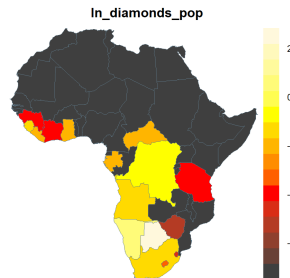
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



	<i>I</i>	<i>p</i> -value	<i>C</i>	<i>p</i> -value
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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

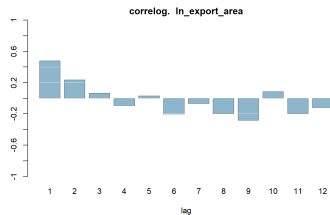
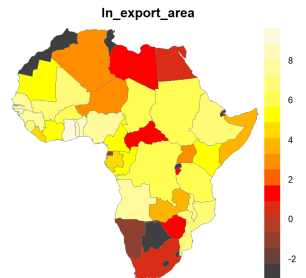
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

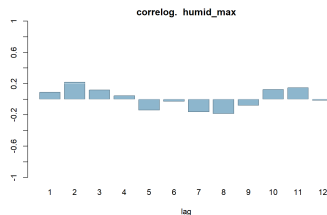
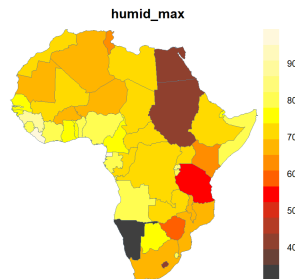
Modelli
spaziali

Test di Moran globale

Tutte le variabili (continue)



	<i>I</i>	<i>p</i> -value	<i>C</i>	<i>p</i> -value
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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

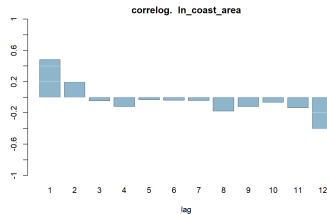
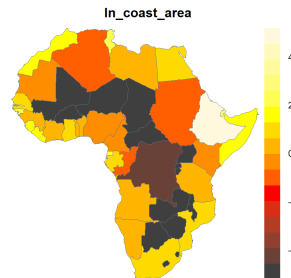
Modelli
spaziali

Test di Moran globale

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

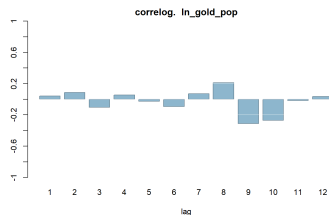
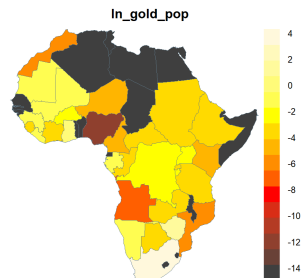
Modelli
spaziali

Test di Moran globale

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

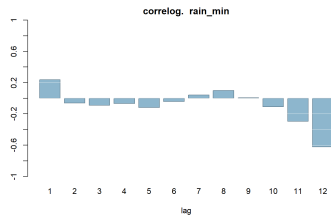
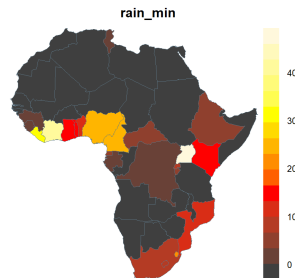
Modelli
spaziali

Test di Moran globale

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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

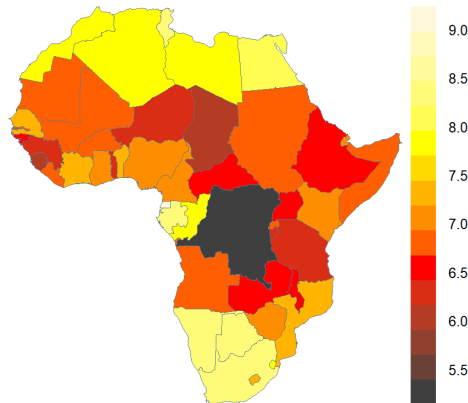
Analisi di ln_pcgdp

Media locale



Dati originali

ln_pcgdp



Geospatial
Data Analysis

D. Comanducci

Introduzione

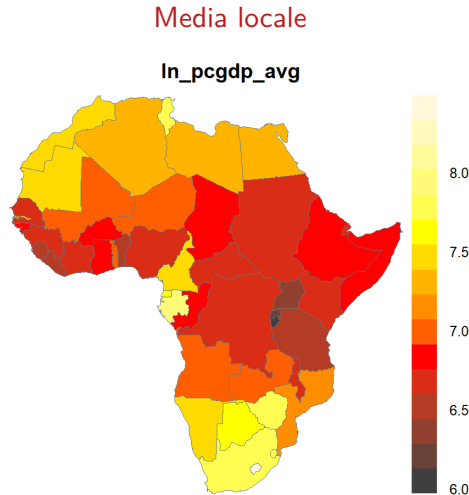
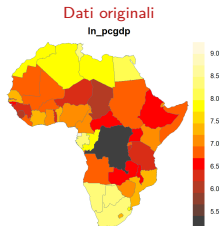
Analisi dei dati

**Analisi
spaziale**

Modelli
spaziali

Analisi di ln_pcgdp

Media locale



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

**Analisi
spaziale**

Modelli
spaziali

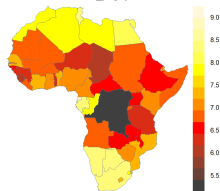
Analisi di ln_pcgdp

Media locale



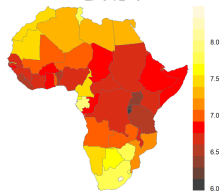
Dati originali

ln_pcgdp



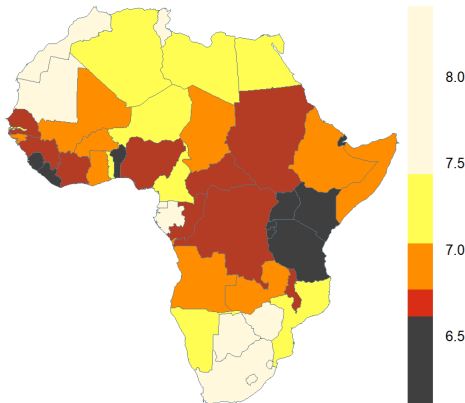
Media locale

ln_pcgdp_avg



Tagli ai quintili sulla media locale

Quintile cuts: ln_pcgdp_avg



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

**Analisi
spaziale**

Modelli
spaziali

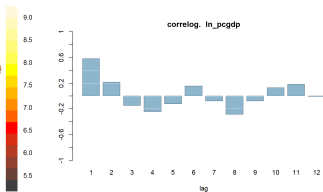
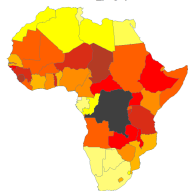
Analisi di ln_pcgdp

Media locale



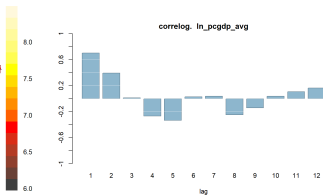
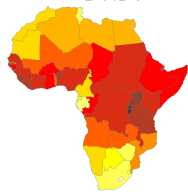
Dati originali

ln_pcgdp



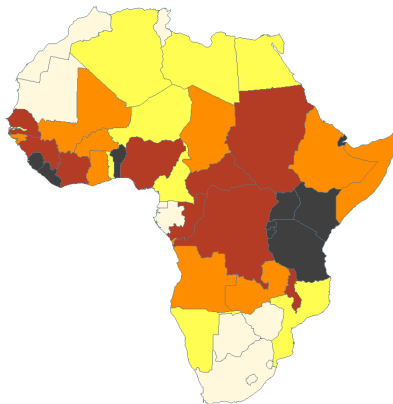
Media locale

ln_pcgdp_avg



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Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

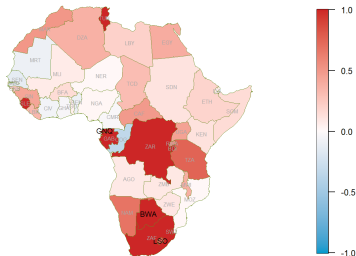
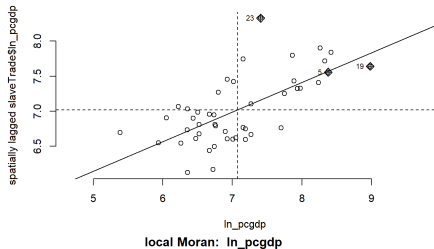
Analisi
spaziale

Modelli
spaziali

Analisi di ln_pcgdp

Moran locale

5: BWA; 19: GNQ; 23: LSO



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

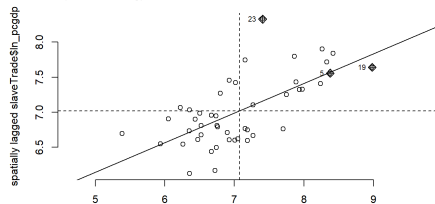
Analisi
spaziale

Modelli
spaziali

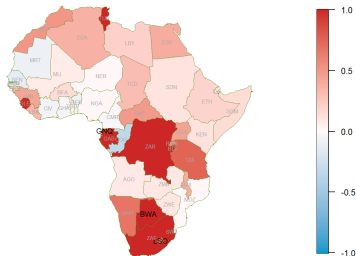
Analisi di ln_pcgdp

Moran locale

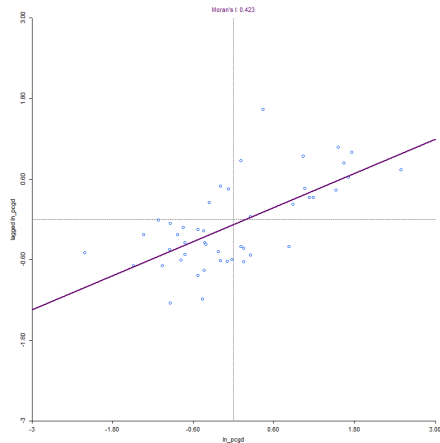
5: BWA; 19: GNQ; 23: LSO



ln_pcgdp
local Moran: ln_pcgdp



GeoDa



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

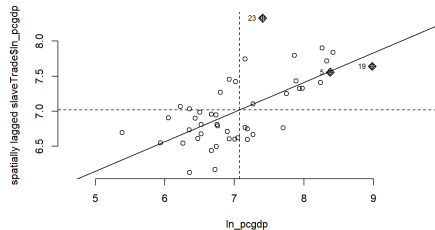
Analisi
spaziale

Modelli
spaziali

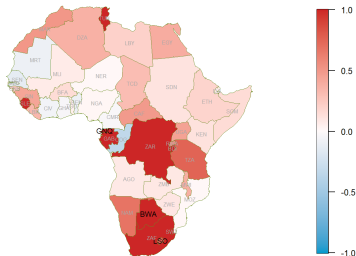
Analisi di ln_pcgdp

Moran locale

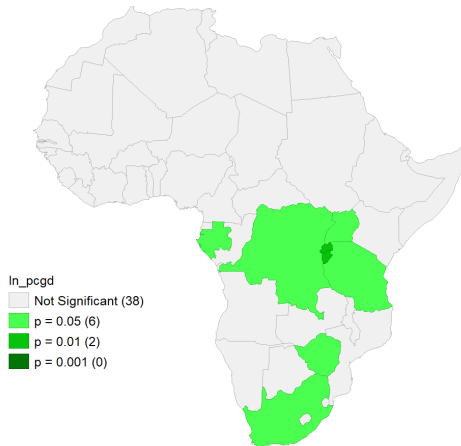
5: BWA; 19: GNQ; 23: LSO



local Moran: ln_pcgdp



GeoDa



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

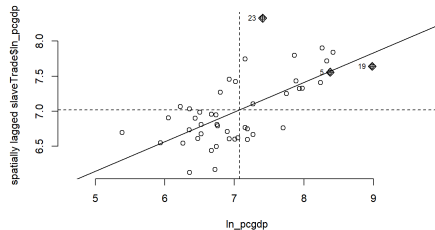
Analisi
spaziale

Modelli
spaziali

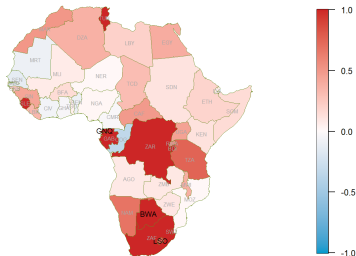
Analisi di ln_pcgdp

Moran locale

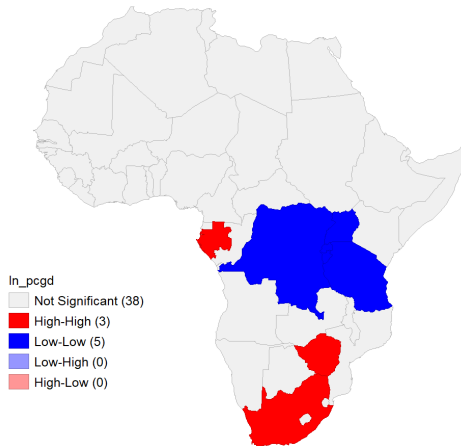
5: BWA; 19: GNQ; 23: LSO



local Moran: ln_pcgdp



GeoDa



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

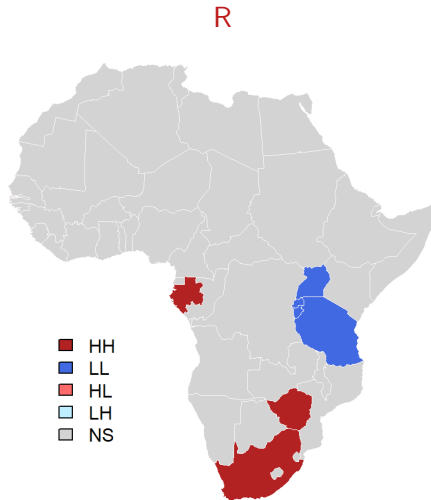
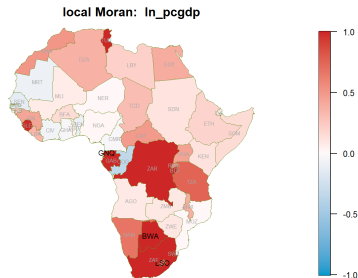
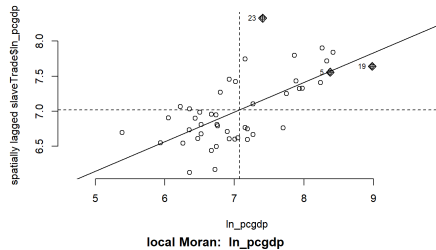
Analisi
spaziale

Modelli
spaziali

Analisi di ln_pcgdp

Moran locale

5: BWA; 19: GNQ; 23: LSO



```
lmii = localmoran(slaveTrade$ln_pcgdp, slaveTrade.lw)
```



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Modello lineare

Stima OLS

```
fmla <- ln_pcgdp ~ ln_export_area + colony1 + colony2 + colony3 + colony4 + colony5 + colony6 + colony7 + rain_min +  
humid_max + low_temp + ln_coast_area + islam + legor_fr + region_n + ln_gold_pop + ln_oil_pop + ln_diamonds_pop
```

Stima

var.	coef.	p-value
(Intercept)	6.409676	7.96e-08
ln_export_area	-0.090781	0.00158
colony1	0.947924	0.04455
colony2	1.043905	0.02563
colony3	0.867653	0.06667
colony4	0.257498	0.66189
colony5	1.559744	0.03579
colony6	1.570997	0.03992
colony7	0.469763	0.47473
rain_min	0.001658	0.82096
humid_max	0.016627	0.07367
low_temp	-0.053279	0.00303
ln_coast_area	0.099378	0.00901
islam	-0.002329	0.40971
legor_fr	0.010320	0.98063
region_n	-0.131477	0.73174
ln_gold_pop	0.012940	0.35193
ln_oil_pop	0.077399	0.00177
ln_diamonds_pop	-0.021472	0.54701



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Modello lineare

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Moran sui residui

```
lm.morantest(modLM, slaveTrade.lw)
```

Moran I	p-value
-0.058976	0.2888



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Modello lineare

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---------	---------

-0.058976	0.2888
-----------	--------

Test di Rao

```
lm.RStests(modLM, listw=slaveTrade.lw, test='all')
```

	statistic	p-value
RSerr	0.3052046	0.5806
RSlag	0.0099526	0.9205
adjRSerr	0.4906222	0.4836
adjRSlag	0.1953702	0.6585
SARMA	0.5005748	0.7786

RSerr verifica l'autocorr. spaz. nel termine di errore (per SEM)

RSlag verifica l'autocorr. spaz. nella variabile dipendente (per SLM)

SARMA verifica la dipendenza combinata tra lag spaziale ed errore



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Modello lineare

Stima OLS

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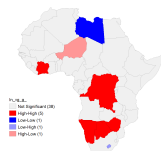
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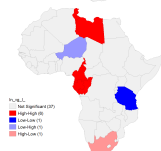
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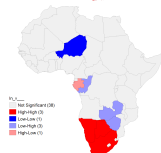
gold



oil



diamonds



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Modello lineare

Stima OLS

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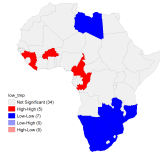
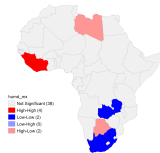
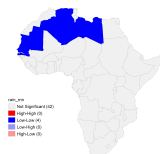
RSslag verifica l'autocorr. spaz. nella variabile dipendente (per SLM)

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rain min

hum. max

low temp



Geospatial
Data Analysis

D. Comanducci

Introduzione

Analisi dei dati

Analisi
spaziale

Modelli
spaziali

Modelli a confronto

Modello lineare vs. modelli spaziali



modello	Moran(res.)	p-value	ρ (* λ)	p-value(ρ)	AIC	" α_d "
LM	-0.0590	0.2888	—	—	62.6452 5	-0.0907
SEM	-0.0502	0.6077	-0.9175*	0.1258	62.3012 8	-0.0599
SLM	-0.0545	0.6243	-0.0169	0.9152	64.6339 1	-0.0912
SDM	-0.1053	0.7927	-0.4888	0.0495	37.4690 8	-0.1522

LM: Linear Model SEM: Spatial Error Model SLM: Spatial Lag Model SDM: Spatial Durbin Model

Conclusioni

- ▶ Tutti i modelli testati riportano un indice di Moran sui residui statisticamente non diverso da 0
- ▶ Ne consegue che in tutti i casi le covariate riescono a spiegare la struttura spaziale rilevata dall'indice di Moran sulla variabile dipendente
- ▶ Il modello con AIC più basso è lo Spatial Durbin Model (SDM)
- ▶ Tuttavia, applicando il rasoio di Occam, possiamo optare per il modello più semplice di tutti: quello lineare (LM)