Leibniz Institute of Agricultural Development
in Transition Economies

Economics of Climate Change: Application of Spatial Econometric Techniques with R

First session

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Organizer: Prof. Dr. Mohammad Reza Farzanegan

NaDiMa Dialogue 11, University of Marburg| 09 & 11 August 2021

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Leibniz Institute of Agricultural Development in Transition Economies

In other languages

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- German

  Räumliche Ökonometrie

- Persian

  اقتصاد سنجی فضایی

Part one

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Introduction

-Spatial pattern

-Importance

-Geostatistcs definition

-Spatial econometrics def.

Introduction

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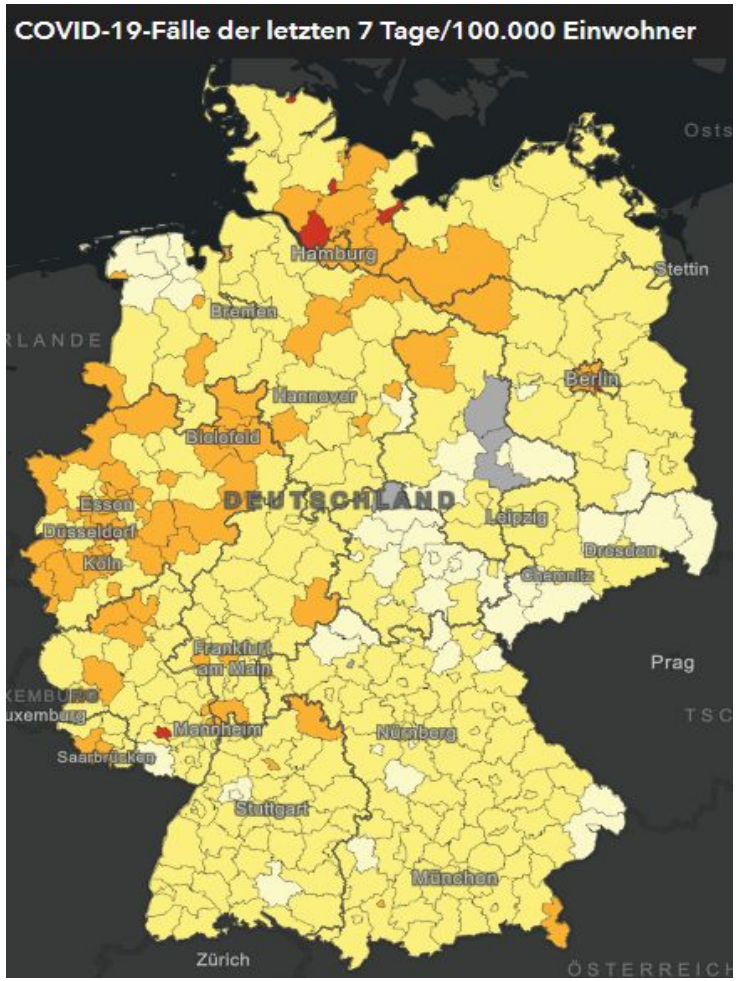
Why spatial relation is an issue? Look to latest COVID 19 distribution! Do we see a pattern?

آبی=کم‌خطر، زرد=خطر متوسط، نارنجی=پرخطر، قرمز=خیلی پرخطر

Source: ISNA, 29.07.2021



Source: RKI, 06.08.2021

Introduction, spatial pattern of conflicts

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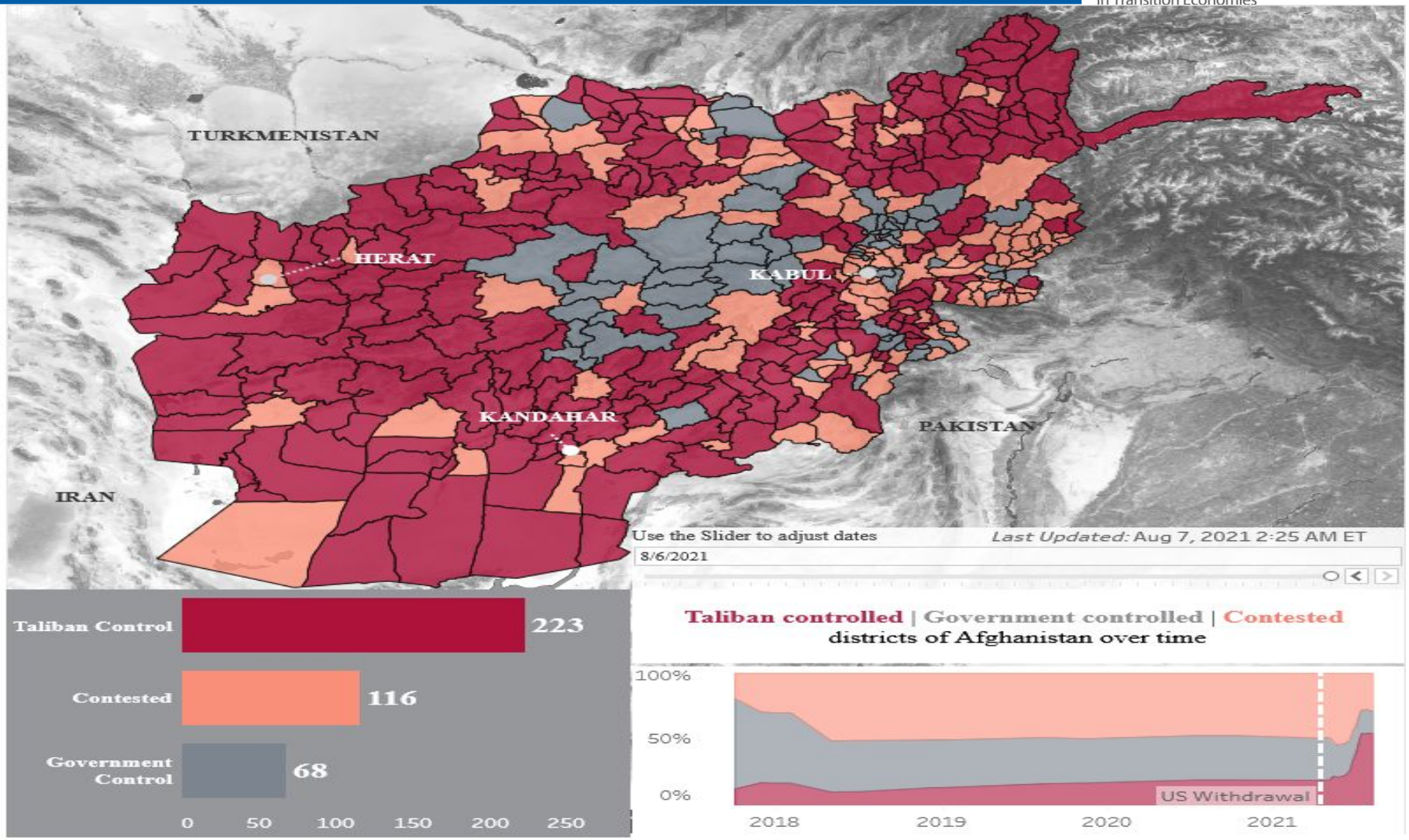

Source: https://www.longwarjournal.org/, access: 07.08.2021

Introduction, special pattern of read meat production

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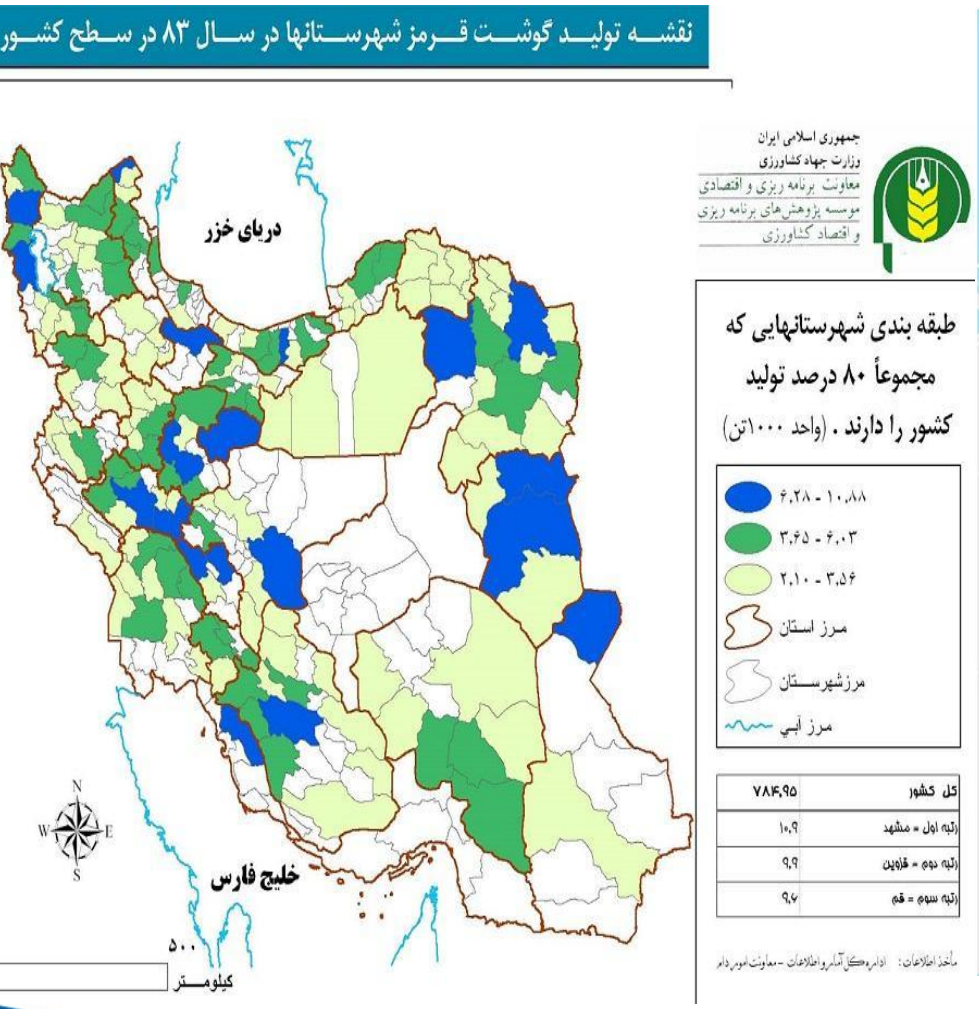
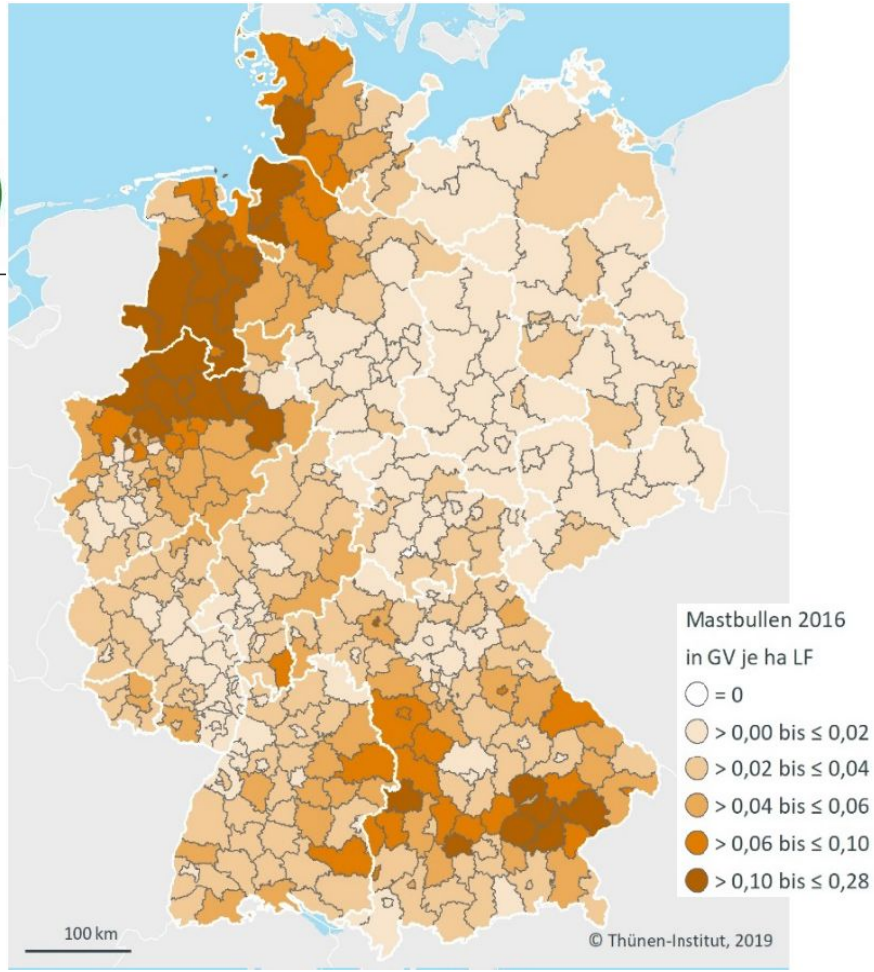
Meat production in different counties, Iran



Beef cattle density (per ha) in Germany



Introduction, special pattern of read meat production

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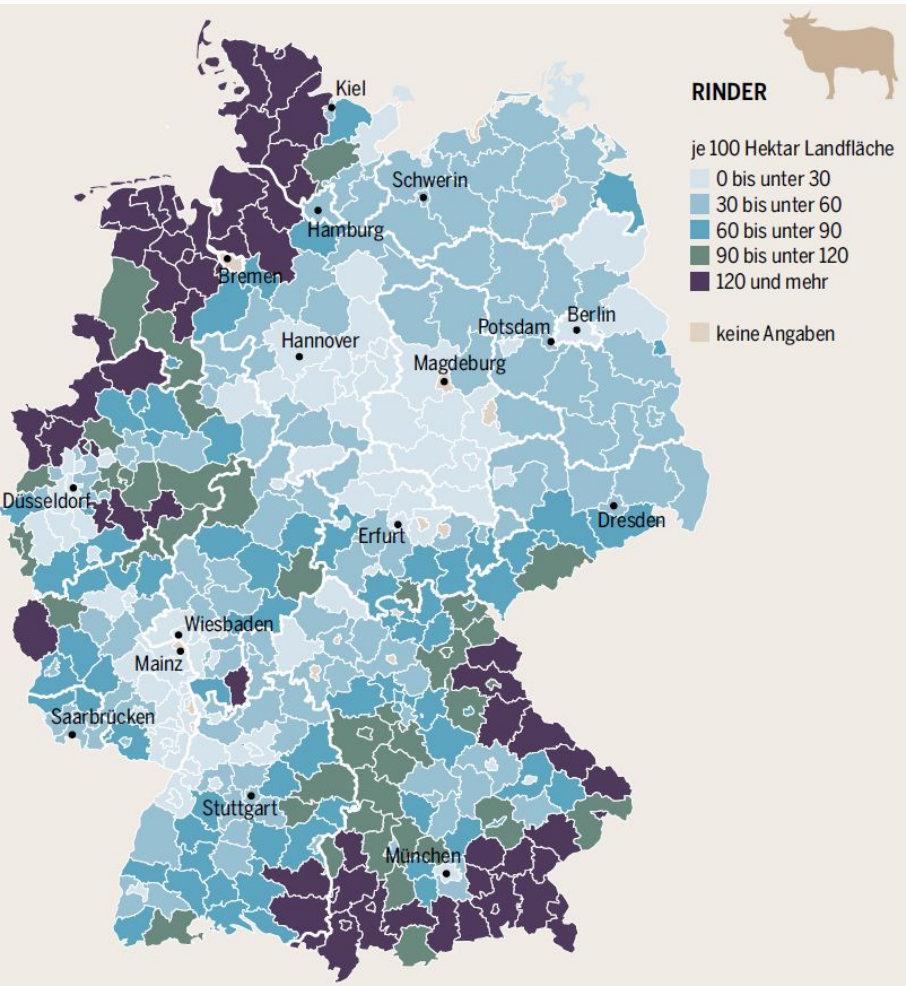
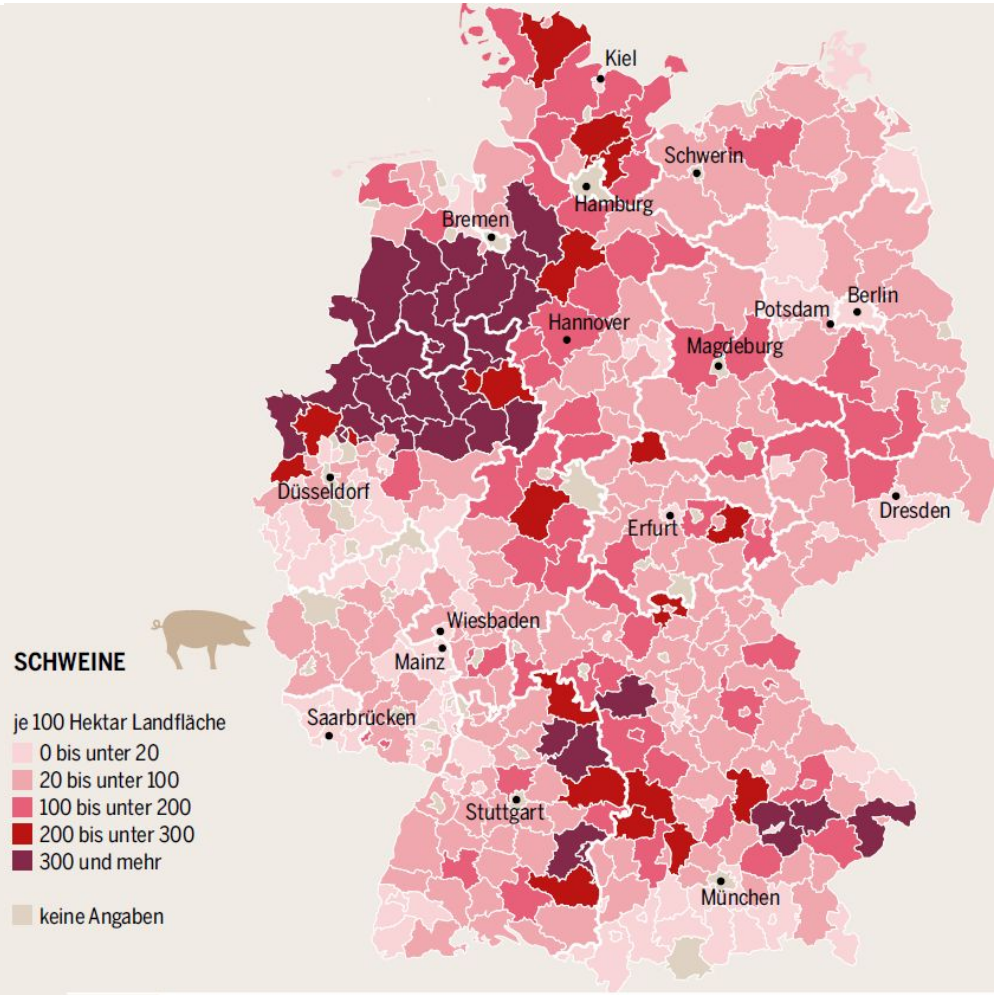
Beef cattle density (per 100 ha) in Germany



Swine density (per 100 ha) in Germany



Source: https://www.bund.net/service/publikationen/detail/publication/fleischatlas-deutschland-regional-2016/

Introduction, causal effects on spatial variables

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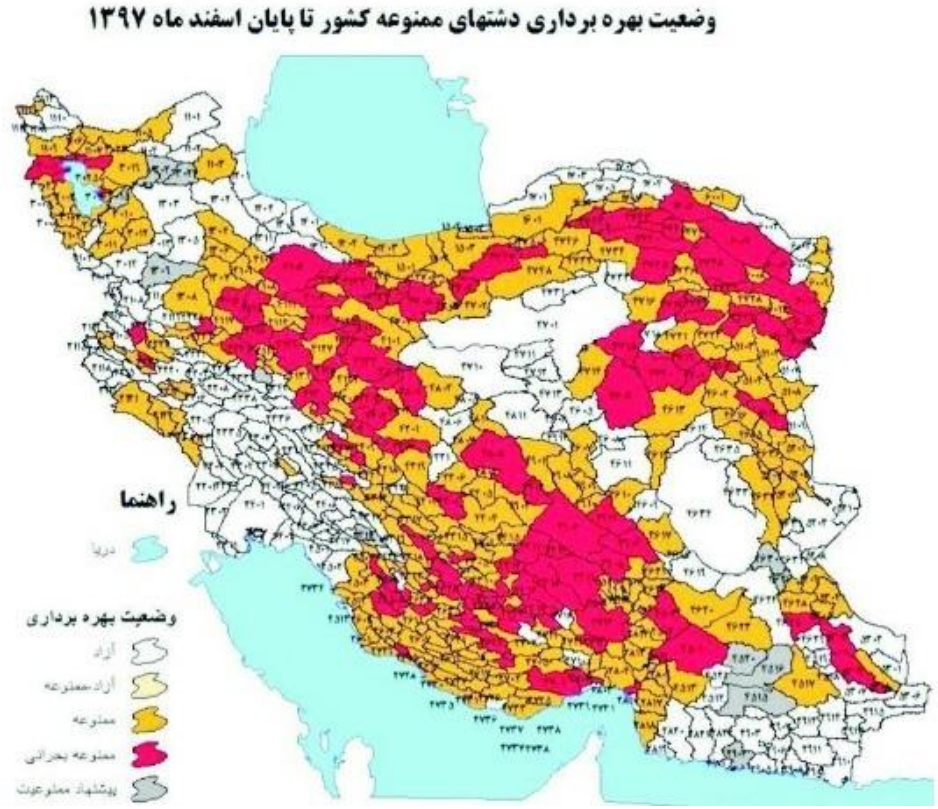
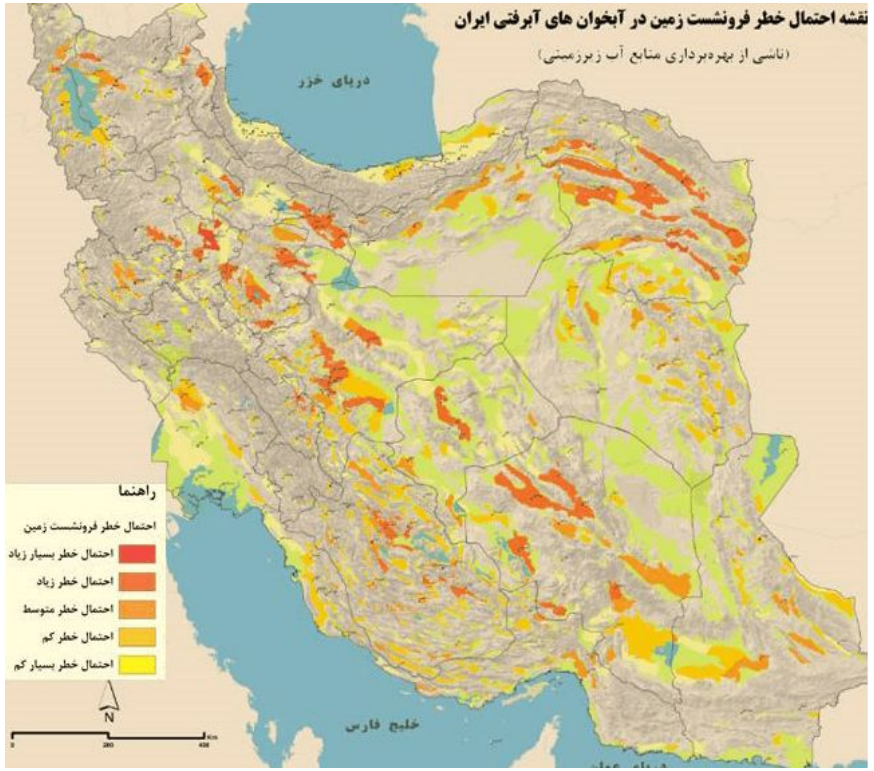
Aquifer conditions in Iran, 2019



Source: Etemad daily, 2020

Land subsidence, 2019



Source: http://saa.ir, 2019

Introduction, Why spatial relation is an issue?

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- It is real issue in statistical observation
- It can be due to
  - Pandemic (COVID 19, black death 14 century, …),
  - Geospatial variables (climate, groundwater, geodesy, ..)
  - Spill over effects for social and economic variables
- Therefore, it is important to account for this issue as
  - It can helps us to understand the patterns
  - It can helps us to interpolate
  - It can helps us to understand the causality
- Spatial data analysis can be categorised to:
  - **Spatial statistics** (primary stages of approach late 60's), finding spatial pattern,
  - **Geostatistics**,
  - **Spatial econometrics**

Spatial models: Geostatistcs and spatial econometrics , the difference!

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- Geostatistical data are data that could in principle be measured anywhere, but that typically come as measurements at a limited number of observation locations. Geostatioctics deal for instance with:
  - The estimation of ore grades over mineable units, based on drill hole data
  - Interpolation of environmental variables from sample or monitoring network data (e.g. air quality, soil pollution, ground water head, hydraulic conductivity)
  - Interpolation of physical or chemical variables from sample data
  - Estimation of spatial averages from continuous, spatially correlated data

Source: Bivand et al (2013, p. 213)

Examples of methods in geostatistics

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- Spatial correlation with Variogram
- Interpolation
- Kriging
- Co-kriging
- Filtering
- Smoothing
- ….

Example of geostatistics

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J.Env. Sci. Tech., Vol 19, No.1, spring 2017

Spatial-Temporal Modeling of Groundwater Level Variations of Urban and Rural Areas in Kashan Aquifer Using GIS Techniques

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Javad Samadi[2]

Abstract

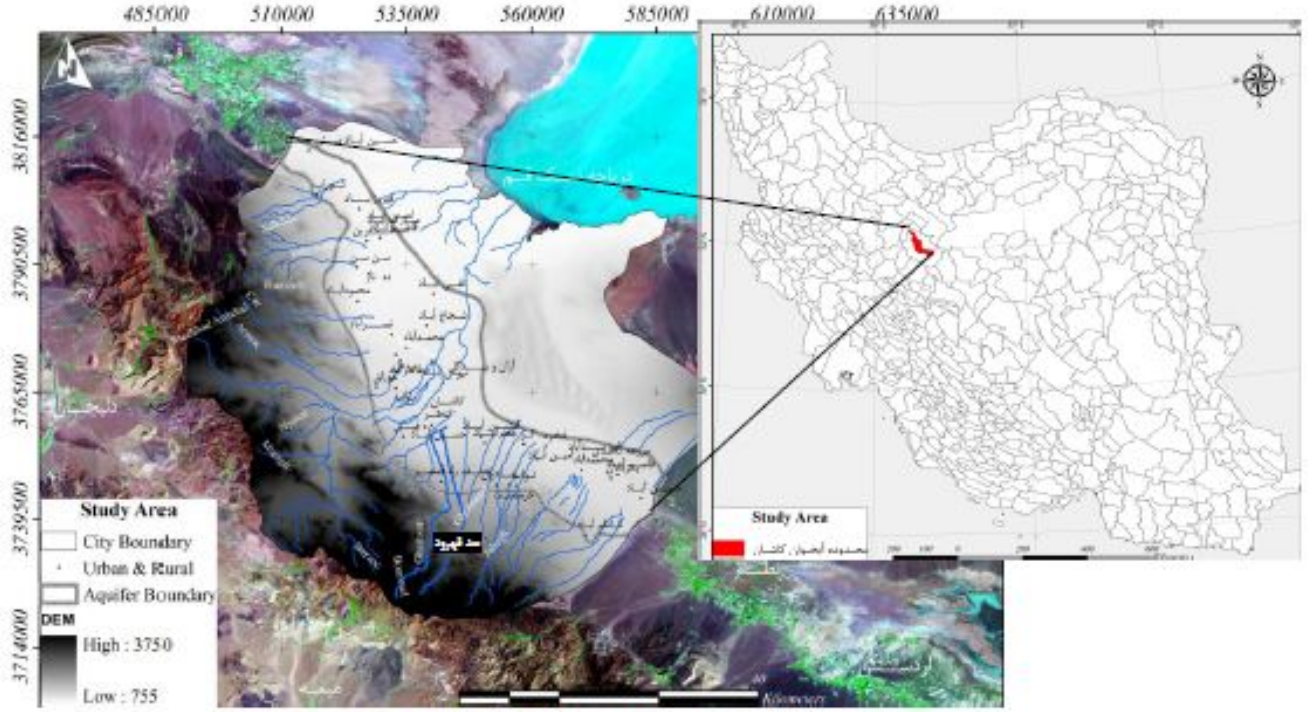
Background and Objective: The hydr
aquifer demonstrate that during 2002-2
meter has decreased about 5.5 meter. W
uses, collecting samples from all parts
zoning methods are powerful tools in the
research aimed, modeling of level, depth
table based on Cross validation techni
interpolation in GIS environment.

Method: water level data of 67 observati
mapping of Kashan groundwater level
employed and some criteria such as mea
square error (RMSE) and R^2 have bee
choosing the best one.

Findings: The results indicated that the
RMSE = 20.29 and R^2 = 0.999 possessed

Discussion and Counclusion: As well a
high population due to the high aggrava
level and activities in the industrial, agri
in groundwater level.

Keywords: Interpolation, Geostatistic a
level, Kashan Aquifer



شکل ۱- نقشه منطقه مورد مطالعه آبخوان کاشان

Figure 1- Study area map of Kashan aquifer

Examples of geostatistics with kriging

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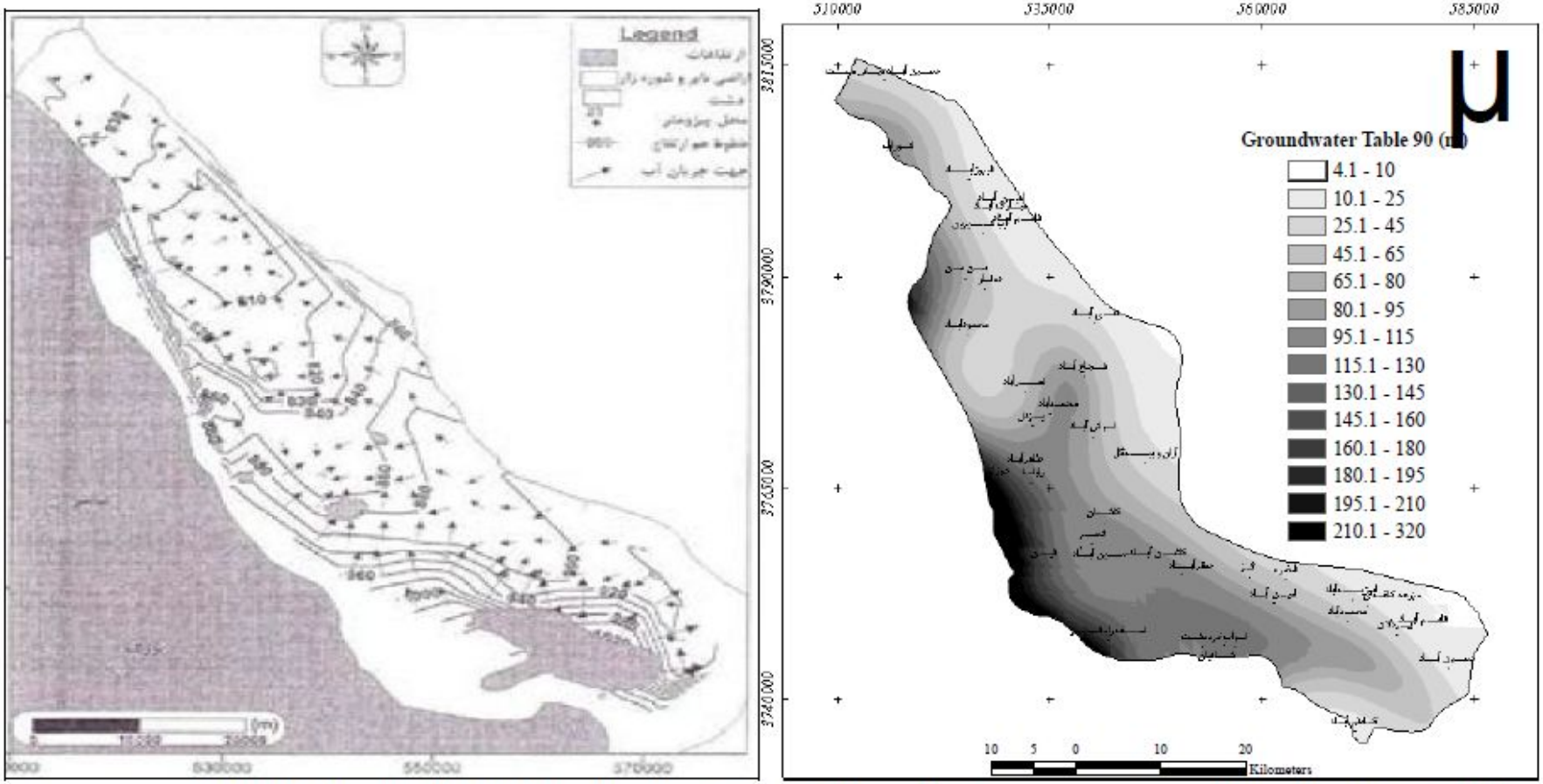

شکل ۴- نقشه‌های تراز، عمق و جهت جریان آب های زیرزمینی سال های ۸۱ تا ۹۰ آبخوان کاشان (از راست به چپ)

Figure 4- Maps of level, depth and groundwater flow direction in Kashan aquifer at years of 2002-2012 (right to left)

Source: Samadi, 2017

Geostastistics and spatial econometrics?

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- In geostatistics, we deal with the characterisation of the formation or development of neighbourhood relations.
  - More: https://spatialanalysisonline.com/index.html

- In spatial econometrics, we will characterise to what extent spatial (or relational) proximity influences an outcome, by controlling multiple characteristics.

What is spatial econometrics:

„A collection of techniques that deal with the peculiarities caused by space in the statistical analysis of regional science models"
Luc Anselin (1988)

- History: The term spatial econometrics first used by Belgian economists *Paelnick and Klaassen (1979)* but the spatial aspects of data long ignored in mainstream economics till 90‘s

Spatial econometrics

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Spatial econometric modelling is a process help us to deal with empirical issues. This is a very wide area which can be summarised with following attributes:

- 1) It is an estimation theory.
- 2) It consist of theoretical models based on the theory of economics, most often consisting of the selection of variables but also determining the form of the model.
- 3) It is a technical way of carrying out the estimation together with the assessment of the fit and quality of the estimated models, the selection of the best model and the implementation of the forecast on new data.
- 4) It is the interpretation of models, on the one hand, consisting of examining the size and significance of the obtained econometric model coefficients but, on the other hand, translating quantitative results into phenomena and mechanisms discussed in theory.

- Source: Kopczewska (2021)

Part 2, Spatial econometrics

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- OLS and assumptions
- Spatial weight matrix
- *Moran I* test
- Spatial regression
- Coordinates and UTM

Spatial econometric model, start

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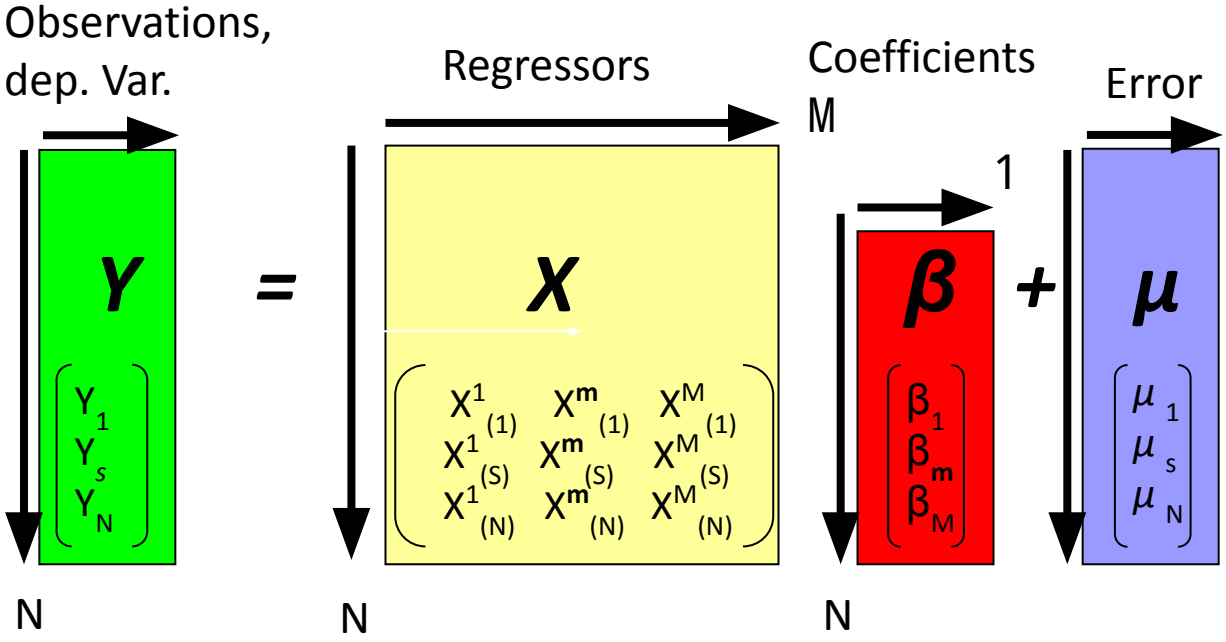
Simple OLS model assumptions, design matrix



$$\mu = Y - \hat{Y} = Y - X\beta$$

$$S = \Sigma\mu^2$$

The error is minimal when

$$\beta = X^T Y (X^T X)^{-1}$$

N: Number of observations
M: Number of regressors

Least squares
Parameter estimates

$$Y = X\beta + \mu,\ \mu \sim N(0, \sigma^2), iid$$

- Identically
- Independently
- Distributed

Regression using spatial data

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- If the spatial autocorrelation is available in the error term, then the assumption of the **independency** is violated:
  - The variance covariance matrix has problems
  - The coefficients are not consistent
  - The prediction of the model is not reliable
- What to do?

  – **Spatial test**
- On what?

  – **Residuals**
- How?
  - First we need spatial weight matrix **W**

Regression using spatial data

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- The major difference between spatial econometrics and standard econometrics lies on two different type of information needed
  - Observed value of economic/non-economic variables
  - Particular location where the data observed
- Spatial map needed
- Closeness is an issue which we need spatial matrix to deal with
- We can start with chessboard example

Spatial weight matrix, start with cross board on chess

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Source: https://en.wikipedia.org/wiki/Chessboard

Spatial weight matrix (W)

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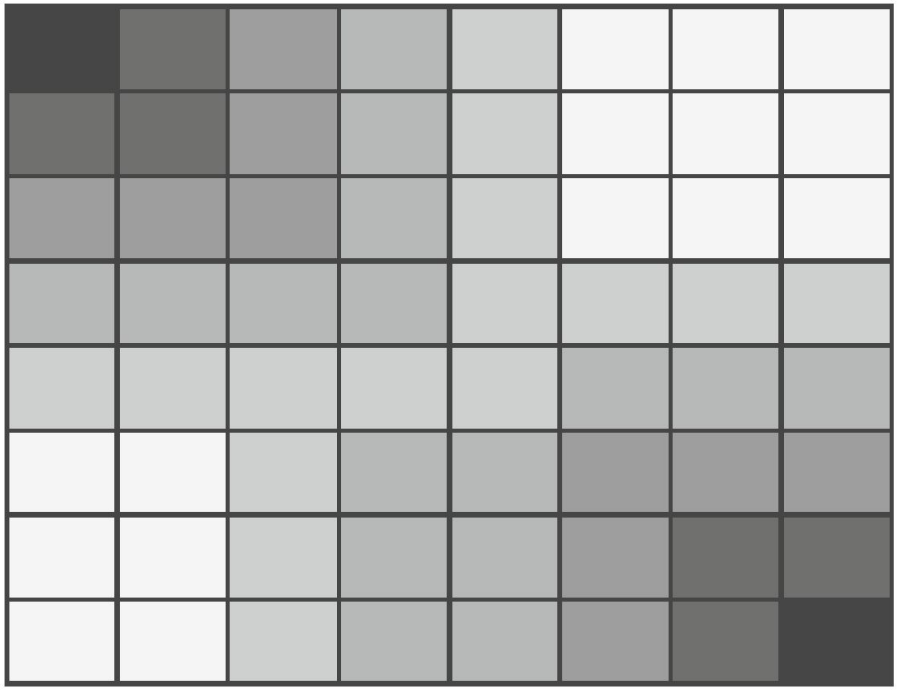
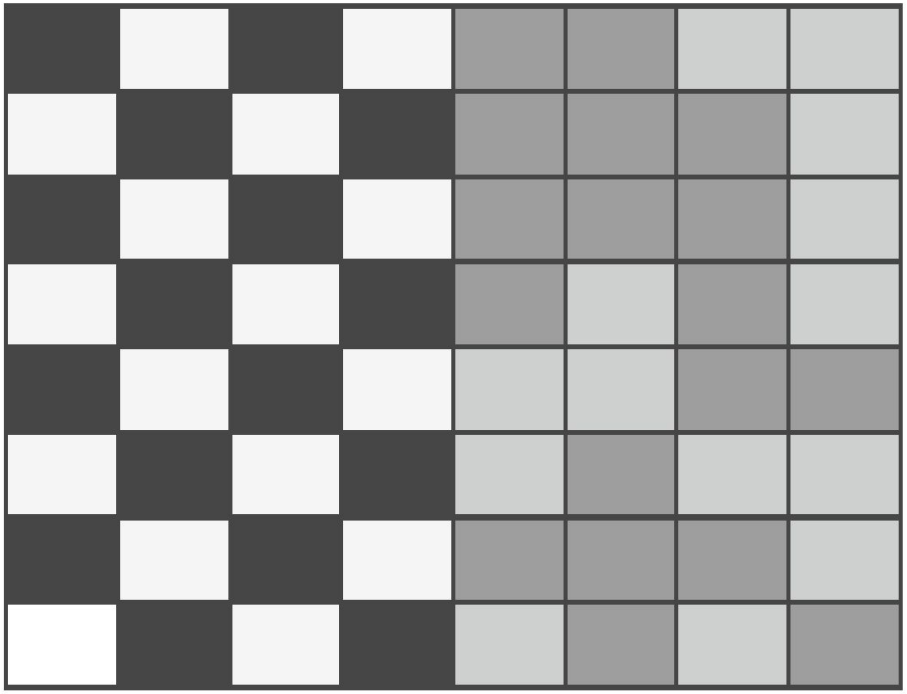
Different grey colours refer to different values of the variables under study ranging from low values (white) to high values (black).



Spatial autocorrelations



Spatial heterogeneity (left)

vs.

Spatial autocorrelations (right)

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Spatial weight matrix (W), crossboard structure

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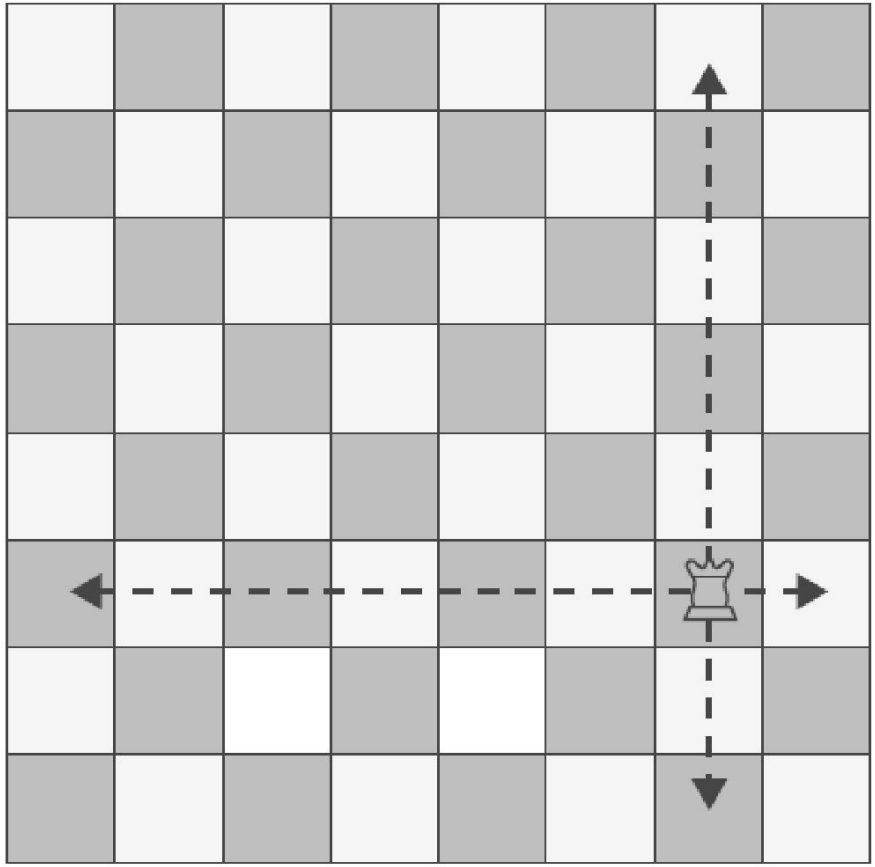
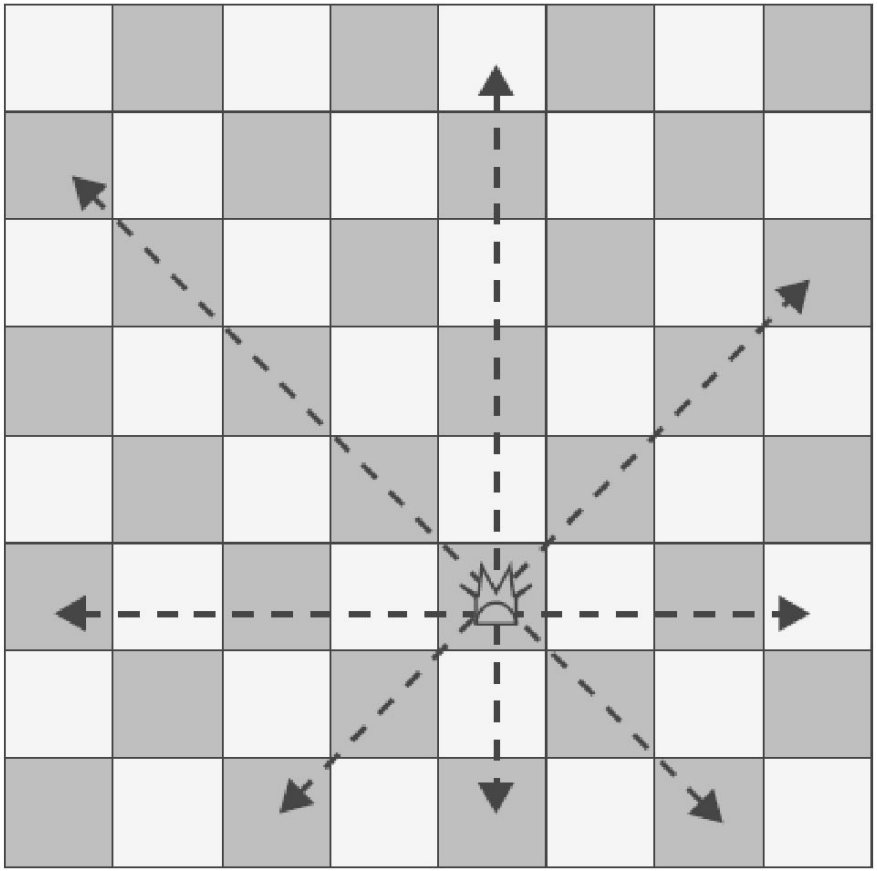


Neighbourhood can be defined base on rook criterion



Neighbourhood can be defined base on queen criterion

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Spatial weight matrix (W), empirical approach

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- In reality the map should be defined base on administrative units or political borders and further definitions needed.
- To start: the heart of spatial econometrics is weight matrix or connectivity matrix

$$ {}_nW_n \begin{bmatrix} W_{11} & \dots & \dots & W_{n1} \\ \dots & W_{ij} & \dots & \dots \\ \dots & \dots & \dots & \\ W_{1n} & \dots & \dots & W_{nn} \end{bmatrix} $$

$$ W_{ij} = \begin{cases} 1 \;\; if \;\; j \epsilon N(i) \\ 0 \; otherwise \end{cases} $$

- *N(i)* being the set of neighbours for location j, and $w_{ii}=0$

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Spatial weight matrix, who is neighbour

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- Many different way can be defined for the neighbour
- 3 major ways:
  - Adjacency between two territorial units
    - (rook criterion, queen criterion)
  - Maximum distance: $j \epsilon N(i)\ if\ d_{ij} < d_{max}$
  - K nearest point
- … Irregular ways also possible for advanced research
- Next an example given for 8 observations
  - Criterion: Nobody is neighbour to itself ☺

a) Adjacency for neighbourhood

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8 regions

1		2	3
		4	
5	6	7	
			8

Spatial matrix

	1	2	3	4	5	6	7	8
1	**0**	1	1	1	1	0	0	0
2	1	**0**	1	1	0	0	0	0
3	1	1	**0**	1	1	1	1	1
4	1	1	1	**0**	0	0	0	0
5	1	0	1	0	**0**	1	0	0
6	0	0	1	0	1	**0**	1	1
7	0	0	1	0	0	1	**0**	1
8	0	0	1	0	0	1	1	**0**

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

b) Nearest point for neighbourhood

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8 regions

1		2	3
		4	
5	6	7	
			8

Spatial matrix

	1	2	3	4	5	6	7	8
1	**0**	1	0	0	0	0	0	0
2	0	**0**	0	1	0	0	0	0
3	0	1	**0**	1	0	0	0	0
4	0	1	1	**0**	0	0	0	0
5	0	0	0	0	**0**	1	0	0
6	0	0	0	0	1	**0**	1	0
7	0	0	0	0	0	1	**0**	0
8	0	0	0	0	0	0	0	**0**

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

c) d<2 for neighbourhood

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8 regions

1		2	3
		4	
5	6	7	
			8

Spatial matrix

	1	2	3	4	5	6	7	8
1	**0**	1	0	1	0	0	0	0
2	1	**0**	1	1	0	0	0	0
3	0	1	**0**	1	0	0	0	0
4	1	1	1	**0**	0	0	1	0
5	0	0	0	0	**0**	1	1	0
6	0	0	0	0	1	**0**	1	0
7	0	0	1	1	1	1	**0**	1
8	0	0	0	0	0	0	1	**0**

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Side by side:

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	1	2	3	4	5	6	7	8
1	**0**	1	1	1	1	0	0	0
2	1	**0**	1	1	0	0	0	0
3	1	1	**0**	1	1	1	1	1
4	1	1	1	**0**	0	0	0	0
5	1	0	1	0	**0**	1	0	0
6	0	0	1	0	1	**0**	1	1
7	0	0	1	0	0	1	**0**	1
8	0	0	1	0	0	1	1	**0**

	1	2	3	4	5	6	7	8
1	**0**	1	0	0	0	0	0	0
2	0	**0**	0	1	0	0	0	0
3	0	1	**0**	1	0	0	0	0
4	0	1	1	**0**	0	0	0	0
5	0	0	0	0	**0**	1	0	0
6	0	0	0	0	1	**0**	1	0
7	0	0	0	0	0	1	**0**	0
8	0	0	0	0	0	0	0	**0**

	1	2	3	4	5	6	7	8
1	**0**	1	0	1	0	0	0	0
2	1	**0**	1	1	0	0	0	0
3	0	1	**0**	1	0	0	0	0
4	1	1	1	**0**	0	0	1	0
5	0	0	0	0	**0**	1	1	0
6	0	0	0	0	1	**0**	1	0
7	0	0	1	1	1	1	**0**	1
8	0	0	0	0	0	0	1	**0**

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Standardising the weight matrix

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- W matrix is standardised to sum unity in each row
- $w_{ij}^{*} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}}, w_{ij}^{*} \epsilon W^{*}$
- Spatially lagged value of variable Y (vector) can be defined as:
- $L(y) = W^{*} Y$
- And for each elements:
- $L(y_i) = \sum_{j=1}^{n} w_{ij}^{*} y_j = \frac{w_{ij} y_j}{\sum_{j=1}^{n} w_{ij}}$

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Example for UK, 12 regions, NUTS1

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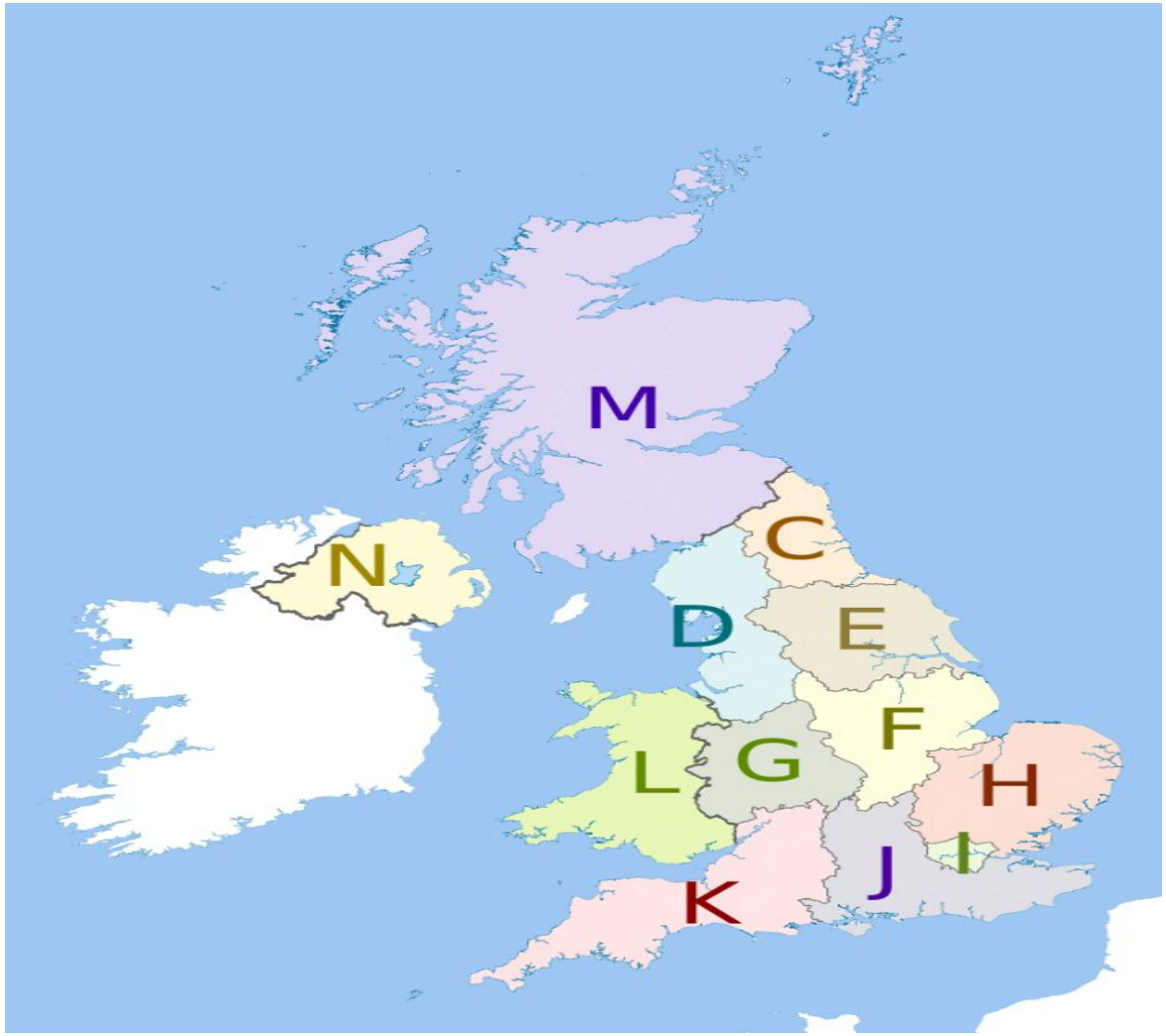
We will stablish the weight matrix based contiguity of 12 regions.

Attention: North Ireland has not border!



Source: https://en.wikipedia.org/wiki/NUTS_statistical_regions_of_the_United_Kingdom

Example for UK, 12 regions, NUTS1

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	1	2	3	4	5	6	7	8	9	10	11	12	Row sum
	Scotland	N Ireland	Wales	N of England	NW England	Yorksh & Humber	W Midlands	E Midlands	E Anglia	SW England	SE England	G London	
Scotland	0	0	0	1	0	0	0	0	0	0	0	0	1
N Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	0	0	0	0	1	0	1	0	0	1	0	0	3
N of England	0	0	0	0	1	1	0	0	0	0	0	0	2
NW England	0	0	1	1	0	1	1	1	0	0	0	0	5
Yorksh & Humber	0	0	0	1	1	0	0	1	0	0	0	0	3
W Midlands	0	0	1	0	1	0	0	1	0	1	1	0	5
E Midlands	0	0	0	0	1	1	1	0	1	0	1	0	5
E Anglia	0	0	0	0	0	0	0	1	0	0	1	0	2
SW England	0	0	0	0	0	0	1	0	0	0	1	0	2
SE England	0	0	0	0	0	0	1	1	1	1	0	1	5
G London	0	0	0	0	0	0	0	0	0	0	1	0	1

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Standardising the weight matrix for UK

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	1	2	3	4	5	6	7	8	9	10	11	12	Row sum
	Scotland	N Ireland	Wales	N of England	NW England	Yorksh & Humber	W Midlands	E Midlands	E Anglia	SW England	SE England	G London	
Scotland	0	0,5	0	0,5	0	0	0	0	0	0	0	0	1
N Ireland	1	0	0	0	0	0	0	0	0	0	0	0	1
Wales	0	0	0	0	0,33	0	0,33	0	0	0,33	0	0	1
N of England	0	0	0	0	0,5	0,5	0	0	0	0	0	0	1
NW England	0	0	0,2	0,2	0	0,2	0,2	0,2	0	0	0	0	1
Yorksh & Humber	0	0	0	0,33	0,33	0	0	0,33	0	0	0	0	1
W Midlands	0	0	0,2	0	0,2	0	0	0,2	0	0,2	0,2	0	1
E Midlands	0	0	0	0	0,2	0,2	0,2	0	0,2	0	0,2	0	1
E Anglia	0	0	0	0	0	0	0	0,5	0	0	0,5	0	1
SW England	0	0	0	0	0	0	0,5	0	0	0	0,5	0	1
SE England	0	0	0	0	0	0	0,2	0,2	0,2	0,2	0	0,2	1
G London	0	0	0	0	0	0	0	0	0	0	1	0	1

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Spatial weight matrix for UK

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W

0	0,5	0	0,5	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0,33	0	0,33	0	0	0,33	0	0
0	0	0	0	0,5	0,5	0	0	0	0	0	0
0	0	0,2	0,2	0	0,2	0,2	0,2	0	0	0	0
0	0	0	0,33	0,33	0	0	0,33	0	0	0	0
0	0	0,2	0	0,2	0	0	0,2	0	0,2	0,2	0
0	0	0	0	0,2	0,2	0,2	0	0,2	0	0,2	0
0	0	0	0	0	0	0	0,5	0	0	0,5	0
0	0	0	0	0	0	0,5	0	0	0	0,5	0
0	0	0	0	0	0	0,2	0,2	0,2	0,2	0	0,2
0	0	0	0	0	0	0	0	0	0	1	0

Scotland
Northern Ireland
Wales
North East England
North West England
Yorkshire and the Humber
West Midlands
East Midlands
East of England
South West England
South East England
Greater London

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Spatially lagged variable: labour productivity in UK: W*y

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NUTS1	y	L(y)=W*y
Scotland	81,5	91,55
Northern Ireland	96,9	81,5
Wales	82,9	105,83
North East England	86,2	86,65
North West England	88,6	86,42
Yorkshire and the Humber	84,7	87,96
West Midlands	89,2	101,72
East Midlands	89,1	93,52
East of England	96,8	98,7
South West England	139,7	98,75
South East England	108,3	100,92
Greater London	89,8	108,3

Source: Arbia, 2014, ch2, ISBN: 978-1-137-31794-0

Regression using spatial data

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- What to do?

  —**Spatial test**

- On what?

  —**Residuals**

- How?
  - First we need spatial weight matrix **W**

- What do we do after having the **W**?
  - We will extract the residuals $\mu = Y - \hat{Y} = Y - X\beta$

  —We do *Moran I Test*

Moran I Test

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- Moran I test (Moran, 1950) is similar to correlation coefficient:
- $\{X_i\}$ i=1,2,3…n, $\{Y_i\}$ i=1,2,3…n,
- $$\rho = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\bar{Y})^2}}$$
- Time series correlation model, **first lag**
- $\{x_{t,1}\}$ t=1,2,3…n-1 and $\{x_{t,2}\}$ t=2,3,4…n
- $\overline{x_{.1}} = \frac{1}{n-1}\sum_{t=1}^{n-1} x_t$, $\overline{x_{.2}} = \frac{1}{n-1}\sum_{t=2}^{n} x_t$, for large n: $\overline{x_{.2}} = \frac{1}{n-1}\sum_{t=1}^{n} x_t$
- Time series autocorrelation model:

$$\rho = \frac{\sum_{t=1}^{n-1}(x_t-\bar{x})(x_{t+1}-\bar{x})}{\sum_{t=1}^{n}(x_t-\bar{x})^2}$$

Moran I Test

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- $\{Z_i\}$ *i*=1,2,3…*n*, *W: standard weight matrix with* w_{ij} *elements*

- $$I = \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}/n} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(Z_i-\bar{Z})(Z_j-\bar{Z})}{\sum_{t=1}^{n}(Z_i-\bar{Z})^2}$$

- How this test work for residuals of OLS regression when W matrix ism standardised (W*)?

- $I = \frac{\mu^T w^* \mu}{\mu^T \mu}$, we have now Moran I Statistics in hand.
- There are some developments on similar tests that we skip here.
- We skip other technical issues on this test

Source: Arbia, (2014, ch2), Kopczewska (2021, ch4)

Spatial regression models

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- Now, imagine that the results of *Moran I test* is significant, we need to deal with spatial autocorrelation in regression model:

- $y = \rho W y + X\beta + WX\theta + \mu \quad , \ |\rho| < 1$
- $\mu = \lambda W \mu + \varepsilon, \qquad |\lambda| < 1$
- $\varepsilon \sim N(0, \sigma^2), iid$

- $y_i = \rho \sum_{j=1}^{n} W_{ij} y_j + \sum_{r=1}^{m} X_{ir} \beta_r + \sum_{j=1}^{n} \sum_{r=1}^{m} W_{ji} X_{ir} \theta_r + \mu_i$
- $\mu_i = \lambda \sum_{j=1}^{n} W_{ij} \mu_i + \varepsilon_i, \varepsilon \sim N(0, \sigma^2), iid$

What happens if coefficients are significant or not????

Source: Elhorst (2010, p.14), Seya et al. (2020), Arbia (2014)

A Taxonomy of Spatial Models

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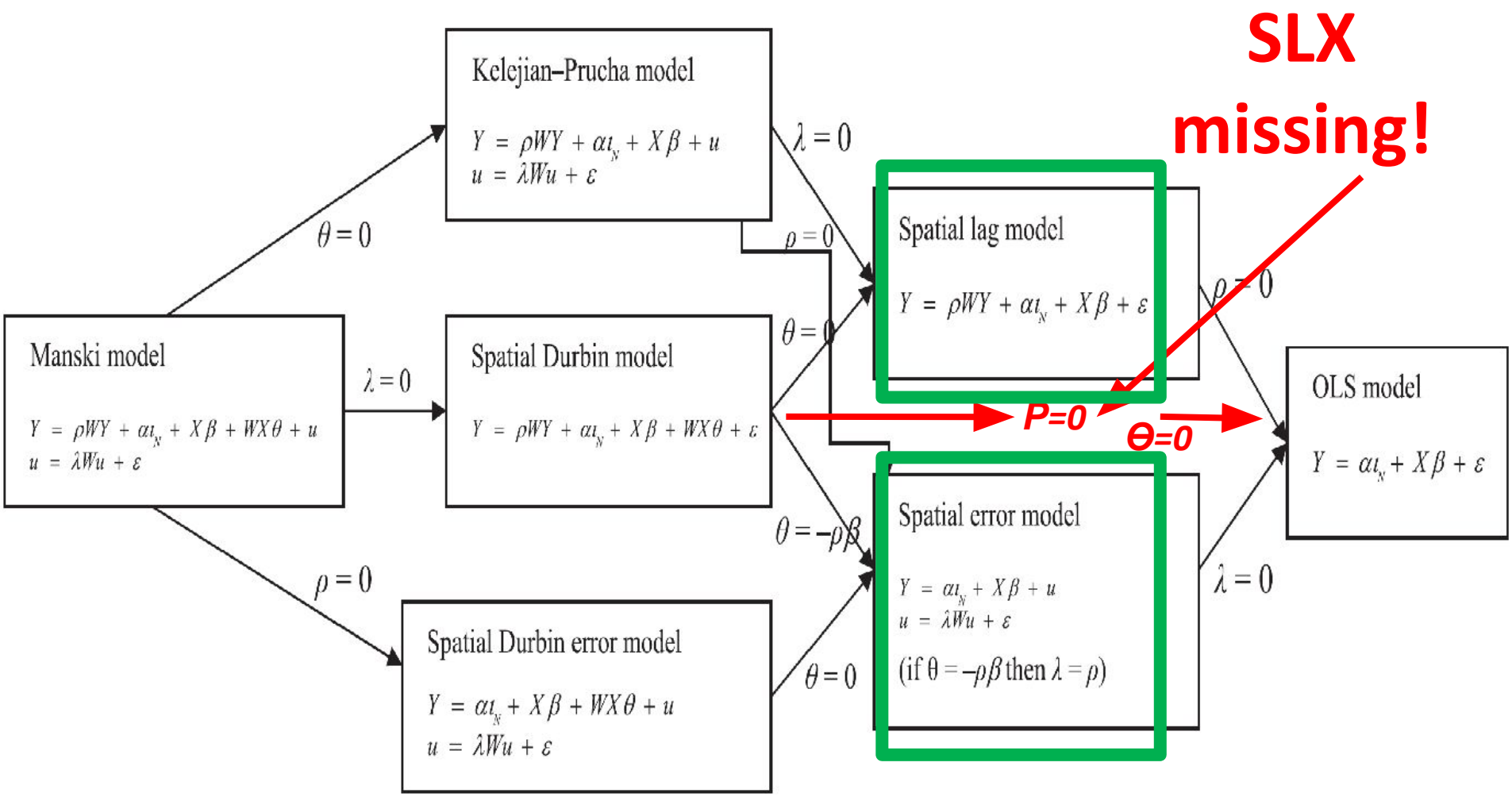

Source: Elhorst (2010, p.14)

Different models in taxonomy

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- **GNS** = general nesting spatial model,
- **SAC** = spatial autoregressive combined model (SARAR),
- **SDM** = spatial Durbin model,
- **SDEM** = spatial Durbin error model,
- **SAR = spatial autoregressive model (spatial lag model),**
- **SLX**= spatial lag of X model,
- **SEM = spatial error model,**
- **OLS** = ordinary least squares

- Today we only focus two classical model of **SAR** and **SEM**

- Base on time limits, we may discuss others next session

Spatial autoregressive model (SAR) (also spatial lag model (SLM))

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- $y = \rho W y + X\beta + \mu \quad , \ |\rho| < 1$
- $\mu \sim N(0, \sigma^2), iid$

To estimate

- $(I - \rho W)y = X\beta + \mu$
- $y = (I - \rho W)^{-1} X\beta + (I - \rho W)^{-1}\mu$

- Estimation method:
  - Maximum likelihood (ML)
  - Two stage least square (2SLS)

- Do to time limit, I skip the mathematical details of estimation

Spatial error model (SEM)

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- $y = X\beta + \mu$
- $\mu = \lambda W\mu + \varepsilon$
- $\varepsilon \sim N(0, \sigma^2), iid$

To estimate

- $(I - \lambda W)\mu = \varepsilon$
- $(I - \lambda W)y = (I - \lambda W)X\beta + (I - \lambda W)\mu$
- $y = \lambda Wy + X\beta - WX\lambda\,\beta + \varepsilon$
- $y = \lambda Wy + X\beta - WX\gamma + \varepsilon$
- $\underline{y = (I - \lambda W)^{-1}(X\beta - WX\gamma) + (I - \lambda W)^{-1}\varepsilon}$

- Estimation method:
  - Maximum likelihood (ML)
  - Feasible GLS (FGLS)

- Do to time limits, I skip the mathematical details of estimation

Next session, impact will be discussed

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- The coefficient and prediction not straightforward in spatial regression.
- We will discuss impact next session.
- It can be tested in the homework

Empirical issues: Coordinates, mapping the earth

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Coordinate systems

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- A geographic coordinate system (GCS) is a reference framework that defines the locations of features on a model of the earth. It's shaped like a globe—spherical. Its units are angular, usually degrees.

- A projected coordinate system (PCS) is flat. It contains a GCS, but it converts that GCS into a flat surface, using math (the projection algorithm) and other parameters. Its units are linear, most commonly in meters.

Source:
https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/coordinate-systems-difference/

Coordinates (GCS)

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- Longitude (East-West)
  - Prime meridian, Greenwich (0)
  - -180 to +180
- Latitude (North-South)
  - Equator (0)
  - -90 to +90

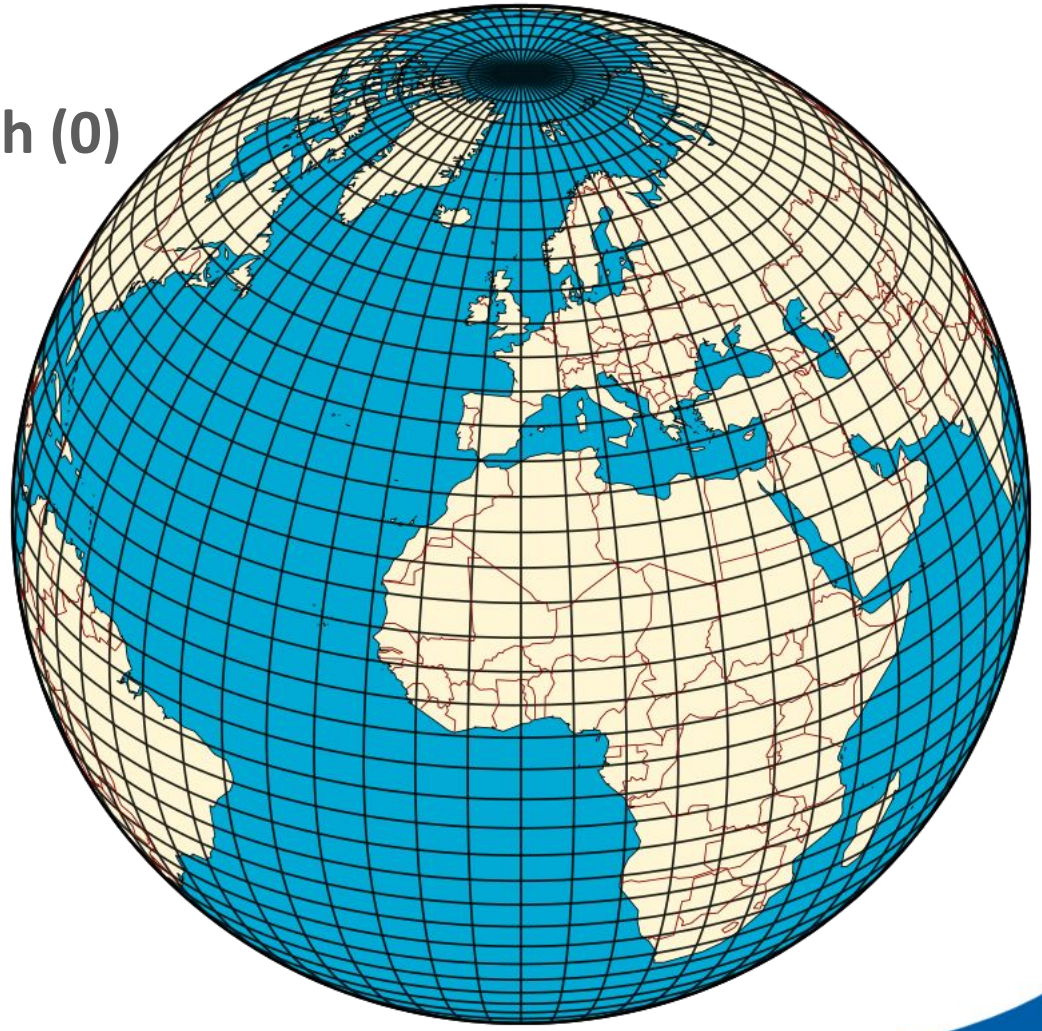

Figure Source: https://en.wikipedia.org/wiki/Longitude

Universal Transverse Mercator coordinate system (UTM)

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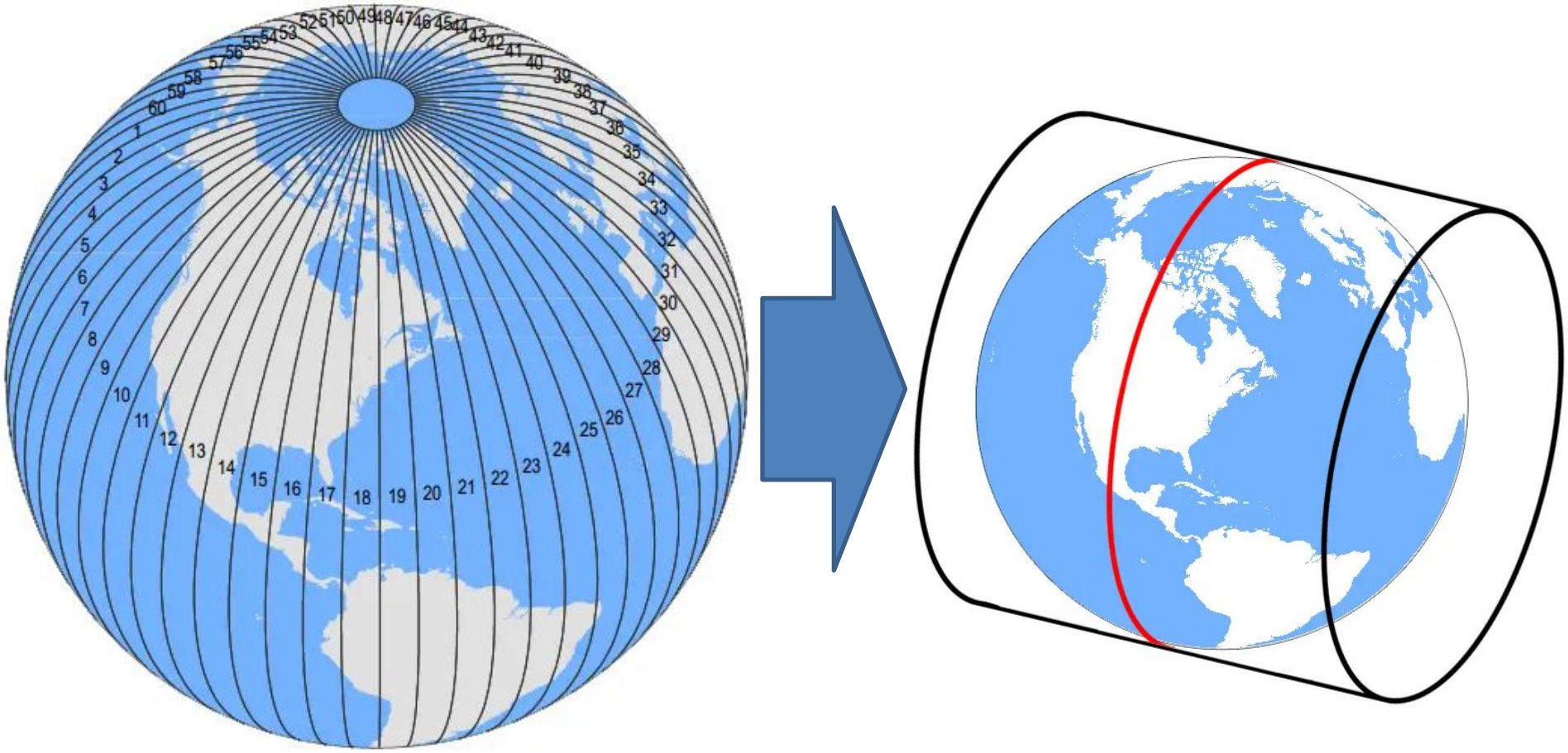
The problem of spherical shape of earth needs to be managed :



Source: https://gisgeography.com/utm-universal-transverse-mercator-projection/

Universal Transverse Mercator coordinate system (UTM)

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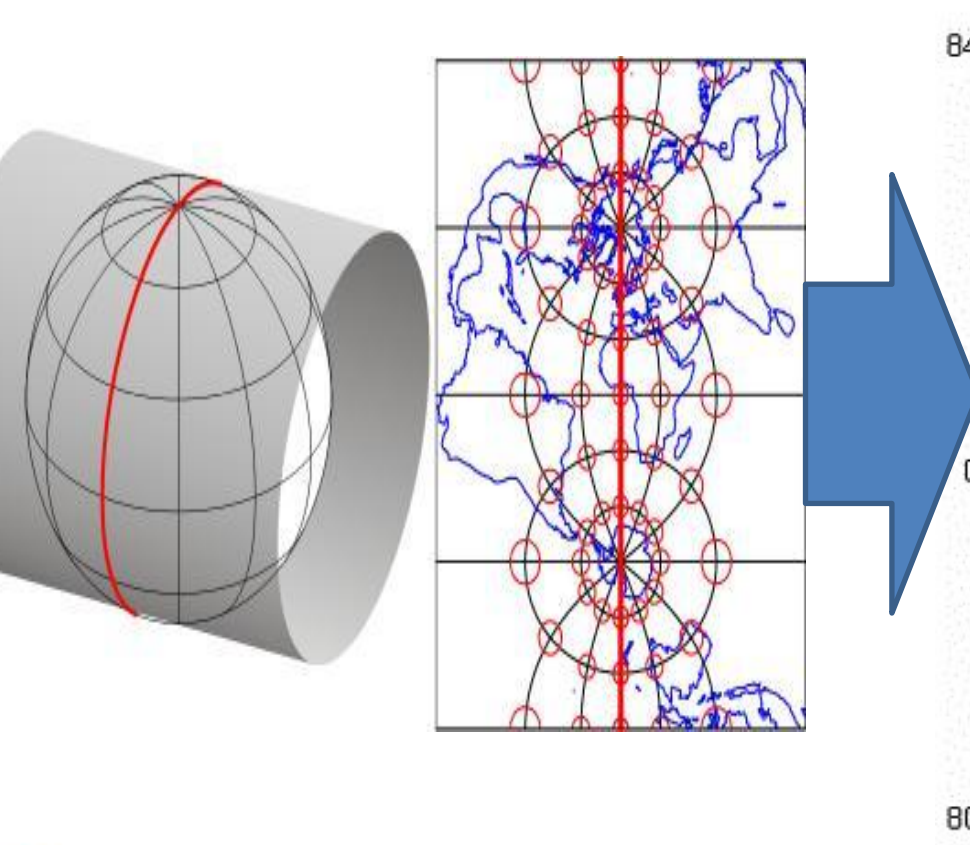
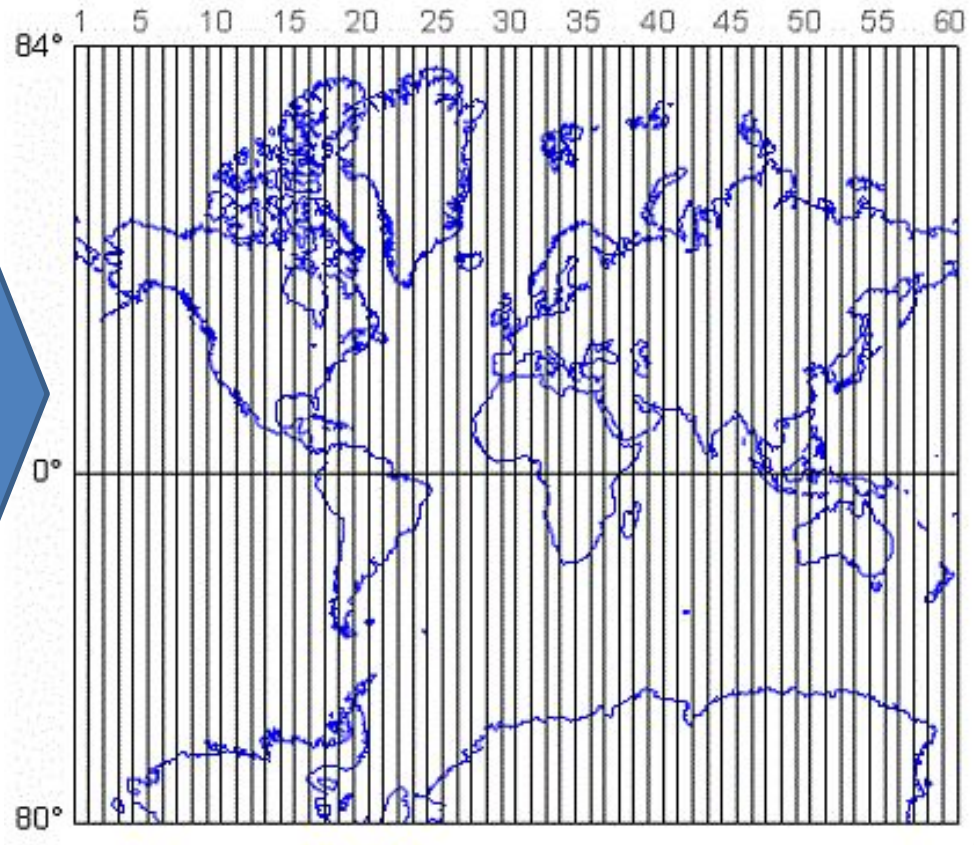
- A UTM zone is a 6° segment of the Earth. Because a circle has 360°, this means that there are 60 UTM zones on Earth. (360 ÷ 6 = 60)
- (Found by US Army Corps of Engineers, starting in the early 1940s)





Source: https://www.e-education.psu.edu/natureofgeoinfo/c2_p22.html

Universal Transverse Mercator coordinate system (UTM)

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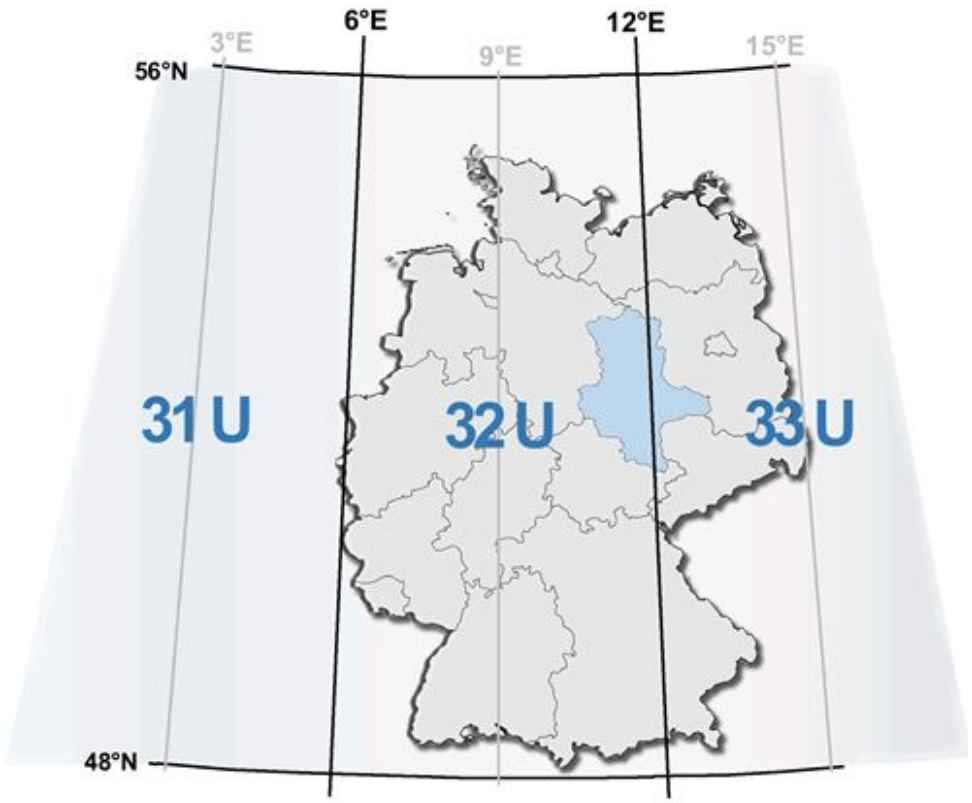
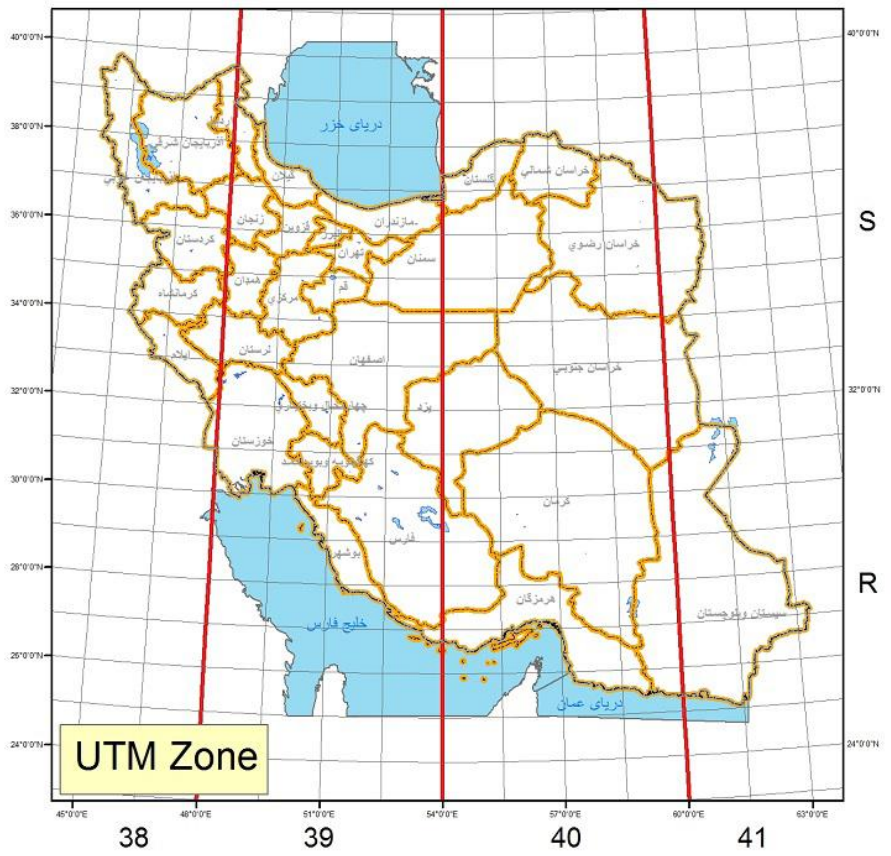
UTM for Germany and Iran





Source of figures:
https://www.lvermgeo.sachsen-anhalt.de/de/etrs89utm/etrs89-european-terrestrial-reference-system-1989.html
https://engclubs.net/needed-softwares/%D9%86%D9%82%D8%B4%D9%87-utm-%D8%A7%DB%8C%D8%B1%D8%A7%D9%86.html

Different measures of coordinates, Marburg

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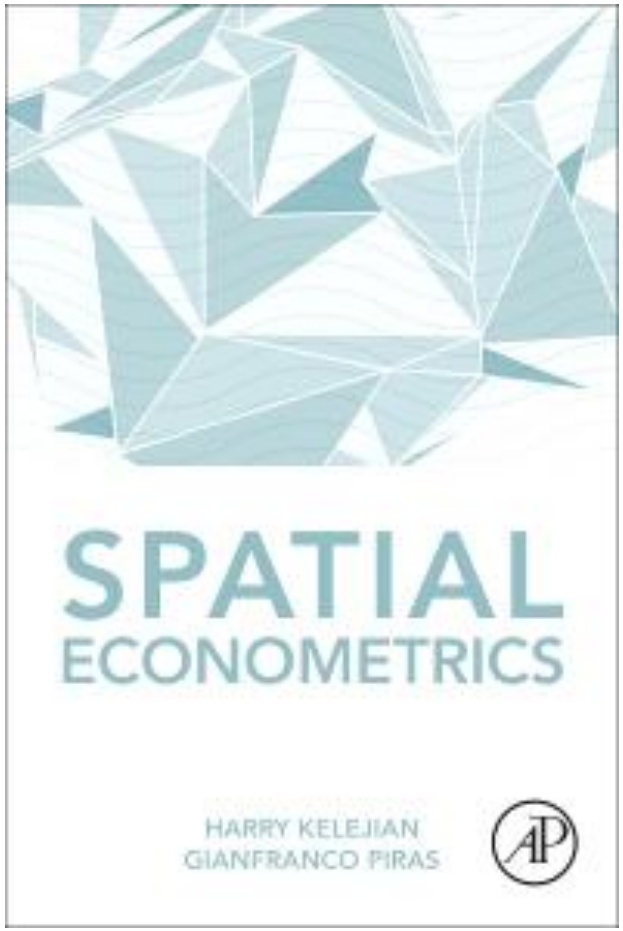
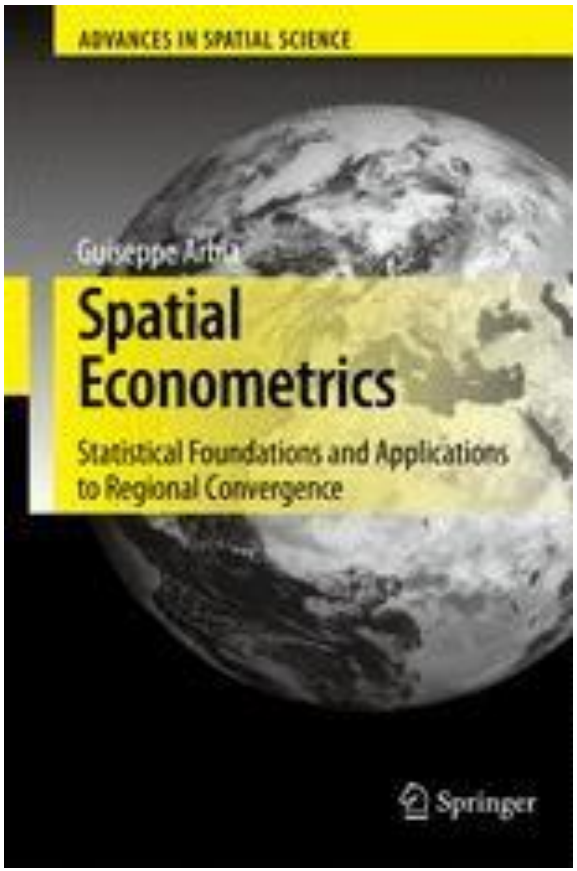
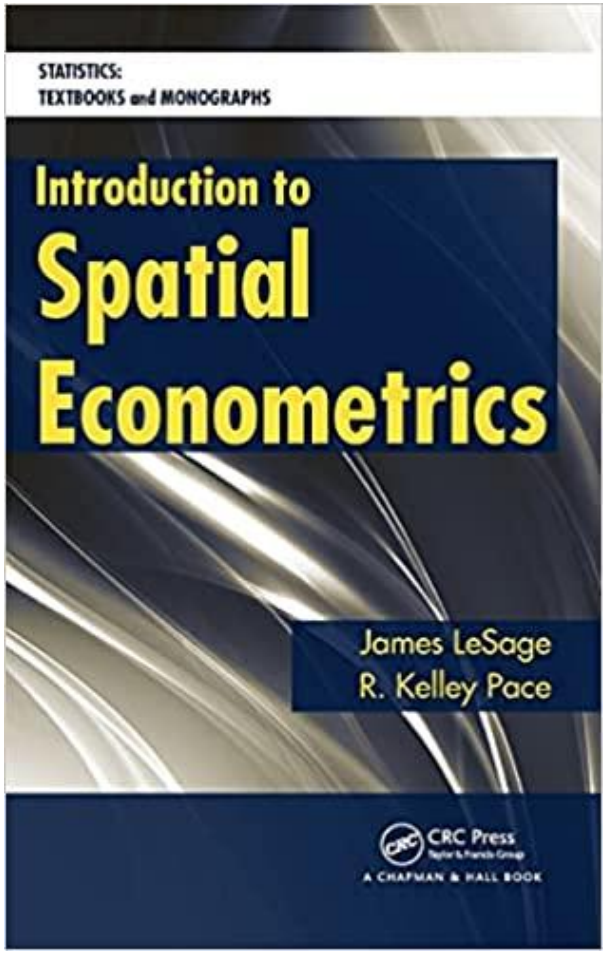
- Degrees, minutes, and seconds (sexagesimal degree):
  - **50°48'21.59" N 8°46'8.99" E**
- Degrees and decimal minutes:
  - **50°48.5424′ N 8°46.2414′ E**
- Decimal degrees:
  - **50.805996776 8.76916359**

- UTM coordinates of Marburg
  - UTM Zone: **32U**
  - Easting: **483843.45952547 m**
  - Northing: **5628614.821735 m**
- **EXAMPLE: GO TO GOOGLE EARTH**

Some references on spatial econometrics







Part 3, Spatial econometrics with R

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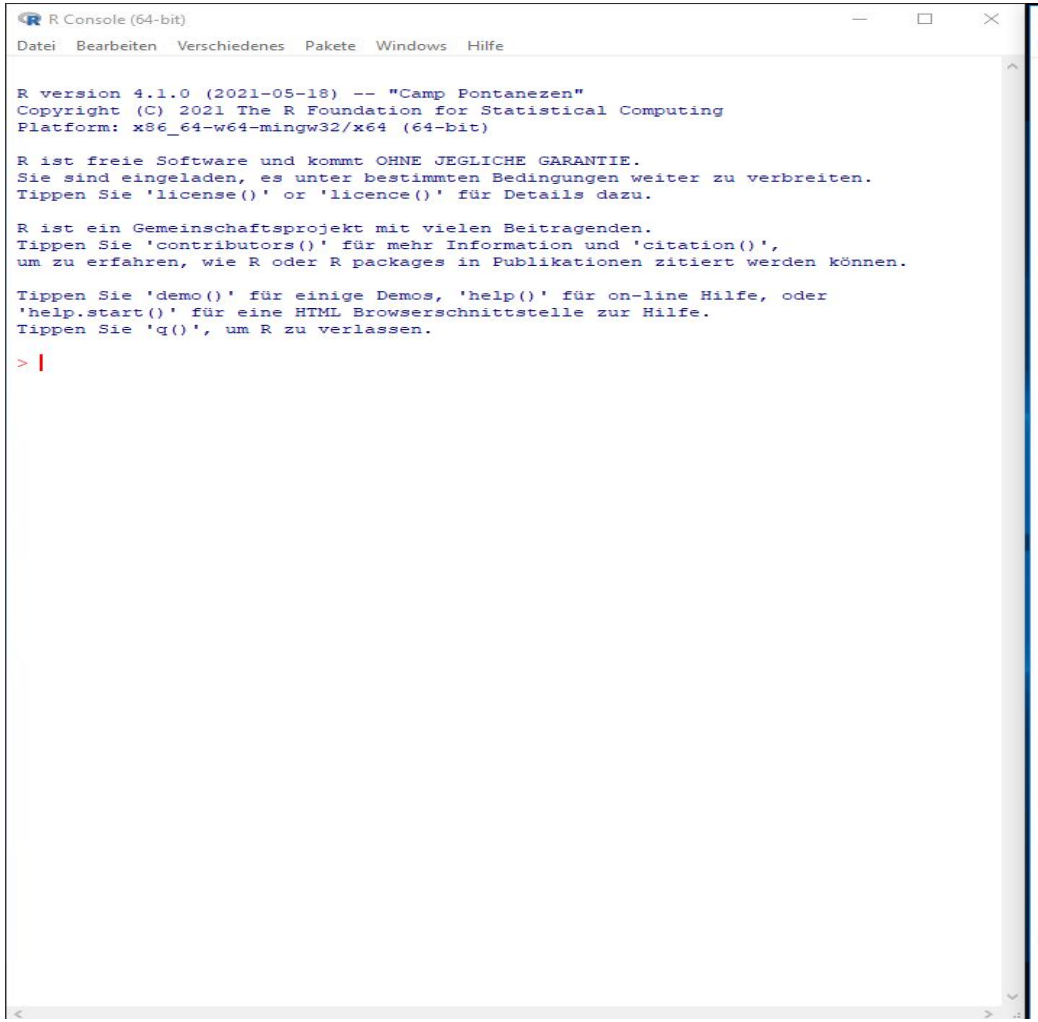
- R Basics
- Spatial packages in R
- Spatial objects
- Spatial regression in spdep
- Examples

R


R Console (64-bit)
Datei Bearbeiten Verschiedenes Pakete Windows Hilfe
R version 4.1.0 (2021-05-18) -- "Camp Pontanezen"
Copyright (C) 2021 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)
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Tippen Sie 'demo()' für einige Demos, 'help()' für on-line Hilfe, oder
'help.start()' für eine HTML Browserschnittstelle zur Hilfe.
Tippen Sie 'q()', um R zu verlassen.
>
Namenlos - R Editor
Datei Bearbeiten Pakete Hilfe

R Studio

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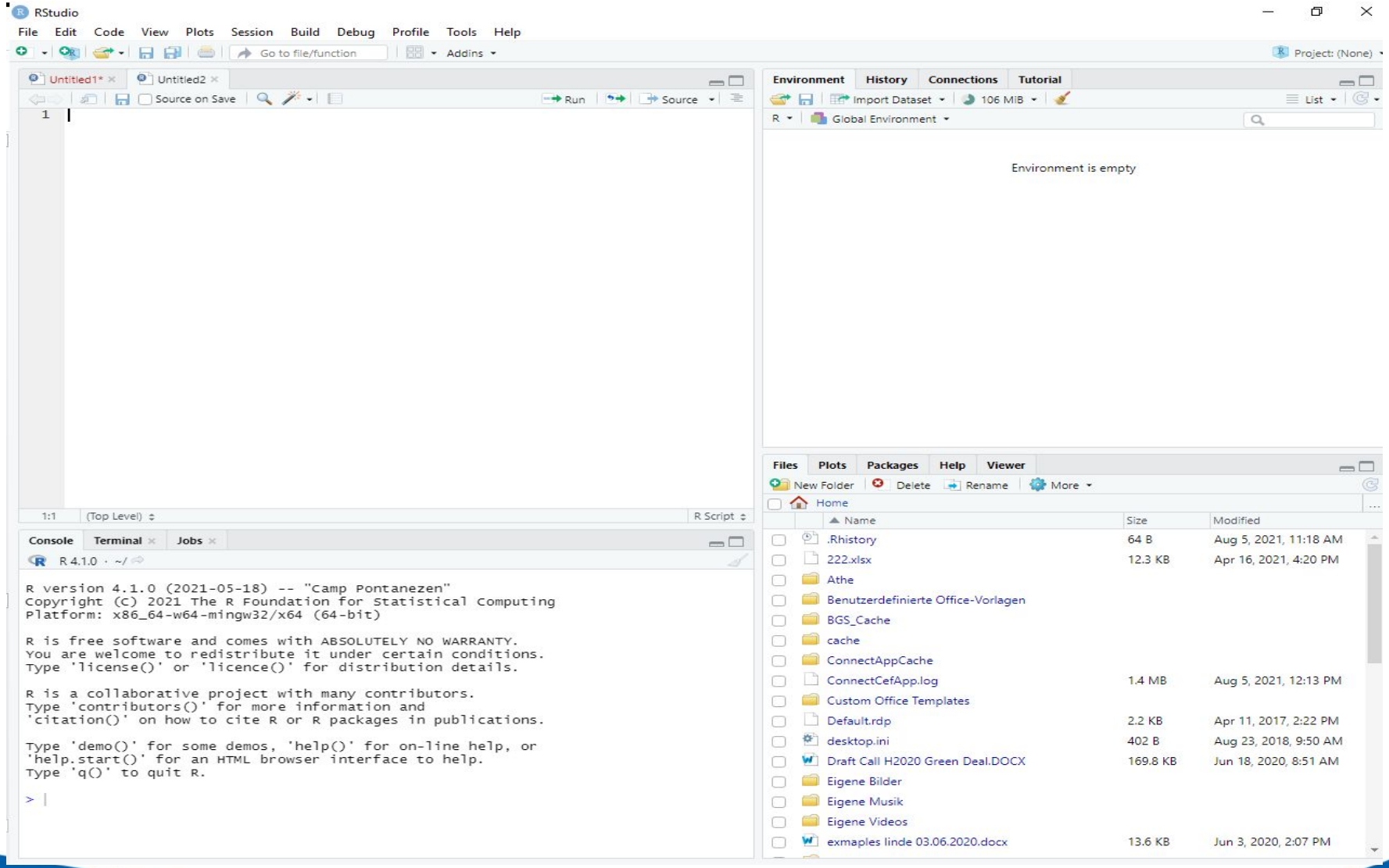

R Basics

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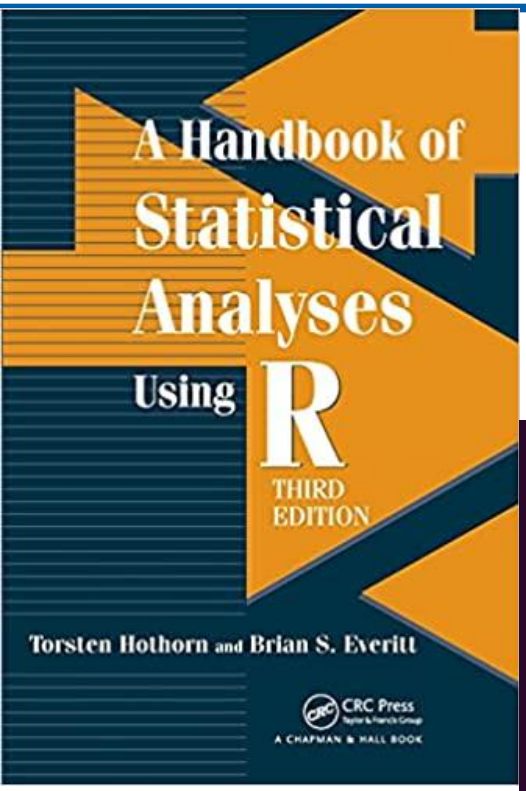
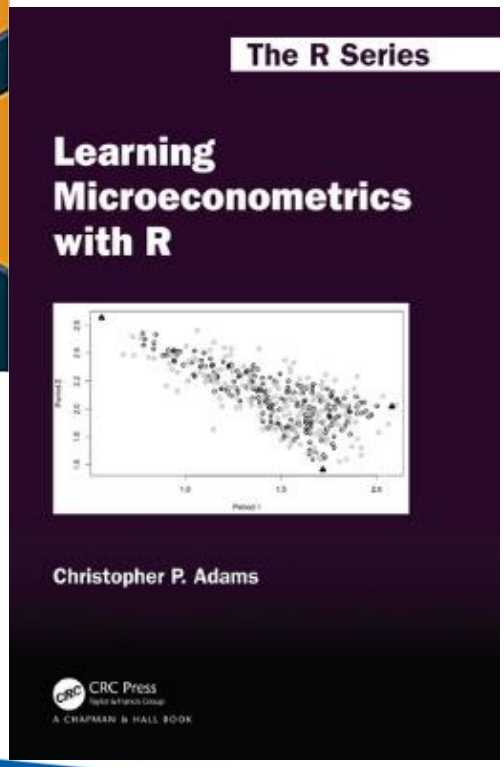
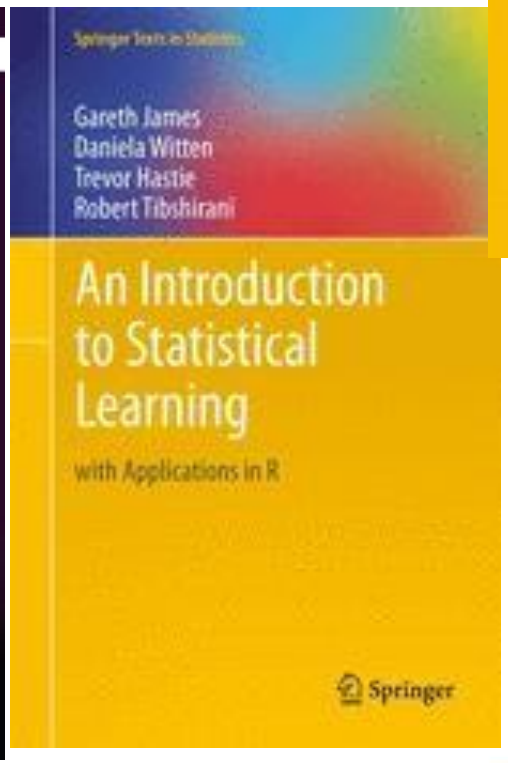
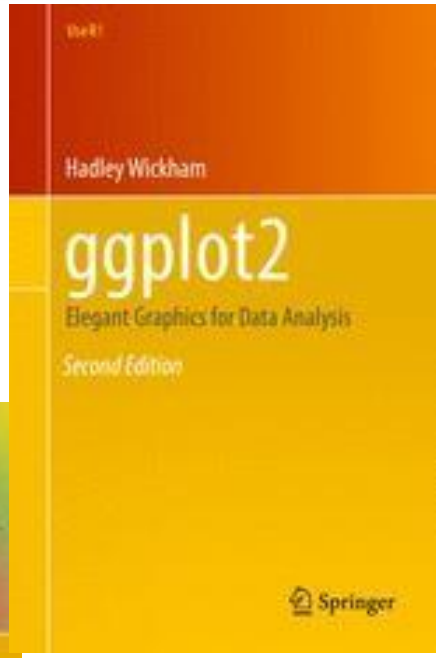
1. **R**oss Ihaka and **R**obert Gentleman (R) after 1991
2. Very strong language with many features
3. Freely available software under GNU GPL v25 licence
4. Many people develop it under R Core team
5. Vector, object, …
6. Command-line interpreter.
7. Packages need to be installed
8. Go to R and R studio, basics training with R, functions, linear model, simple plotting, exercise one: “ExampleOneBasics”

Introduction









Spatial packages in R

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1. Sp, spdep, maptools, needed
2. Go to R / R studio, for installation 
3. ExamplesTwoPackages

Spatial objects in R

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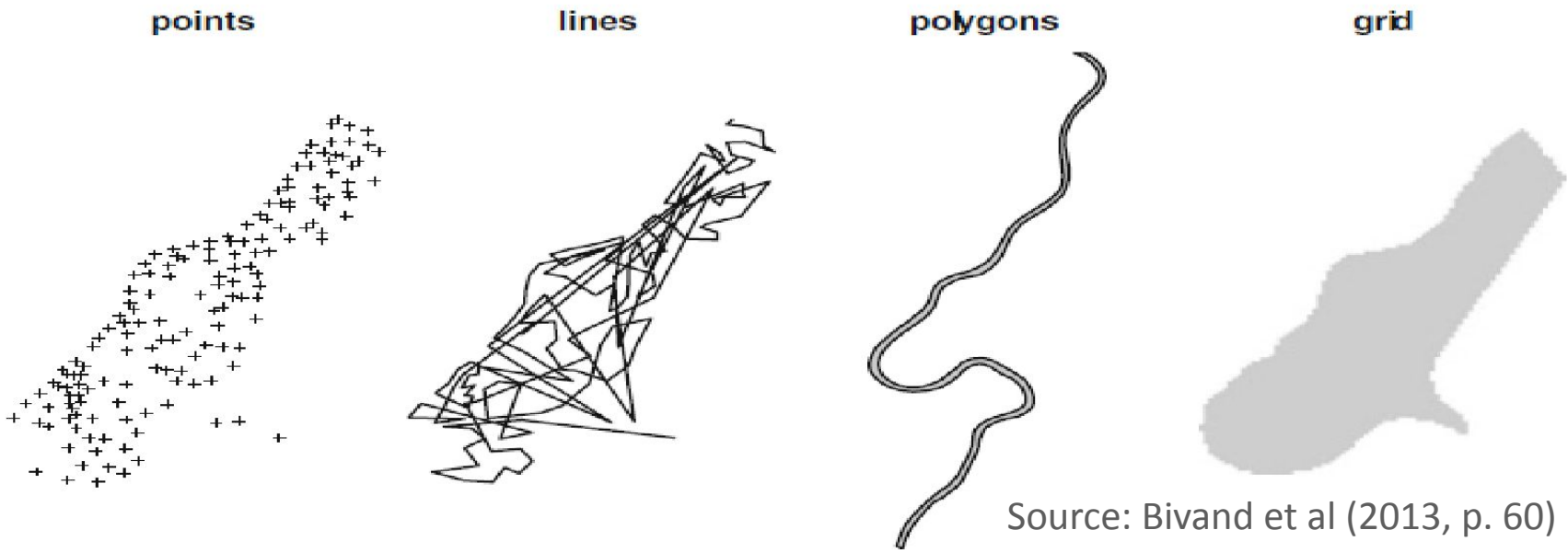

Source: Bivand et al (2013, p. 60)

1. Shape files
2. Go to R/R studio, plotting shape files Germany, Iran, coordinates,
3. A)ExampleThree1IranMap, B)ExampleThree2GermanyMap

Spatial weight matrix in spdep,

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- If time left Coordinates to UTM
- Important do following:

1. **“spatial object”** go to
2. **“neighbour list** (nb)” **go to**
3. **“spatial weights** (listw)”

- In spdep:
  - neighbourhood
    - cell2nb
    - grid2nb
    - Knn2nb
    - poly2nb
  - Weight
    - nb2listw

Spatial regression in spdep, examples

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- Two examples used from the following websites:
- http://www.econ.uiuc.edu/~lab/workshop/Spatial_in_R.html
- https://rpubs.com/quarcs-lab/tutorial-spatial-regression
- https://rdrr.io/rforge/spdep/man/bptest.sarlm.html
  - More play with weight matrix with Iran/Germany coordinates

Some references on spatial econometrics with R

iamo
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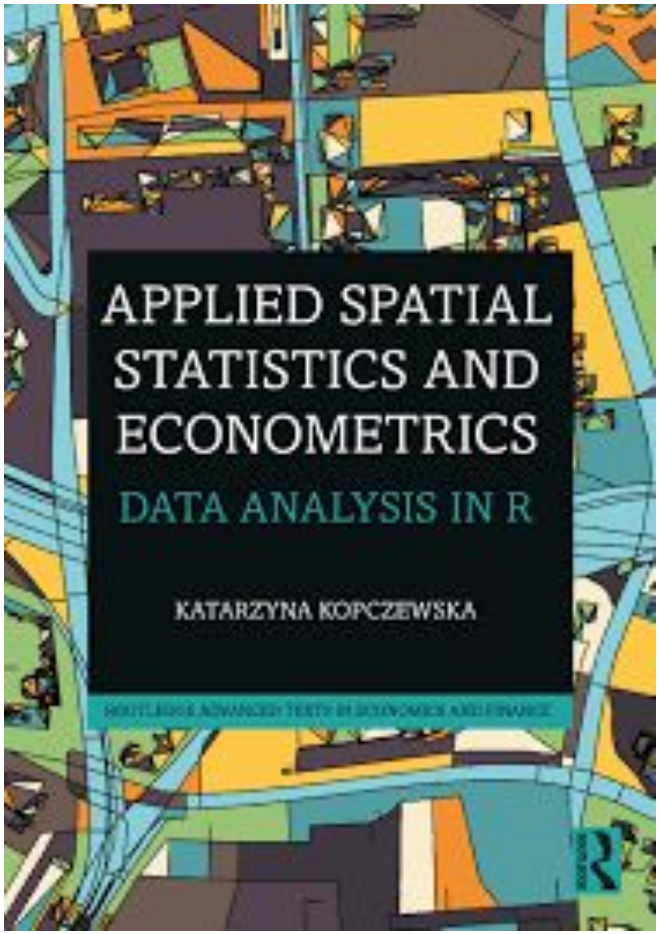

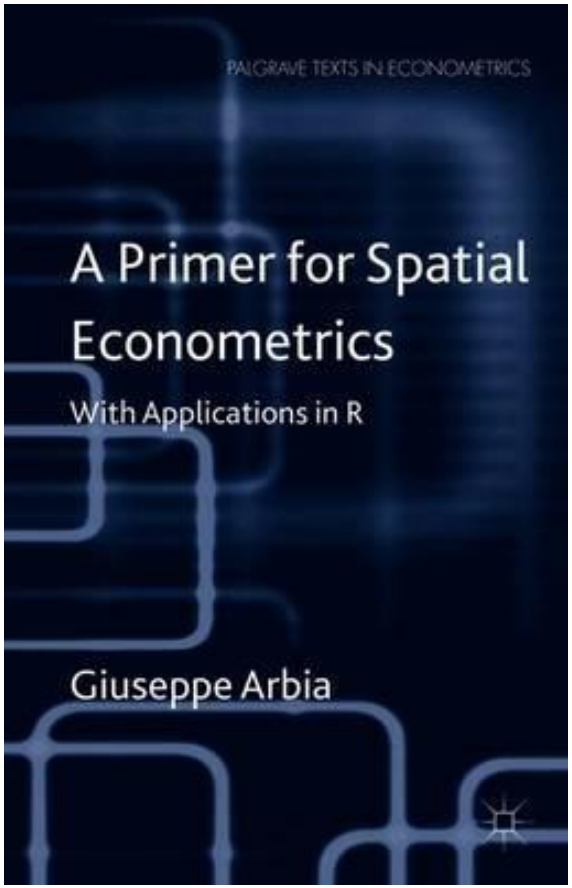

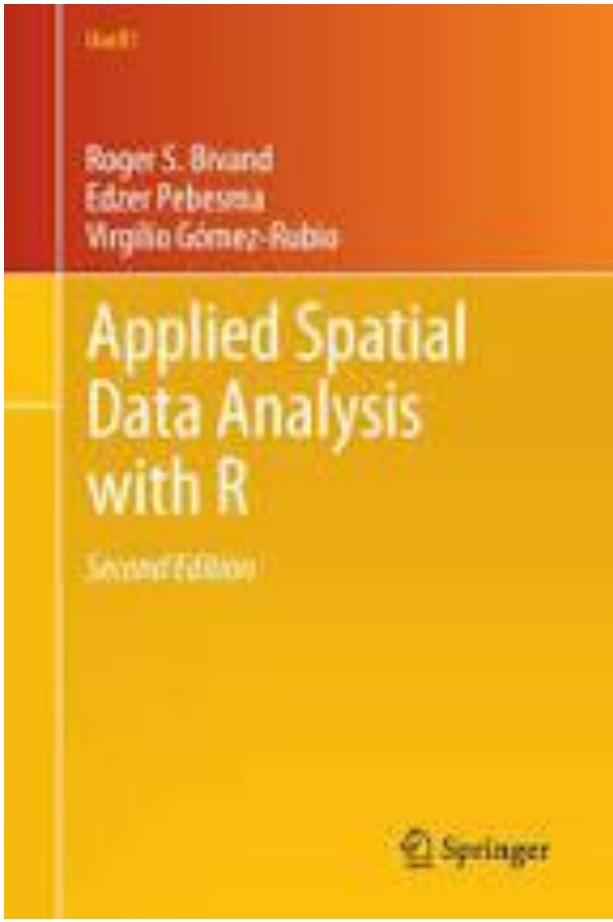

Groups and exercises

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- 5 exercises prepared
- 2 on Germany
- 3 on Iran
- Groups will arranged
- Tasks
  - Data needs to put together (coordinates and variables of interest)
  - SAR and SEM tested
  - Results presented in PowerPoint next session

End of session 1

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THANK YOU

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