

# **Convergence Clubs and Regression Trees**

0686 - Spatial Economics

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Based on Postiglione, Benedetti, and Lafratta (2010)

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# Data

Recap: European Regional Database by Cambridge Econometrics

We limit the dataset to:

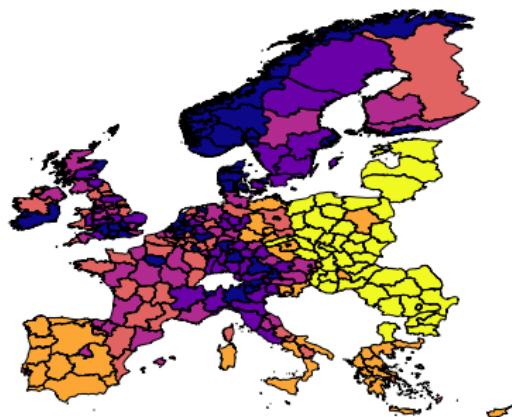
- timeframe 2000-2015
- no Croatia (i.e. two fewer NUTS 2 regions)

This means we get to:

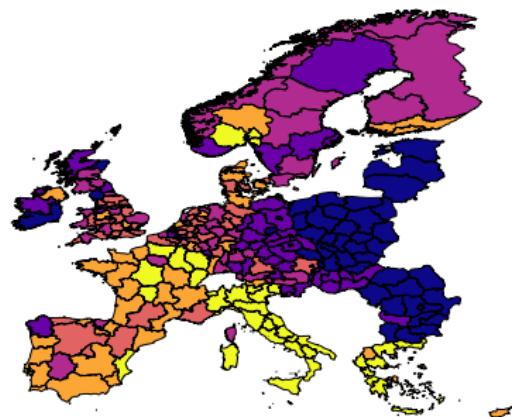
- use the full set of variables
- keep a detailed London (five NUTS 2 regions)

# Motivation

GDP p.c. in 2000  
Quantile map

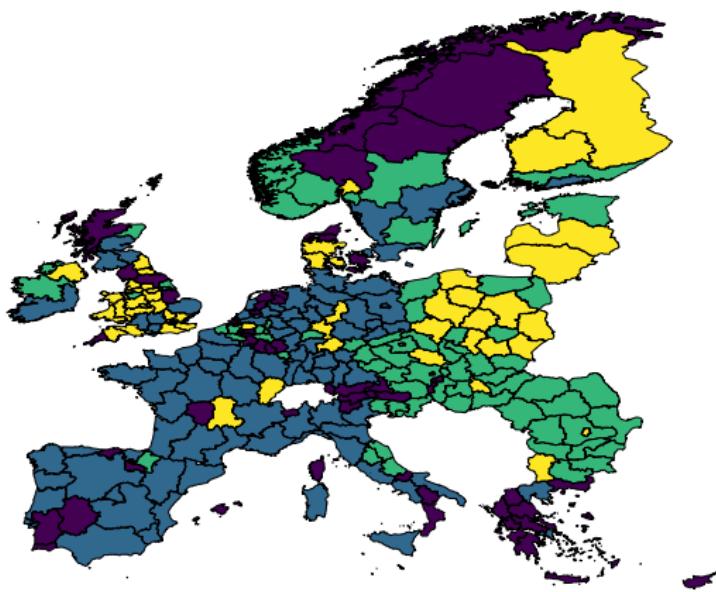


GDP p.c. growth 2000–15  
Quantile map



# Results

Convergence clubs NUTS 2  
Unfiltered data



Club 1 Club 2  
Club 3 Club 4

# Results

**Table 1:** Regression results using unfiltered data

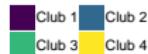
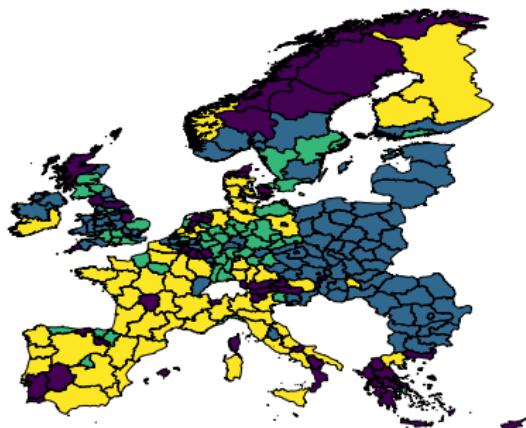
<i>Dependent variable:</i>				
	GDP p.c. growth rate 2000-15			
	(1)	(2)	(3)	(4)
Constant	-1.139*** (0.323)	-0.265 (0.360)	1.769*** (0.146)	2.922*** (0.147)
Initial GDP p.c.	0.120*** (0.032)	0.035 (0.036)	-0.159*** (0.016)	-0.275*** (0.015)
Observations	63	92	67	51
Residual Std. Error	0.118 (df = 61)	0.105 (df = 90)	0.129 (df = 65)	0.086 (df = 49)

Note:

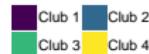
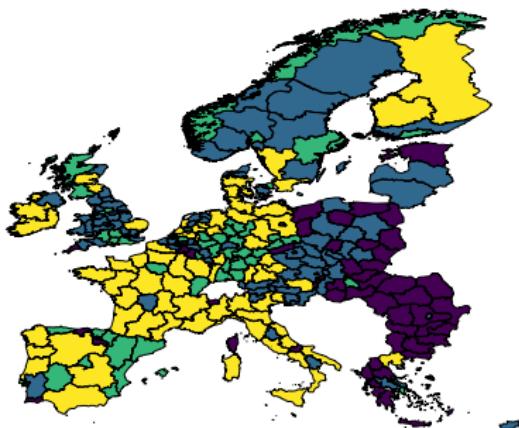
\*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$

# Results

Convergence clubs NUTS 2  
SAR-filtered data



Convergence clubs NUTS 2  
SEM-filtered data



# Results

**Table 2:** Regression results using SAR-filtered data

<i>Dependent variable:</i>				
	GDP p.c. growth rate 2000-15			
	(1)	(2)	(3)	(4)
Constant	-1.174*** (0.343)	1.445*** (0.122)	1.296*** (0.383)	-0.037 (0.470)
Initial GDP p.c.	0.109*** (0.034)	-0.142*** (0.013)	-0.128*** (0.037)	-0.003 (0.047)
Observations	63	97	55	58
Residual Std. Error	0.125 (df = 61)	0.124 (df = 95)	0.073 (df = 53)	0.110 (df = 56)

Note:

\*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$

# Results

**Table 3:** Regression results using SEM-filtered data

<i>Dependent variable:</i>				
	GDP p.c. growth rate 2000-15			
	(1)	(2)	(3)	(4)
Constant	-0.039** (0.018)	0.088*** (0.014)	0.016 (0.020)	-0.021 (0.022)
Initial GDP p.c.	-0.277*** (0.022)	-0.265*** (0.026)	-0.061** (0.028)	-0.132*** (0.047)
Observations	55	89	59	70
Residual Std. Error	0.117 (df = 53)	0.120 (df = 87)	0.086 (df = 57)	0.106 (df = 68)

Note:

\*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$

## CS excursion

**Regression vs. Iteration** Fibonacci sequence:

1, 1, 2, 3, 5, 8, 13, 21, ...

Defined by

$$f(n) = f(n - 1) + f(n - 2)$$

with the base

$$f(1) = f(2) = 1$$

# Regression tree

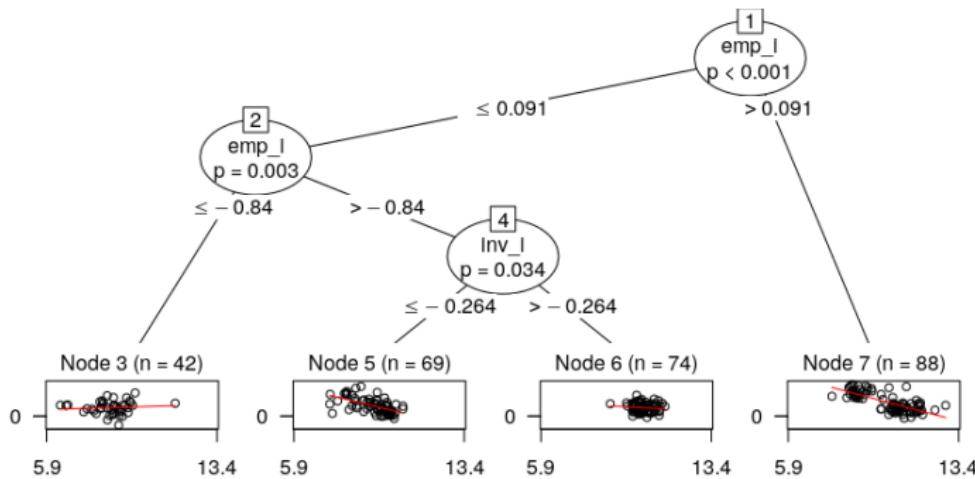
Split observations into branches:

```
tree <- function(data, split_vars, end_criteria) {  
  split <- find_best_split(...)  
  if (!end_criteria) {  
    return(list(tree(split$data1, ...),  
               tree(split$data2, ...)))  
  } else { # if(end_criteria)  
    return(data)  
  }  
}
```

# Oh what a merry regression tree

We receive a recursive, tree-like data structure that is:

- hard to deal with (**a lot** of helper functions are necessary)
- pretty nice



**Figure 1:** A partykit (Hothorn and Zeileis 2015) tree

# Arboretum

## 1. Grow the tree

• w_tree	list [2]	List of length 2
• [[1]]	list [2]	List of length 2
• df	list [63 x 18] {S3: data.frame}	A data.frame with 63 rows and 18 columns
• node	list [1]	List of length 1
• [[2]]	list [2]	List of length 2
• [[1]]	list [2]	List of length 2
• [[1]]	list [2]	List of length 2
• df	list [67 x 18] {S3: data.frame}	A data.frame with 67 rows and 18 columns
• node	list [3]	List of length 3
• [[2]]	list [2]	List of length 2
• df	list [51 x 18] {S3: data.frame}	A data.frame with 51 rows and 18 columns
• node	list [3]	List of length 3
• [[2]]	list [2]	List of length 2
• df	list [92 x 18] {S3: data.frame}	A data.frame with 92 rows and 18 columns
• node	list [2]	List of length 2
• [[1]]	list [3]	List of length 3
pval	double [1]	1.335496e-23
name	character [1]	'emp_ind'
value	double [1]	-0.7057793
• [[2]]	list [3]	List of length 3
pval	double [1]	7.152432e-12
name	character [1]	'inv_nms'
value	double [1]	-0.04690463

# Arboretum

## 2. Fell the tree

❸	u_nodes	list [4]	List of length 4
❸	[[1]]	list [1 x 4] (S3: data.frame)	A data.frame with 1 rows and 4 columns `1.33549573594655e-23`
	pval	character [1]	'emp_ind'
	name	character [1]	'emp_nms'
	value	character [1]	'-0.705777934346498'
	direction	character [1]	'leq'
❸	[[2]]	list [2 x 4] (S3: data.frame)	A data.frame with 2 rows and 4 columns `1.33549573594655e-23` "7.15243206573357e-12`
	pval	character [2]	'emp_ind' "inv_nms"
	name	character [2]	'emp_nms'
	value	character [2]	'-0.705777934346498' "-0.0469046310811765`
	direction	character [2]	'gre' "gre"
❸	[[3]]	list [3 x 4] (S3: data.frame)	A data.frame with 3 rows and 4 columns `1.33549573594655e-23` "7.15243206573357e-12` "2.28459268934336e-08`
	pval	character [3]	'emp_ind' "inv_nms" "emp_nms"
	name	character [3]	'emp_nms'
	value	character [3]	'-0.705777934346498' "-0.0469046310811765` "-0.311514464909221`
	direction	character [3]	'gre' "leq" "leq"
❸	[[4]]	list [3 x 4] (S3: data.frame)	A data.frame with 3 rows and 4 columns `1.33549573594655e-23` "7.15243206573357e-12` "2.28459268934336e-08`
	pval	character [3]	'emp_ind' "inv_nms" "emp_nms"
	name	character [3]	'emp_nms'
	value	character [3]	'-0.705777934346498' "-0.0469046310811765` "-0.311514464909221`
	direction	character [3]	'gre' "leq" "gre"

# Arboretum

```
untree <- function(nodes, simplify = FALSE){  
  out <- list()  
  lumberjack <- function(nodes){  
    # ...  
    parent <- parent.frame()  
    pos <- length(parent$out) + 1  
    # if(...){ ...  
    }else if(term_leq){  
      parent$out[[pos]] <- leq  
      Recall(gre)  
    }  
    #...} # lumberjack  
    lumberjack(nodes)  
    return(out)  
}
```

# Arboretum

### 3. Plan the furniture

```
> plan
$0|an
[1] "emp_ind <= -0.70577934346498"
[2] "emp_ind > -0.70577934346498"
[3] "emp_ind > -0.70577934346498 & inv_nms > -0.0469046310811765"
[4] "emp_ind > -0.70577934346498 & inv_nms <= -0.0469046310811765"
[5] "emp_ind > -0.70577934346498 & inv_nms < -0.0469046310811765 & emp_nms <= -0.311514464989221"
[6] "emp_ind > -0.70577934346498 & inv_nms <= -0.0469046310811765 & emp_nms > -0.311514464989221"

$terminal
[1] "emp_ind <= -0.70577934346498"
[2] "emp_ind > -0.70577934346498 & inv_nms > -0.0469046310811765"
[3] "emp_ind > -0.70577934346498 & inv_nms <= -0.0469046310811765 & emp_nms <= -0.311514464989221"
[4] "emp_ind > -0.70577934346498 & inv_nms < -0.0469046310811765 & emp_nms > -0.311514464989221"
```

```
cumPaste <- function(vec, collapse = NULL) {
  return(sapply(vec, function(x)
    paste(vec[1:which(vec == x)], collapse = collapse)))
}
```

## 4. Build the furniture

---

dat	list [4]	List of length 4
df1	list [63 x 18] (S3: data.frame	A data.frame with 63 rows and 18 columns
df2	list [92 x 18] (S3: data.frame	A data.frame with 92 rows and 18 columns
df3	list [67 x 18] (S3: data.frame	A data.frame with 67 rows and 18 columns
df4	list [51 x 18] (S3: data.frame	A data.frame with 51 rows and 18 columns

## Computational concerns

May turn out highly branched:

- For each splitting variable
- For each value in variable

Thus we use Rcpp (Eddelbuettel and Balamuta 2017):

1. Write function in C++

```
// [[Rcpp::export]]  
NumericVector get_var_stat(arma::rowvec & y,  
                           mat & X, vec & Z,  
                           double min_obs){ // ... }
```

2. Source in R

```
Rcpp::sourceCpp("get_var_stat.cpp")
```

## Discussion

### **Regression tree algorithm for convergence club identification?**

Postiglione, Andreano, and Benedetti (2013) document drawbacks:

- spatial information as nuisance
- strict jumps on boundaries
- not globally optimal
- no other controls

Andreano, Benedetti, and Postiglione (2017)

- spatial augmented convergence model (SDM), iterated spatially weighted regression algorithm

## Literature

- Andreano, M Simona, Roberto Benedetti, and Paolo Postiglione. 2017. "Spatial Regimes in Regional European Growth: An Iterated Spatially Weighted Regression Approach." *Quality & Quantity* 51 (6). Springer: 2665–84.
- Eddelbuettel, Dirk, and James Joseph Balamuta. 2017. "Extending R with C++: A Brief Introduction to Rcpp." *PeerJ Preprints* 5 (August): e3188v1. <https://doi.org/10.7287/peerj.preprints.3188v1>.
- Hothorn, Torsten, and Achim Zeileis. 2015. "partykit: A Modular Toolkit for Recursive Partytioning in R." *Journal of Machine Learning Research* 16: 3905–9.  
<http://jmlr.org/papers/v16/hothorn15a.html>.
- Postiglione, Paolo, M Simona Andreano, and Roberto Benedetti. 2013. "Using Constrained Optimization for the Identification of Convergence Clubs." *Computational Economics* 42 (2). Springer: