Master Thesis Conference

Regional Growth Determinants Across the European Union and its Candidates

Elia Di Gregorio

Vienna University of Economics and Business

25 Otober 2024

Table of Contents

Paper Inspiration

Cuaresma et al. [2014]: *The Determinants of Economic Growth in European Regions.*

- Analyze determinants of regional economic growth in 255 European regions (1995-2005) using Bayesian Model Averaging (BMA).
  - **Income Convergence:** Strong convergence in newer EU member states, especially in capital regions.
  - **Human Capital:** Higher education share boosts GDP growth.
  - **Spatial Spillovers:** Positive but limited spillover effects from explanatory variables.

Paper Inspiration

Cuaresma et al. [2014]: *The Determinants of Economic Growth in European Regions.*

- Analyze determinants of regional economic growth in 255 European regions (1995-2005) using Bayesian Model Averaging (BMA).
  - **Income Convergence:** Strong convergence in newer EU member states, especially in capital regions.
  - **Human Capital:** Higher education share boosts GDP growth.
  - **Spatial Spillovers:** Positive but limited spillover effects from explanatory variables.

Renewed Accession Efforts for Western Balkan Countries, Moldova, and Ukraine

- Consecutive crises reinforced the importance of EU unity but challenges include compliance with the *acquis communautaire*, military/ethnic disputes, and corruption.

Contribution

Replication and Expansion of Cuaresma et al. [2014]

- Applies the same methodological framework to 2009-2019 data.

Comprehensive Analysis : expands analysis to include following EU Candidate countries:

1. Republic of Serbia
2. Bosnia and Herzegovina
3. Montenegro
4. Kosovo
5. Albania
6. North Macedonia
7. Turkey
8. Moldova

Policy Relevance

- Inform policies targeting disparities between Member States and Candidate countries.

Literature Review

Regional Growth Determinants and BMA

- The use of BMA in growth models allows for addressing uncertainty by averaging across multiple models, ensuring robust identification of growth determinants.

Convergence and Regional Disparities

- The thesis explores the theory of convergence, where poorer regions or countries grow faster than wealthier ones, and how this process has been uneven across Europe, particularly in Central, Eastern, and Southeastern European (CESEE) regions.

Policy Implications and Cohesion

- Literature focusses on the impact of EU cohesion policy, particularly how it has influenced regional growth strategies in both Member States and Candidate countries, and its varying effectiveness in reducing regional disparities.

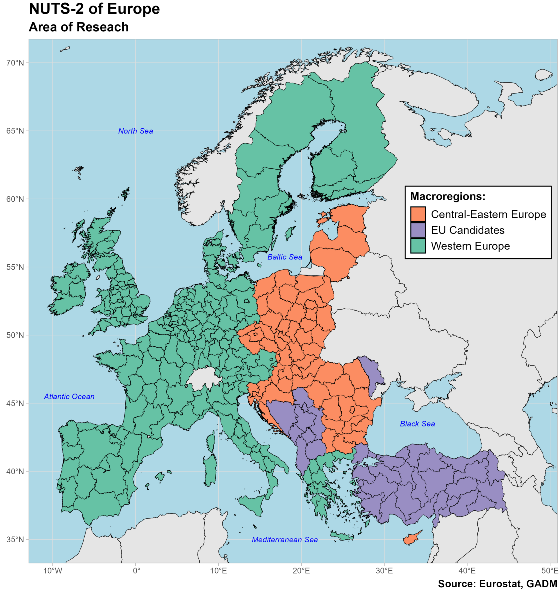
Regional Coverage

This study covers 265 EU and 36 candidate regions based on NUTS-2 classification.

Data Sources:

- EU Databases: ARDECO, Eurostat, ESPONS;
- World Bank;
- National Statistical Offices;
- WiiW;
- ILOSTAT.

Regional Coverage



Variables

Dependent variable: GDP Growth (Base price EUR09)

Explanatory Variables:

1. GDP per capita (log),
2. Net Migration rate,
3. Labor Productivity (log),
4. Gross Wage in EUR,
5. Activity rate,
6. NEET rate,
7. Life expectancy,
8. Fertility rate,
9. Share of Population by Educational Attainment,
10. Employment rate,
11. Unemployment rate,
12. Investment rate,
13. Sectoral components of GVA,
14. Output density,
15. Employment density (km^2),
16. Population density (km^2),
17. Distance from Bruxelles (km),
18. *Dummy variables and interactions.*

Variables Breakdown

Sectoral Components of GVA[1]**:**

- Agriculture (NACE A)
- Industry (NACE B-E)
- Construction (NACE F)
- Services (NACE G-N)
- Public Sector (NACE O-U)

Educational Attainment[2]**:**

- Basic Education (ISCED 0-2)
- Secondary Education (ISCED 3-4)
- Tertiary Education (ISCED 5-8)

Dummy Variables:

- CEE/Candidate Flag
- Capital Region
- Island Region
- Objective 1 Region
- Border Region

Interaction Terms: CEE/Candidate×

- Capital region
- Population with tertiary education
- Sectoral components of GVA

[1] Based on NACE Rev. 2.
[2] Based on ISCED 2011.

Basian Model Averaging

- BMA addresses model uncertainty by averaging across models, rather than selecting a single "best" model → models are weighted by their ability to explain the data.
  - ▷ This prevents issues like overfitting and multicollinearity.

- Incremental model specifications:
  1. **Cross-sectional baseline** model for regions.
  2. Baseline model expanded with **country bfixed effects** model to control for unobserved heterogeneity.
  3. Baseline adjusted by **Spatial Autoregressive** (SAR) model to account for spatial spillover effects.

Econometric Model

The 3 BMA Model specification as in Cuaresma et al. [2014] which can all be nested within a general SAR model of the form:

$$\gamma = \alpha \iota_N + \rho W \gamma + X_K \vec{\beta}_k + \epsilon \tag{1}$$

- γ is an N-dimensional column vector of stacked growth rates of income per capita for N regions;
- ι_N is an N-dimensional column vector of ones;
- $X_K = (x_1, \ldots, x_k)'$ is a matrix whose columns are stacked data for K explanatory variables;
- $\vec{\beta}_k = (b_1, \ldots, b_k)'$ is the k-dimensional parameter vector corresponding to the variables in X_K;
- W first-order queen contiguity matrix with inverse distance weights;
- ρ is a scalar indicating the degree of spatial autocorrelation;
- ϵ is an error term which may contain country-specific fixed effects.

Bayes' Theorem

BMA averages over 2^K models, M_j ($j = 1, ..., K$), with weights based on posterior model probabilities (PMPs).

- PMP is derived using Bayes' Theorem:

$$p(M_j|\mathcal{D}) = \frac{p(\mathcal{D}|M_j)p(M_j)}{\sum_{j=1}^{2^K} p(\mathcal{D}|M_j)p(M_j)}$$

  where $p(M_j)$ is the prior on model M_j and $p(\mathcal{D}|M_j)$ is the likelihood of M_j.

- The resulting posterior distribution of coefficient β_k is:

$$p(\beta_k|\mathcal{D}) = \sum_{j=1}^{2^K} p(\beta_k|M_j, \mathcal{D})p(M_j|\mathcal{D})$$

Parametrization

- **Parameter Prior:** Zellner's g-prior balances between the number of observations and the number of variables, following a standard benchmark approach.
- **Model Prior:** A binomial-beta prior that sets an expected model size of half the total number of variables.
- **MCMC Sampling (MC^3):** Efficiently searches the model space without evaluating all possible models.
  - The Birth-Death sample was used;
  - 10 million draws and a 3 million iteration burn-in period;
  - Strong-heredity Principle.

Spatial Weight Matrices in SAR Model

- The Spatial Autoregressive (SAR) model accounts for spatial dependencies by using multiple spatial weight matrices:

  1. **Inverse Distance:** Weights decrease with distance, using exponents (ϕ) of 1 or 2.
  2. **Queen-Contiguity:** First-order (direct neighbors) and second-order (neighbors-of-neighbors).
  3. **k-Nearest Neighbors (k-NN):** Defines spatial relationships by the $k = 5$ closest neighbors.

- Combining different matrices helps ensure robustness by capturing varied spatial structures.

Between Countries Baseline Model

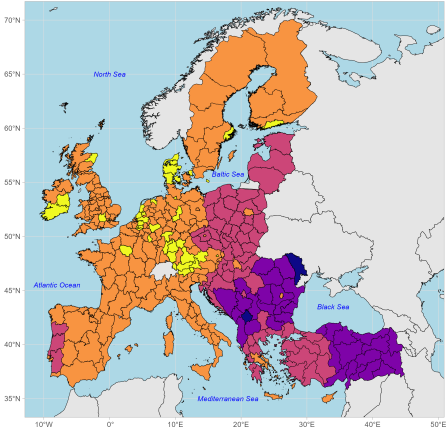
	Model 1			*Model 2*			*Model 3*		
Variable	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**
Unemployment Rate	1.000	-0.118	0.013	0.999	-0.073	0.017	-	-	-
NEET Share	0.999	0.074	0.013	0.813	0.042	0.025	0.717	0.029	0.022
GVA Construction	0.999	-0.150	0.031	0.999	-0.147	0.034	0.998	-0.147	0.032
Investment Rate	0.999	0.052	0.010	-	-	-	-	-	-
GDP per Capita	0.998	-0.017	0.005	-	-	-	-	-	-
GVA Public	0.997	-0.059	0.014	-	-	-	-	-	-
Pop. with Tertiary Edu.	0.986	0.055	0.010	0.983	0.050	0.011	1.000	0.046	0.009
Migration Rate	0.846	-0.273	0.143	0.991	-0.385	0.096	-	-	-
Labor Productivity	0.535	0.005	0.005	0.520	0.006	0.007	0.999	0.018	0.004
GVA Industry	-	-	-	0.690	0.273	0.207	1.000	0.025	0.012
Capital	-	-	-	0.795	-0.006	0.004	1.000	-0.002	0.003
Wage EUR	-	-	-	-	-	-	0.996	-0.020	0.005
Distance from Buxelles	-	-	-	-	-	-	0.980	-0.000	0.000
CEE/Candidates - Dummy interactions									
Candidates				1.000	0.039	0.004	1.000	0.107	0.011
CEE				1.000	0.023	0.003	1.000	-0.009	0.010
Candidates × GVA Industry							1.000	-0.153	0.020
CEE × Pop. Tertiary Edu							1.000	0.142	0.023
Candidates × Pop. with Tertiary Edu.							1.000	-0.194	0.031
Candidates × Capital							0.983	-0.025	0.007
CEE × Capital							0.999	-0.026	0.005
Share of posterior probabilities - Best model		0.25			0.14			0.11	
Share of posterior probabilities - Top 25 models		0.80			0.71			0.45	
Share of posterior probabilities - Top 50 models		0.87			0.78			0.53	
Corr PMP		1.0000			1.0000			0.9999	
Adjusted R^2		0.37			0.39			0.42	

Notes: PIP, posterior inclusion probability; PM, posterior mean; PSD, posterior standard deviation. Time fixed effects were included across all model specifications. Model 1: Cross-section of regions (baseline). Model 2: Cross-section of regions including the Central and Eastern Europe (CEE) and Candidates dummy variable. Model 3: Cross-section of regions further including interaction terms and strong heredity principle application.

Distribution Effects

Spatial Distribution PMs

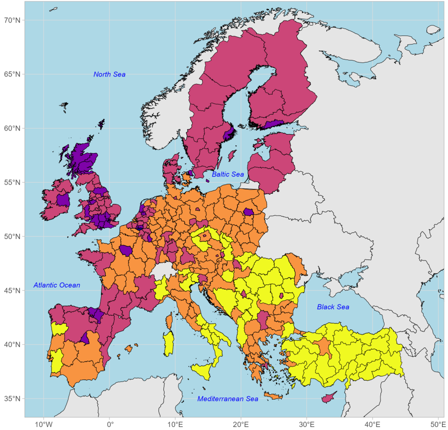
Initial Income



Average estimated effect:

- -2.03% to -1.88%
- -1.88% to -1.72%
- -1.72% to -1.57%
- -1.57% to -1.42%
- -1.42% to -1.26%

Human Capital



Average estimated effect:

- 0.32% to 0.83%
- 0.83% to 1.34%
- 1.34% to 1.86%
- 1.86% to 2.37%
- 2.37% to 2.88%

Within Countries Baseline Model

	Model 1			*Model 2*		
Variable	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**
GVA Construction	0.999	-0.284	0.042	0.999	-0.295	0.036
NEET Share	0.996	0.102	0.022	-	-	-
Pop. with Primary Edu.	0.900	-0.066	0.026	0.977	-0.067	0.015
Unemployment Rate	0.867	-0.069	0.033	-	-	-
GDP per Capita	0.793	-0.010	0.006	0.996	-0.025	0.007
GVA Public	-	-	-	0.650	-0.042	0.035
CEE/Candidates - Dummy interactions						
Candidates$\times$GVA Services				0.995	0.135	0.026
CEE$\times$GDP per Capita				0.998	0.049	0.014
Candidates$\times$GDP per Capita				0.993	-0.041	0.008
CEE$\times$Capital				0.846	-0.022	0.011
CEE$\times$GVA Public				0.665	0.142	0.111
Share of posterior probabilities - Best model		0.12			0.09	
Share of posterior probabilities - Top 25 models		0.72			0.66	
Share of posterior probabilities - Top 50 models		0.80			0.72	
Corr PMP		0.9998			1.0000	
Adjusted R^2		0.46			0.48	

Notes: PIP, posterior inclusion probability; PM, posterior mean; PSD, posterior standard deviation. Model 1: Cross-section of regions with country-fixed effects. Model 2: Cross-section of regions further including the interaction terms. Time and country fixed effects were included as fixed regressors in both models. The CEE and Candidates dummy variables were left out because of perfect multicollinearity, thus the 'strong heredity prior' was not implemented.

SAR Baseline Model

	Model 1			*Model 2*			*Model 3*		
Variable	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**
GVA Construction	0.999	-0.231	0.035	0.999	-0.227	0.034	1.000	-0.205	0.032
NEET Share	0.994	0.081	0.020	0.994	0.082	0.020	0.719	0.029	0.022
Pop. with Tertiary Edu.	0.968	0.044	0.013	0.947	0.043	0.015	1.000	0.058	0.011
Unemployment Rate	0.954	-0.062	0.022	0.960	-0.064	0.022	-	-	-
Labor Productivity	0.950	0.012	0.004	0.911	0.011	0.005	0.960	0.012	0.004
GDP per Capita	0.719	-0.010	0.007	0.661	-0.009	0.008	-	-	-
Gross Wage	0.694	-0.010	0.008	0.698	-0.010	0.007	0.998	-0.021	0.005
GVA Industry	-	-	-	-	-	-	0.996	0.015	0.010
CEE/Candidates - Dummy interactions									
Candidates							1.000	0.064	0.011
Candidates×Pop. with Tertiary Edu.							1.000	-0.203	0.028
Candidates×GVA Industry							0.996	-0.099	0.018
Share of posterior probabilities - Best model		0.07			0.05			0.17	
Share of posterior probabilities - Top 25 models		0.46			0.37			0.65	
Share of posterior probabilities - Top 50 models		0.54			0.45			0.74	
Corr PMP		0.9999			0.9998			0.9948	
Adjusted R^2		0.37			0.39			0.42	

Notes: PIP, posterior inclusion probability; PM, posterior mean; PSD, posterior standard deviation. Model 1: Cross-section of regions with spatial eigenvectors. Model 2: Cross-section of regions including the Central and Eastern Europe (CEE) and Candidates variable. Model 3: Cross-section of regions further including interaction terms. Under Model 3 the 'strong heredity prior' was employed. Time fixed effects were not included as fixed regressors because of the `spatFilt.bms()` function argument's limitation.

Robustness Check

1. Replication method with different temporal and subregional perspectives, and to control for potential variations in economic dynamics and structural differences among regions.
2. Imputation method (`mice`)
3. Multicollinearity (`mprior = dilut`);
4. Combination of Spatial Weight Matrices;
5. Unconstrained Durbin Model.

Key Findings

- **Human capital** is a strong driver of regional growth across Europe.
- **Sectoral composition** is crucial:
  - *Industrial* activity boosts growth.
  - Over-reliance on *construction* hinders long-term productivity.
- Evidence of **convergence** between EU and Candidate countries.
- **Policy implications**:
  - Invest in education and skills.
  - Promote industrial development and diversify economic structures.
  - Enhance interregional knowledge exchange.
  - Tailored strategies needed for Candidate countries to address structural challenges.

References I

All resources are available on: GitHub

Jesús Crespo Cuaresma, Gernot Doppelhofer, and Martin Feldkircher. The determinants of economic growth in european regions. Regional Studies, 48(1):44–67, 2014.

Carmen Fernandez, Eduardo Ley, and Mark FJ Steel. Benchmark priors for bayesian model averaging. Journal of Econometrics, 100 (2):381–427, 2001.

NUTS-2 Specification

NUTS Regions are defined based on Population Thresholds:

NUTS Level	Min. Pop	Max. Pop
NUTS-1	3,000,000	7,000,000
NUTS-2	800,000	3,000,000
NUTS-3	150,000	800,000

Not all Candidate countries follow NUTS system, and/or have good regional data availability. Overall:

- **Single NUTS-2 regions** → Kosovo, North Macedonia, Montenegro, Albania, Bosnia and Herzegovina, Moldova.
- **Multiple NUTS-2 regions** → Serbia, Turkey.

In some cases, EU territorial units diverge from the 2021 NUTS Classification System to ensure consistent and comprehensive data coverage over time across EU.

Prior Structure

Zellner's g-prior, which can be written as:

$$p(\beta_k \,|\, \underbrace{(\alpha, \rho, \sigma, M_j)}_{g}) \sim \mathcal{N}(0, \sigma^2 g(X_k' X_k)^{-1}),$$

- I used the benchmark prior suggested by Fernandez et al. [2001], i.e $g = max(N, K^2)$, where N is the number of observations and K is the number of covariates.

For **Model Prior**: binomial-beta hyperprior on the a priori inclusion probability with prior expected value of the model size prior set to $K/2$.

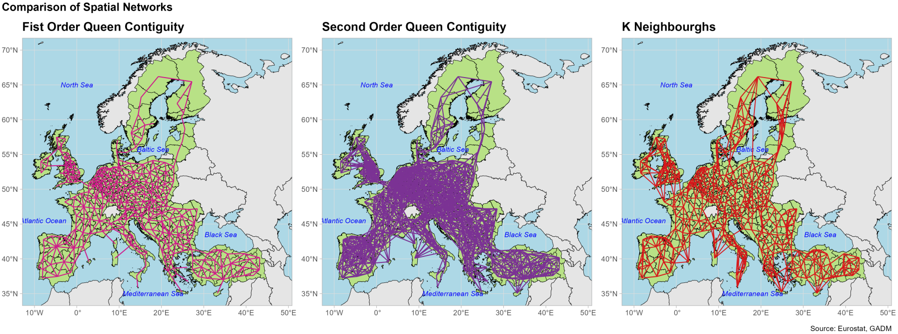
Markov Chain Monte Carlo

The MC^3 allows to identify the most important models and make reasonable predictions without the need to explore all 2^K models. Birth-death sampler used to add or drop covariates systematically:

$$p_{i,j} = \min\left(1, \frac{p(M_j|\mathcal{D})}{p(M_i|\mathcal{D})}\right)$$

1. This sampler starts at model M_i with a posterior model probability of $p(M_i|\mathcal{D})$.
2. One of the k potential covariates in X_k is randomly chosen.
3. If the covariate is part of M_i, it is dropped ("dies"), otherwise it is added ("born") to create another model M_j.
4. The sampler now switches from M_i to M_j with the probability $p_{i,j}$.

Spatial Networks



Spatial Weight Matrices Impact

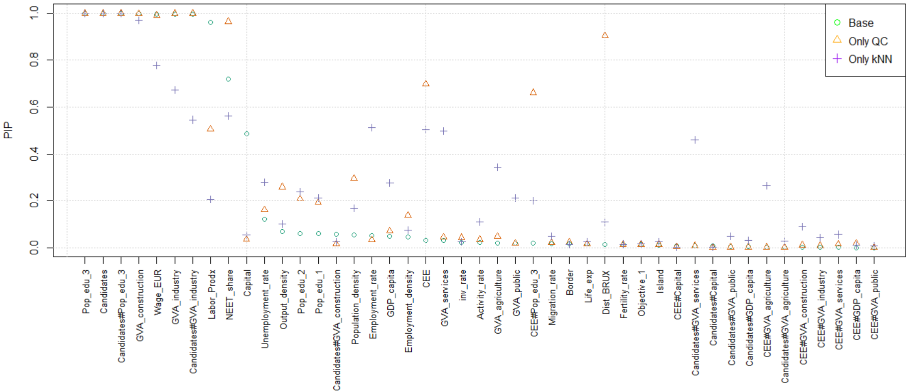


Figure: Effects of Spatial Matrices on PIPs

Spatial Weight Matrices Impact

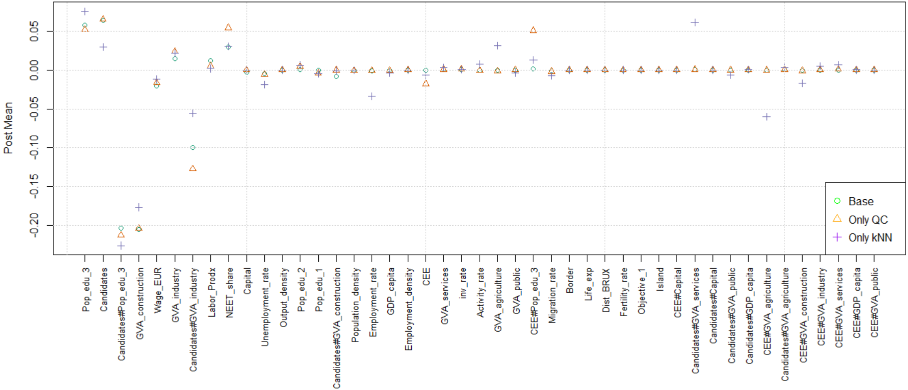


Figure: Effects of Spatial Matrices on PMs

Unrestricted Spatial Durbin Model

	Model 1			*Model 2*			*Model 3*		
Variable	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**	**PIP**	**PM**	**PSD**
W GDP per Capita	1.000	-0.0443	0.0092	0.999	-0.0255	0.0056	0.999	-0.0242	0.0052
W GVA Construction	1.000	-0.347	0.0448	1.000	-0.318	0.0438	1.000	-0.367	0.0404
W Labor Productivity	0.999	0.0264	0.0063	0.770	0.0171	0.0110	1.000	0.0382	0.0057
W Unemployment Rate	0.998	-0.112	0.0177	-	-	-	-	-	-
Wage	0.758	-0.0109	0.0067	-	-	-	0.999	-0.0213	0.0067
Pop. with Tertiary Edu.	0.981	0.0431	0.0108	0.975	0.0432	0.0112	0.996	0.0619	0.0086
GVA Industry	-	-	-	-	-	-	0.888	0.0280	0.0130
Output Density	0.520	-0.0001	0.0001	-	-	-	0.690	-0.00004	0.00005
Capital	-	-	-	0.909	-0.0079	0.0032	-	-	-
Migration Rate	-	-	-	0.850	-0.319	0.158	-	-	-
CEE/Candidates - Dummy interactions									
Candidates				1.000	0.0416	0.0038	0.654	0.0349	0.0288
CEE				1.000	0.0258	0.0032	-	-	-
W Candidates$\times$Capital							1.000	-0.0480	0.0082
W CEE$\times$Capital							0.999	-0.0454	0.0071
Candidates$\times$Pop. with Tertiary Edu.							0.999	-0.204	0.0427
W CEE$\times$Pop. with Tertiary Edu.							0.993	0.148	0.0245

Notes: PIP, posterior inclusion probability; PM, posterior mean; PSD, posterior standard deviation. Model 1: Cross-section of regions with spatially lagged variables. Model 2: Cross-section of regions including CEE and Candidates variables. Model 3: Cross-section of regions with interaction terms. Spatial lags of variables are denoted by W.