SPATIAL INEQUALITIES IN THE CENTRE OF GRAVITY IN CENTRAL-EASTERN EUROPE BASED ON THE GVA AND THE EMPLOYMENT RATE

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Abstract
The issue of territorial disparities is an interesting subject of study in Europe, as there are significant socio-economic disparities between regions, which do not disappear over time, despite substantial levels of funding. The Central-Eastern European region is lagging significantly behind the EU as a whole and the Western regions, with significant intra-country differences. This study aims to examine six countries in the Central-Eastern European region in terms of county-level gross value added and employment rates, examining the convergence processes in the region. In addition to the growth rates of the regions, the study examines the emergence of sigma and beta convergence phenomena, as well as the importance of spatial spillover effects and neighbourhood relations in catching up. I investigate the probability that the spatial distribution of each indicator is heterogeneous, which I also illustrate by the change in the spatial centre of gravity. Convergence studies highlight the internal convergence of the region but also draw attention to the impact of different crises on inequalities.

Keywords: *spatial inequalities, CEE, gross value added, employment, centre of gravity*

1. Introduction

The analysis of territorial inequalities is not new, nowadays it is in the forefront of research in different levels of policy makers, institutes. Some researchers have found that peripheral regions and countries in the EU tend to grow faster than richer ones, but there is more divergence between regions in the long run (Alcidi et al., 2018), suggesting that the longer-term growth rates of regions depend on several country- or region-specific factors that have a significant impact on the convergence process and cause different development paths. In addition, long-term sustainable growth is also influenced by factors such as the geographical location of regions compared to each other and the resulting spatial spill-over effects, or different economic and, for example, environmental shocks.

In economic growth theories, the study of convergence is also not new, and one of the EU's main goals is the convergence of peripheral regions. Rapid and intensive technological change and global economic integration over the past decade have created new challenges for regions, where the regions' resilience is not homogenous. As an effect of it, the development path of some regions has improved, while others have failed to adapt to the new challenges.

The paper aims to examine the changes in specific income and employment centre of gravity in the NUTS3 (county level) regions of six Central-Eastern European economies over the last 15 years, particularly in the light of the impact of the various crises (economic and financial crisis, pandemic situation). This may also shed light on how far the spatial centre of gravity of employment and income are from each other, and whether different types of crises have led to convergence or divergence processes in this area.

2. Theoretical background

Territorial disparities are critical problems in Europe. Regions may differ not only in their initial conditions and socio-economic characteristics but also in their short- and long-term development paths. In today's globalised world, the factors of production, information and various economic processes (e.g. working capital, trade) are spread globally, but the resulting benefits are very unequal. As a result of this, disparities are likely to increase among regions. Local specificities are increasingly important in these rapidly changing circumstances and can contribute to improving the resilience of regions.

The EU's 8th Cohesion Report in 2022, focuses on the long-term evolution of regional disparities, and highlights some major trends in Europe. For example, the Eastern European region has shown a steady convergence with the rest of the EU since 2001, leading to a significant narrowing of the gap in GDP per capita in Europe. Their high economic growth is explained by their economic restructuring and the shift of production to higher value-added sectors. It suggests that the future challenge for these regions (and the long-term sustainability of growth) is to strengthen R&D and innovation (European Commission, 2022). The 9th Cohesion Report finds that by 2023, more than one in four people (28%) in the EU will live in a region with a GDP per capita below 75% of the EU average. Most people live in the eastern Member States, but there are also regions in Greece, Portugal, Spain and southern Italy (European Commission, 2024). For these reasons, it is relevant to examine the evolution of territorial disparities by geographical area, with particular attention to the impact of individual crises, as the resilience of regions to crises and their potential for growth may vary depending on their relative geographical position.

At the same time, the development of economies (countries/regions) and the extent of territorial disparities are affected by trends that are fundamentally reshaping the way things have been done so far. Some of these are in the form of crises (economic, financial, health, natural, etc.), while others are linked to major transformations such as industrial revolutions (e.g. Industry 4.0, robotics, automation), which are the result of the emergence of key innovations and which are bringing about significant changes at the national and the regional level. In today's Europe, the main concern, in addition to widespread regional inequalities (increased further by the coronavirus pandemics and the impact of the Russian-Ukrainian war), is the increasing inflationary pressures (as a shock), which are particularly affecting peripheral countries in Central-Eastern Europe, and are testing their resilience (Baba et al., 2023).

The EU has looked at the impact of the economic crisis on gross value added and employment. Their results show that the NUTS2 effects of the crisis differed significantly across Member States, with Latvia, Estonia, Lithuania, Romania and Spain being the countries most severely affected by the economic downturn (gross value added (hereinafter referred to as GVA) declines averaging between -3 and -5.7% per year between 2008 and 2010). At the other end of the spectrum, a group of countries including Malta, Slovakia and Poland, as well as Sweden, Cyprus and the Czech Republic, recorded positive annual growth rates in GVA of between 0.7 and 1.5% (European Parliament, 2014). The loss of employment also varied greatly between the countries, ranging from a decline of less than 5% in employment in Cyprus to about 21% employment loss in Latvia (European Parliament, 2014).

Researchers argue that it is worth looking at changes across multiple indicators (Widuto, 2019), as different crises can affect convergence processes to different degrees and directions, depending on the indicator. Comparing the effects of the COVID-19 crisis with the economic crisis, it has been shown that COVID-19 did not have the same impact on the extreme values as the financial crisis (Antonescu and Florescu, 2023). Licchetta and Mattozzi (2023) also investigated the impact of the pandemic on inequality and found that the COVID-19 crisis temporarily slowed down convergence, but the estimated negative impact is significantly smaller than that observed during the global financial crisis.

Some researchers state that some economies of Central-Eastern Europe can be one of the new centres of gravity inside Europe concentrating intense growth rates and rapid catch up to the more developed parts of Europe (Rybacki, 2023). In the economic/income centre of gravity, large cities are playing a critical role, as they are concentrating a significant share of the gross value added (Bessis, 2016).

My research hypothesis is that based on different socio-economic indicators, the regions' performance is also different. The stability in the centres of gravity is very different based on the specificity of the indicators and regional characteristics. The population dispersion of the given regions may be the least sensitive one due to external shocks. The aim of the research is the following, to check the spatial centre of gravity based on the GVA and the employment rate in Central-Eastern-Europe, and to check whether the tendencies of Europe are valid for smaller territorial units and for other indicators (in the GVA in Europe, the first wave of the crisis in 2008-09 shifted the spatial centre of gravity strongly southwards, the second wave had no significant impact, first wave of the COVID19 epidemic shifted the centre of gravity significantly to the north-east).

3. Methodology

In my study, I examine the distribution of gross value added and employment rates in Central-Eastern Europe, analysing 6 countries (Hungary, Poland, Czech Republic, Slovakia, Romania and Bulgaria) and their NUTS3 counties for the period 2005-2021. The period under study includes the 1st wave of the economic and financial crisis of 2008-09 and, due to the W nature of the crisis, also the period of the European sovereign debt crisis and the 1st wave of the Covid 19. This allows for a longer-term trend to be used in the analysis. The choice of regions is justified by the significant effects of the crises on the broader region and the similarity of current development paths (as well as the common post-Soviet past). In my research I have used the Eurostat database for collecting data of the six countries' NUTS3 regions on the analysed period. I have checked the gross value added per capita, the thousand number of employed persons, and the population number of territories. The applied statistical program for regression and spatial analysis were the Gretl and GeoDa software.

In the literature, different types of convergence analyses are used to detect trends in differences (e.g. sigma, beta and gamma tests), which try to explain the development path of given regions. Sigma convergence examines the dispersion of GDP (or any other indicator) across regions, i.e. whether income dispersion decreases over time (Kocziszky and Szendi, 2020). Sigma convergence is usually measured by trends in the coefficient of variation (CV) indicator.

The basic idea of beta convergence is related to Solow's neoclassical model, which assumes that the rate of economic growth depends essentially on the growth rate of capital stock and labour (Andrei et al., 2023) and takes into account the change in average GDP relative to the base period. If the beta coefficient is negative and significant, then beta convergence can be verified (Stanisic, 2012).

Beta convergence tests also seek to answer the question of how long it takes to reach the half-life state. The time required to reach 50% of the inequality reduction can be calculated using the following formula (Furková & Chocholatá, 2016; Mindaugas et al., 2018):

$$HL = \frac{-\ln(2)}{\ln(1+\beta_1)} \quad (1)$$

where β is the speed of convergence.

A significant measure of the convergence process is therefore the half-life, defined as the time needed for economies to complete half of the deviation from their steady state (Arbia et al., 2005; Belardi, 2019).

One of the methods to characterise the spatial structure is to calculate the spatial centre of gravity and determine the potential of an indicator (Nemes Nagy, 1998; Tóth, 2013). The analysis aims to illustrate the internal structure of an area and its changes over time, i.e. to review both spatial and temporal movements. In the calculation, if the spatial coordinates of the geographical units are given and weights can be assigned to the areas based on an indicator, the weighted average of the coordinates gives the value of the potential of the area for the given indicator.

$$x = \frac{\sum_{i=1}^{n} x_i}{n} \text{ and } y = \frac{\sum_{i=1}^{n} y_i}{n} \tag{2}$$

where x and y are the two coordinates of the centre of gravity, while x_i and y_i are the coordinates of the base points, and f_i is the weight of the base points (Nemes Nagy, 1998; Tóth, 2013).

4. Results

To illustrate the intra-regional differences, in the figure below I have examined the county-level differences in specific gross value added and employment rates in Central-Eastern Europe, with a particular emphasis on the change in the extreme value of the series and the average value between 2005 and 2021. I first examined what differences can be identified in each indicator and whether the extreme values indicate convergence or divergence. In the case of gross value added, the maximum value in both years is concentrated in the region of Prague (almost 48,500 Euro, **Figure 1**), which is a kind of outlier value according to the graphical test, as it differs significantly from the average.

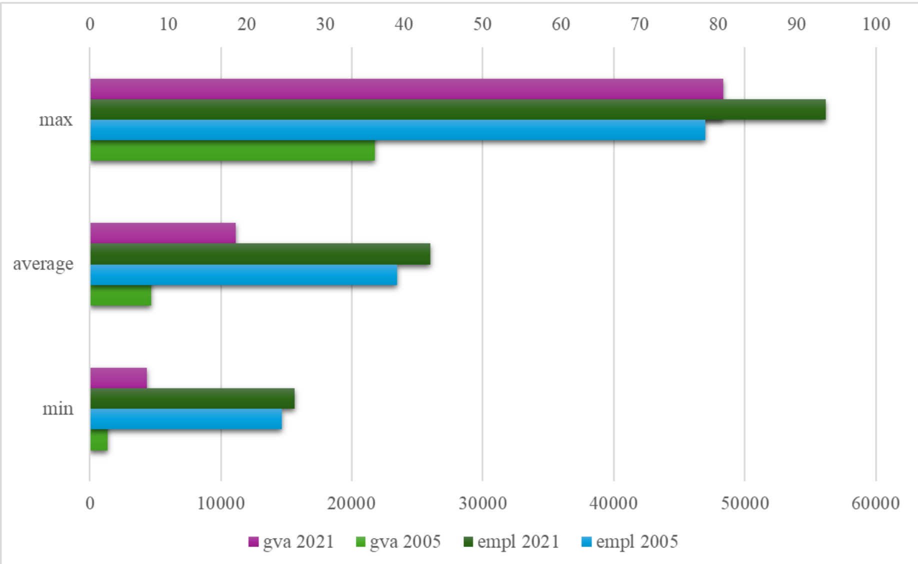

Figure 1. *Extreme values of the gross value added (lower axis) and employment (2005, 2021) in CEE*
Source: own compilation

For the specific gross value added, the minimum values show a more variable picture, as in 2005 a Romanian region, Vaslui (one of the most Eastern territories in Romania near the Moldavian border), was the region's leader, but by 2021 this had been replaced by a Bulgarian region (Haskovo in Southern Bulgaria).

In terms of employment rates, Budapest shows the best performance (in terms of working-age population) in both periods, also significantly outperforming its surroundings and the average. In terms of the lowest employment rate, the situation is stable over the period under review, with Nógrád County not being able to move away from the worst position.

In my analysis, first I checked the convergence tendencies of the six examined countries' NUTS3 regions based on their specific gross value added level, and employment rate. The sigma convergence analyses the dispersion of the data, and a decreasing tendency indicates convergence processes, as mentioned in the methodology chapter. The trends of the CV indicator can be seen in the following **Figure 2**.

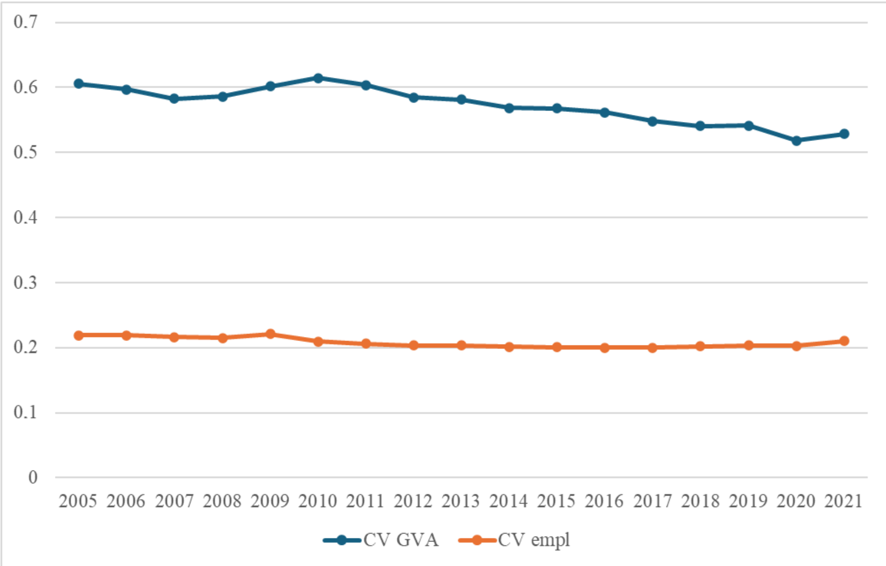

Figure 2. *Sigma convergence process in CEE based on the gross value added and employment (2005-2021) Source: own compilation*

As the sigma convergence analysis of the two indicators shows, in both cases for the whole time frame there is a convergent tendency, although it is shaded by shorter time frames, where the territorial differences are widening. The value of the CV indices indicates larger disparities in the case of gross value added as in the employment rate (almost three-fold disparities). However, the decrease in the CV indicator is much more intense by the GVA. Figure 2 also depicts that the first wave of the economic and financial crisis had more intense effects on both indicators, than the European sovereign debt crisis (in 2011-2012). The wave of 2008-2009 has resulted in a strong increase in the inequalities of both indicators, which can be also noticed by the first wave of COVID-19.

To underline the above-mentioned tendencies, I have checked the distribution of gross value added per capita and employment rate and their change over time (growth rate) in the period 2005-2021 in the regions studied, as shown in the following graphs. There is a noticeable west-east division in the distribution of gross value added, with the highest in the capital regions, some large cities and, in the Czech Republic, the wider Prague area and its surroundings and the North-West Transdanubian region (**Figure 3**). In contrast, the lowest values of specific gross value added can be found in Bulgaria and parts of Romania, but the eastern part of Poland also belongs to the cluster with particularly low values. As in the case of the sigma convergence indicator, the analysis of the GVA growth rate also suggests convergent trends, with the highest values in the period 2005-2021 in Romania and Bulgaria, in many cases approaching the average annual growth rate of 8-9%. In contrast, the lowest values are found in western Hungary and the north-western Czech Republic.

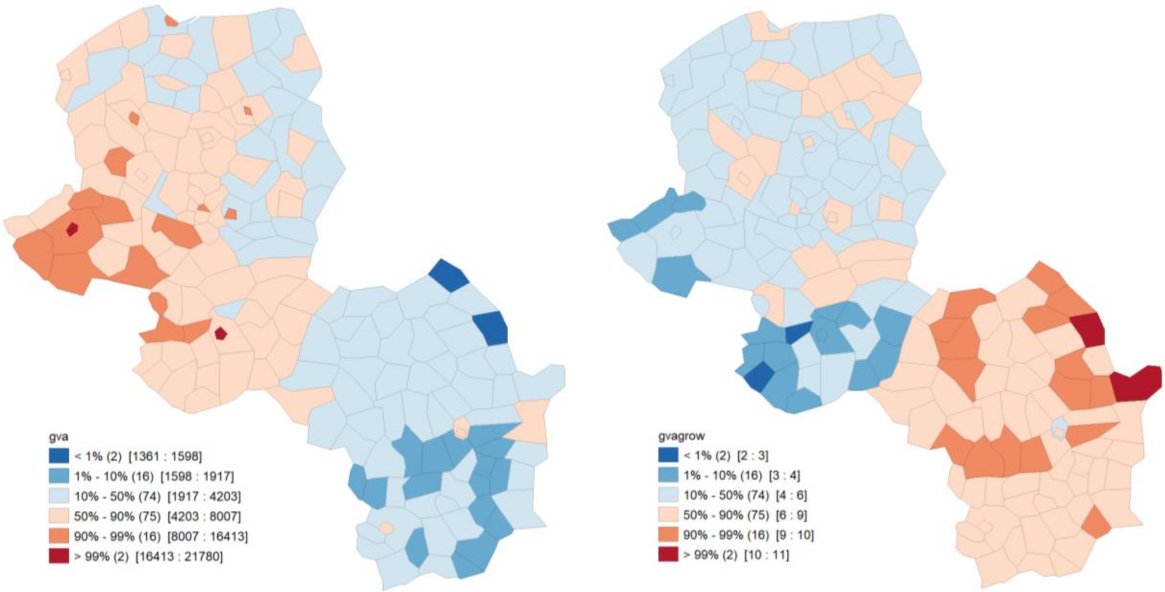

Figure 3. *Patterns of gross value added per capita in Central-Eastern Europe (2005, left) and its yearly average growth rate (2005-2021, right) Source: own compilation*

In terms of employment rates, the picture is somewhat different, in addition to the Czech NUTS3 regions seen above, some areas in Romania and Bulgaria also have particularly high employment rates (**Figure 4**). It was due to the effect of the restructuring of employment in the construction and industrial sectors (mainly from agriculture, as indicated by Mlady, 2016).

This suggests that the patterns of employment rates in the regions of the six countries under study are much more heterogeneous, as we have seen in the case of sigma convergence, with smaller differences in the values of the individual counties than in the distribution of income-type indicators. But the growth rate in this case shows its lowest values in Bulgaria (decreasing employment rate, with an annual average of 1-2%), while Northern, North-Western Poland meanwhile has a growth rate of 1-2%. So employment growth is not always positive in this period.

To test the convergence process more precisely, I have also checked the beta convergence of the two indicators. The idea behind it is, that different measures can lead to different results (e.g. sigma convergence's CV indicators can also decrease in the case of negative convergence, when the more developed territories are losing their positions compared to the less developed ones, Nagyné Molnár, 2007). For specific gross value added in the region, the results of the OLS (ordinary least squares) model show that the linear equation explains 37.3% of the variance. The value of the F-statistic confirms the null hypothesis and thus supports the validity of the model. The value of the multicollinearity condition is 3.57. This is lower than the benchmark value of 30 for this indicator (Tóth et al., 2023), i.e. there is no confounding multicollinearity between variables. When testing the normality of the residuals, I used the Jarque-Bera test, which rejects the null hypothesis at the 1% significance level.

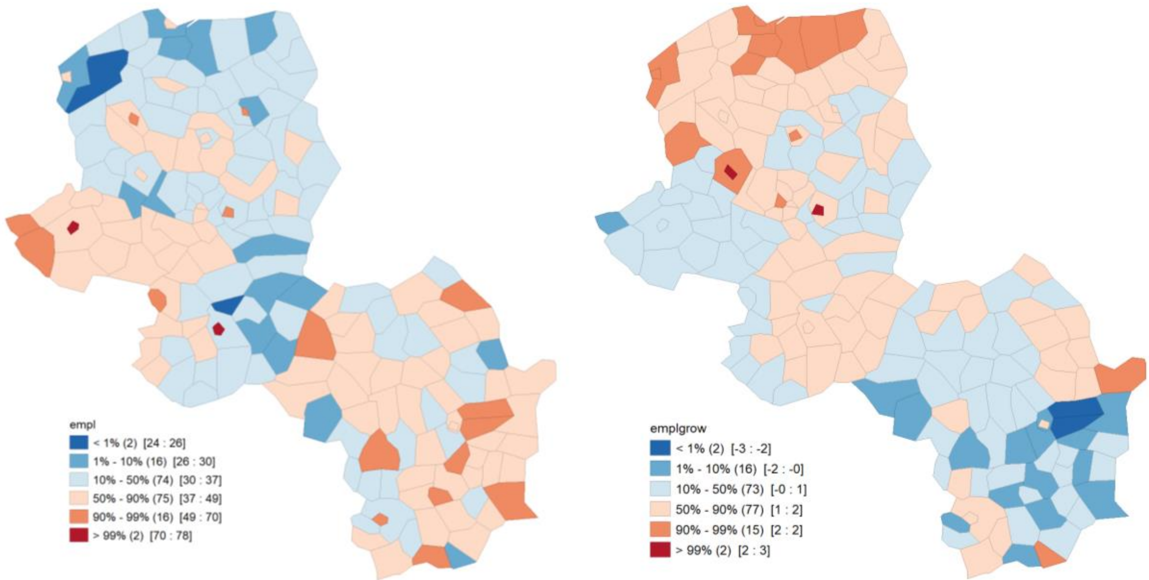

Figure 4. *Patterns of the employment rate in Central-Eastern Europe (2005, left) and its yearly average growth rate (2005-2021, right) Source: own compilation*

The sign of the beta coefficient is negative and significant, indicating beta convergence to the region in the present case. I also examined the role of neighbourhood relations in beta convergence using Moran I statistics. The index value of the global autocorrelation (0.5081) indicates a moderately strong, positive and significant autocorrelation (**Table 1**), which means that the gross value added of NUTS3 counties in the region is dependent on the values of its neighbours. The half-life analysis for the region indicates 16.57 years, which is the time needed to halve the differences in the gross value added between regions.

Because of the significant presence of spatial effects, I examined whether the autocorrelation model of spatial lag or spatial error seems to be correct for the region. Since both the LM-lag and LM-error models are significant (p-value 0.0000), the robustness tests should be considered. Since the significance of the lag model is lower than the one of the error model, I decided to use it. This assumes that there is an autocorrelation between different levels of the dependent variable (lagged values of the growth rate). The Akaike Information Criterion (AIC) and the Schwarz Criterion (SC) also support the validity of the spatial model, showing lower values for the model with a spatially lagged dependent variable (explanatory power of the model increases to 76%).

The model estimates the spatial autoregressive coefficient to be 0.77, which is significant based on the p-value (0.0000). In this case, a 1% change in GVA for adjacent areas will cause a 0.77% increase in the area under study. However, the spatial lag model suggests a slower catch-up than the OLS estimation, whereby the half-life of the model increases to 58.1 years (it means stronger influence from the given neighbouring spatial units on the dispersion of the GVA).

***Table 1.** Beta convergence of gross value added – OLS and spatial estimates*

REGRESSION OLS METHOD **(GVA - V4+2)**				SPATIAL LAG MODEL	
	Coefficient	Std. error	Prob.		Value
Constant	8.51676	0.215528	0.00000*	Mean dependent var	6.5907
Log of „initial year"	-0.0004097	3.9206e-05	0.00000*	S.D. dependent var	1.90933
R-squared		0.373690		Lag coeff. (Rho)	0.770191
F-statistic		109.187		R-squared	0.761080
Prob(F-statistic)		2.4336e-20		Sigma-square	0.870989
Multicollinearity		3.579732		S.E of regression	0.933268
Condition Number				Log-likelihood	-265.207
Jarque-Bera test		2.8774	0.23724	Akaike info criterion	536.414
Breusch-Pagan test		48.7364	0.00000	Schwarz criterion	546.075
Koenker-Bassett test		49.5067	0.00000	W_log growth rate	0.770191
Log-likelihood		-338.871			(0.0000)
Akaike info criterion		681.742		Constant	2.06214
Schwarz criterion		688.182			(0.0000)
				Log of „initial year"	-0.000118
					(0.0001)
half-life (years)	16.57			58.1	
	Moran I/ Degrees of Freedom	Value	Prob		
Moran's I (error)	**0.5081**	10.7629	0.00000		
Lagrange Multiplier (lag)	1	160.0138	0.00000		
Robust LM (lag)	1	**57.4665**	0.00000		
Lagrange Multiplier (error)	1	107.6683	0.00000		
Robust LM (error)	1	5.1210	0.02364		
LM (SARMA)	2	165.1348	0.00000		

Source: own compilation

The beta convergence analysis on the employment rate supports the validity of the OLS model at a lower level of confidence compared to the previous one for specific gross value added, with an explanatory power of around 17%. The F-statistic supports the model in this case as well. The multicollinearity is higher for the employment rate, but still not disturbing. The beta coefficient of the regression line takes a negative value here as well, i.e. it supports convergent processes, but the half-life of the model is estimated to be one year slower than in the other indicator (**Table 2**). The phenomenon of spatial co-movement is also observed in this case, but its value is weak, indicating a significant positive (0.3003) spatial autocorrelation.

The spatial autocorrelation tests also support the spatial lag model for the employment rate, based on the Akaike and Schwarz criterion mentioned earlier, as well as the Log-Likelihood. In this case, the estimated growth rate (Rho value) is 0.54, while the explanatory power of the model is increased to 40.8% compared to OLS. The half-life of the spatial model shows a smaller increasing trend than the gross value added, increasing here only to 28.48 years. So, the spatial spillovers have smaller impact for the employment.

After the analysis of the convergence processes, I wanted to check the spatial distribution of the indicators further. I was curious how far the centroids of the indicators are from each other, whether there is a concentration, or whether the different socio-economic indicators are following various paths in the CEE area.

Table 2. *Beta convergence of employment – OLS and spatial estimates*

REGRESSION OLS METHOD **(employment - V4+2)**				SPATIAL LAG MODEL	
	Coefficient	Std. error	Prob.		Value
Constant	2.17187	0.252446	0.00000*	Mean dependent var	0.662378
Log of „initial year"	-0.0386489	0.0063145	0.00000*	S.D. dependent var	0.800483
R-squared		0.169927		Lag coeff. (Rho)	0.548748
F-statistic		37.4626		R-squared	0.408894
Prob(F-statistic)		5.5376e-09		Sigma-square	0.378765
Multicollinearity		9.257100		S.E of regression	0.615439
Condition Number				Log-likelihood	-179.384
Jarque-Bera test		6.3837	0.04110	Akaike info criterion	364.768
Breusch-Pagan test		56.2577	0.00000	Schwarz criterion	374.429
Koenker-Bassett test		38.8855	0.00000	W_log growth rate	0.548748
Log-likelihood		-204.106			(0.0000)
Akaike info criterion		412.213		Constant	1.26762
Schwarz criterion		418.654			(0.0000)
				Log of „initial year"	-0.02404
					(0.0001)
half-life (years)	17.58			half-life (years)	28.48
	Moran I/ Degrees of Freedom	Value	Prob		
Moran's I (error)	**0.3003**	6.3787	0.00000		
Lagrange Multiplier (lag)	1	64.2514	0.00000		
Robust LM (lag)	1	**44.6825**	0.00000		
Lagrange Multiplier (error)	1	37.6156	0.00000		
Robust LM (error)	1	18.0466	0.00002		
LM (SARMA)	2	82.2981	0.00000		

Source: own compilation

The purpose of the centroid study is to analyse the internal structure of the space and its changes over time, i.e. to review both spatial and temporal changes of specific indicators' dispersion. In the calculation, I have analysed the centre of gravity in gross value added and employment rates and its change over time between 2005 and 2021 in the NUTS3 regions of the six countries, calculating the coordinates of the centroids and their spatial movements in the years under study. I have also included the population of the areas, which shows an interesting density in the six-country area. The results can be seen on the following **Figure 5**.

The spatial centre of gravity for gross value added is in Slovakia, in the High Tatras region, shifting south-eastwards in time (difference between two endpoints 52 km). The centre of gravity for the population is also in Slovakia, the eastern part of the Slovak Paradise region (not far away from the one of the GVA), shifting north-westwards in time (difference between two endpoints 21 km). The spatial centre of gravity of the employment rate is located in Hungary, in Borsod-Abaúj-Zemplén county, in the Cserehát and Zemplén micro-regions, shifting north-westwards in time (30 km in total). So, the stability of the population's centre of gravity can be underlined the most in the CEE region (as is also suggested by the graphical test), while economic/income-type indicators are the most sensitive to extern shocks, which is why it shows the most volatile changes in the centre of gravity analysis. In my further research, I will test this hypothesis for more geographical areas to get more generalizable results.

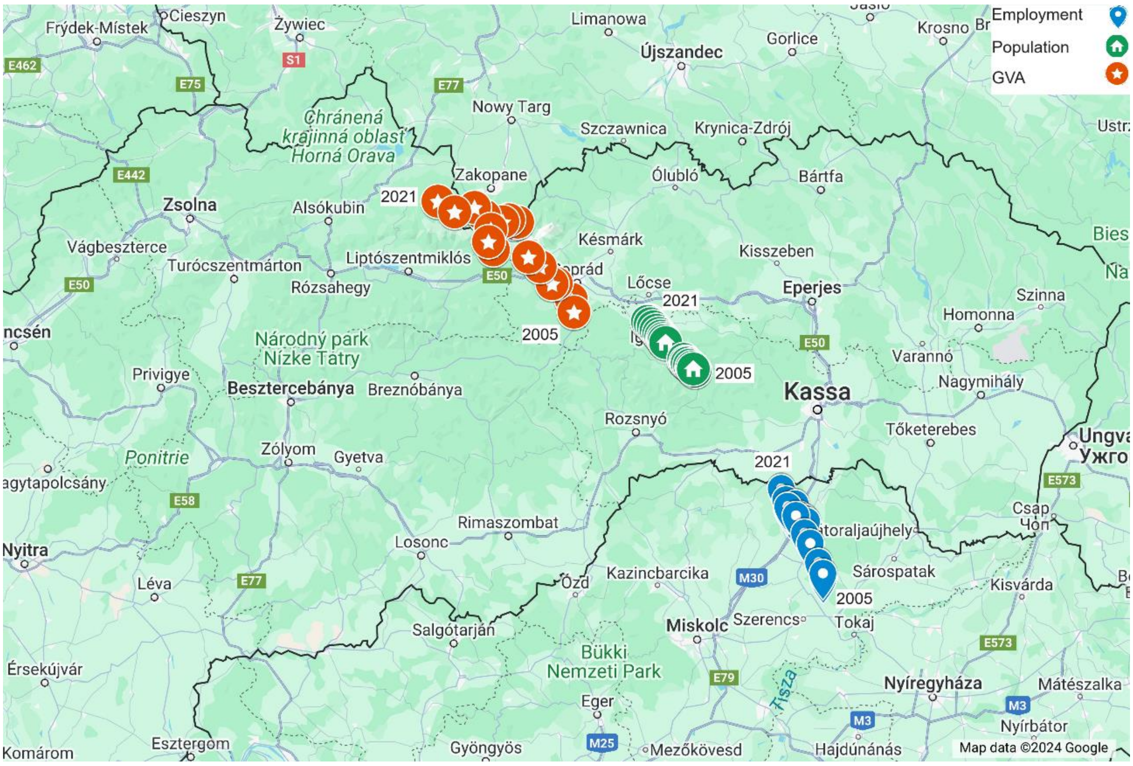

Figure 5. *Centroids of the specific gross value added; population and employment (2005-2021)*
Source: own compilation

In Europe, based on former studies, the first wave of the economic and financial crisis caused a southward shift in the centre of gravity in most geographical areas, but the second wave caused almost no noticeable change. The COVID crisis shifted the centre of gravity in a north-eastern direction. These trends are also observed in the countries studied, as the first wave of the economic and financial crisis shifted the centre of gravity of specific GVA in the region by 7 km southwards, while the second wave did not cause a significant shift (2 km eastwards). The same trend is observed for the employment rate, but the magnitude of the shift is smaller (2 km), while the population was the least sensitive to the crisis. The first wave of COVID caused the largest displacement in employment rates (6 km north-westwards in a single year), while for GVA it was only 4 km in the same direction, and the population did not show any significant sensitivity to this shock. The effects of crises can be different based on their nature as well (economic, social, healthcare or environmental shock, etc.).

5. Conclusion

In my research, I have analysed the convergence process of six CEE countries in the last 15 years based on the specific gross value added and the employment rate. I hypothesised that the stability in the centres of gravity is very different based on the specificity of the indicators and regional characteristics.

Based on the results, it can be seen that both the sigma and beta convergence processes can be verified in the six-country area by both indicators for the whole period. However, it is shaded by the external shocks of the last decades (economic and financial crises, sovereign debt crises and pandemics) with varying degrees. By both indicators, neighbourhood effects are significant, as well as spatial spillovers, and in both cases the spatial lag model's significance can be verified.

The different centres of gravity are relatively far away from each other also in this relatively small area, and they have shifted significantly in the last 15 years. This method can be used also for detecting the intervention points of spatial development decisions. By tracking changes in the centres of gravity, better forecasts can be made in case of a new shock situation. It also shows that an economic shock can cause a shift of 6-7 kilometres in the spatial centre of gravity for up to one year in economic characteristics, while the population is the least sensitive to external shocks.

So, the longer term implications of the study can be that it is worth looking at changes on the basis of several indicators and in different territorial units for a higher degree of generalisability of the results, as the application of different methods can often yield different results (depending on e.g. the influence of outliers or even the level of spatial aggregation) for the same areas.

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