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Measuring economic spatial evolutionary trend of Central and Eastern Europe by SDE method

Xiaoxin Yang¹, Adriana Grigorescu²

ABSTRACT

The economic crisis affected the Central and Eastern European economic spatial structure and reshaped perspectives at the European Union and international levels. Whereas Western Europe's stable economic system has entered maturity, Eastern Europe's economic landscape is still constantly evolving and improving. From a geographical perspective, based on standard distance and the standard deviational ellipse method, we examine the space-time evolution of the Central and Eastern European economy from 1995-2015. During this period, the Central and Eastern European economic spatial barycenter moves northeastward, and the economic distribution scale extends north-south in space. At the same time, the demographic barycenter moves northwestward, with an intense contraction in space. By comparing the economic and demographic standard deviation ellipses, we found a large degree of spatial differentiation, which gradually decreases. This trend shows that in Central and Eastern Europe, the economic development and demographic distribution is not symmetrical, and there still is large potential for the internal market. We propose that Eastern European countries such as Romania and Bulgaria, which have an abundant population, can increase investment in their home market by linking up with Asian countries. This connection can enable them to make full use of external capital, mine demographic advantages and exploit the benefits of being the hub of both Europe and Asia.

KEY WORDS:

economic landscape; evolution of space time, spatial difference; the standard deviation ellipse; economic development

JEL Classification: O11, O40, O52

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1. Introduction

In the late 1980s, Central and Eastern Europe (CEE) entered an era of transformation. On the economic front, Central and Eastern Europe transitioned from

being an inefficiently operated planned economy system to establishing a market economy system. In May 2004, countries in Central and Eastern Europe started to join the European Union, ushering in new opportunities and challenges. With the 2008 financial crisis, Central and Eastern European countries suffered severely. Therefore, in the current steady development period of the global economy, it is of vital importance to stimulate both production and consumption in the

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CEE region in order to promote coordinated development of regional endogenous growth. Central and Eastern Europe is not only an economic region but also a densely populated region. Therefore, after a series of changes and transformations, how has the economic development of at national spatial level in Central and Eastern Europe changed? What kind of influence do Central and Eastern European markets have on the economic landscape? The answer to these questions can provide a quantitative basis for an investment and development strategy to promote the balanced growth of economic space and provide important references for optimizing spatial development patterns.

In PricewaterhouseCoopers' study "Central and Eastern Europe. Economic scorecard: A sustainable future in a great region" (2013), based on a scorecard comparison, the top four countries in terms of growth conditions are the Czech Republic, Slovakia, Poland and the Baltic States. In terms of the size of the economy, Poland outperforms the others.

Studying the potential economic growth in CEE countries, Dombi (2013) uses a growth accounting model that highlights the accumulation of capital. Baltic States, such as Romania and Bulgaria, are better positioned than other countries in terms of the differences between investing and saving rates. The study, which references the German economy (considered the leading economy in Europe), concludes that the CEE countries possess "considerable potential", even if there will continue to be a gap between them and Western European countries. These findings support our theory and confirm the instability between European member states.

Economic convergence is of great interest in the European Union, but some achievements are incomplete. For example, countries such as Slovenia and Hungary have limited results (Dąbrowski, 2014; Forgó & Jevcák, 2015), but the GDP per capita increased in Baltic countries, Poland, Romania and Slovakia and even Bulgaria. Forgó and Jevcák (2015) found that the share of gross fixed capital formation (GFCF) in the GDP was 25% in the Czech Republic, Estonia and Romania in 2014, followed by Poland and Lithuania with 20%. Another difference between EU countries is export accounting, which has very large distribution rates, from 90% of the GDP for Hungary to less than 50% for Poland and Romania.

Monastiriotis (2011) used theoretical and empirical models of regional growth, focusing on three models: neoclassical convergence, cumulative causation and the regional Kuznets Curve. The findings revealed that "this process is not applicable with the same force and in the same manner to the case of the older member states of the EU". The efforts of convergence have side effects, as there is evidence that the more developed Western countries have a more robust process of growth than the CEE countries. The CEE countries made efforts to address the convergence requirements, and even they have had growth in the cumulative force, while polarization is still produced. The polarization and disparities of the development in the EU will probably have a chance to be reduced if the development model of the CEE influences the process in the more advanced EU member states.

The economic crisis caused an important recession in CEE countries due to their transitional fragile economies, as confirmed by the negative rates of economic growth. This heterogeneous recovery process was started at the end of 2009 by Poland, the Czech Republic and Estonia. Hungary and Latvia followed in the beginning of 2010, while Romania and Bulgaria were the last and consequently the weakest (European Central Bank [ECB], 2010). The latest figures turned expectations upside down by showing that Romania has had the highest rate of economic growth in Europe in the last few years—Economic Growth (GDP, annual variation in %) 2011 – 1.1%; 2012 – 0.6%; 2013 – 3.5%; 2014 – 3.0%; 2015 – 3.8%, according to Eurostat—while the Bloomberg analysis reveals a higher regional growth (Jordan, <http://www.sciencedirect.com/science/article/pii/S2212567115002749> - cor0005 Chilian, & Grigorescu, 2015; Kluvánková-Oravská, Chobotová, Banaszak, Slavikova, Trifunovova, 2009). It must be considered that this growth is based on consumption and does not show any Western influences or structural changes. Ultimately, due to its fragility, the economy could be blown away at the slightest gust of wind.

The CEE region is a fascinating area in terms of economic growth after the last recession. This growth was supported by competitive advantages such as a highly educated workforce, a stable macroeconomic environment, favorable business environments and strategic locations (Labaye et al., 2013; Thies, 2016). This region

also has weaknesses, highlighted by its interdependence with Western European countries; for instance, foreign investment and exports comprise more than 2/3 of the economy, and it depends on older developed economies.

To accurately reveal the spatial evolution of Central and Eastern Europe's economy, driven by both the labor and consumer markets, we used the spatial statistics method of standard distance and standard deviational ellipse. Using ArcGIS10.2 software, we were able to analyze the economic elements of space and time changing processes from multiple angles, depict quantitative identification and the overall characteristics of the pattern of economic evolution in the form of visual space-time and space processes in order to inform decision-making in the development of economic policy and strategy.

This article comprehensively reveals the overall trend of space-time evolution for Central and Eastern Europe's economy. It was considered previous spatial studies as Chang, Hu, and Chou (2012); Li and Wei (2010); Visser (1980; 1999); Yeung, He and Liu (2012) for Chinese economy or banking and finance studies. The spatial characteristics of CEE economic evolution have not aroused the concern of academia (Klůvanková-Oravská et al., 2009). Previous researchers have conducted related work from the angle of regions and adopted a non-spatial view to analyze the economic development of Central and Eastern Europe. Part 1 of this article introduces the main research methods and data. Part 2 focuses on analyzing the evolution trend of economic space. Finally, Part 3 summarizes this paper, and we draw the main conclusions and discuss relevant policy recommendations.

2. Research methods and data

Standard deviational ellipse (SDE) is a spatial statistics method that can accurately reveal the economic characteristics of spatial distribution. SDE was first introduced by Lefever in 1926 to reveal the geographical characteristics of spatial distribution elements (Burt & Barber, 1996; Yuill, 1971). At present, the SDE method is widely accepted in the spatial statistical field. With the development of GIS technology, the SDE method based on geographic information has become a conventional module of ArcGIS spatial statistical tools (Furfey, 1927; Gong, 2002; Li, Wei, 2010; Tellier, 1995;

Wong, 1999). SDE from multiple perspectives reflects the characteristics of the integrity of the spatial distribution of economic elements. For example, the SDE barycenter reflects the relative position of the overall center using two-dimensional geographic coordinates with the weight of the economic elements in the spatial distribution. The long axis direction reflects its main trend orientation using the azimuth angle, which is the measure of the clockwise rotation angle from the arctic direction to the standard deviation ellipse's vertex. The long axis length is the characterization of the spatial distribution of elements in the main direction, while the short axis length describes the secondary direction of the spatial distribution. The length ratio of the long and short axes can reflect the element's shape of the spatial distribution. Therefore, the barycenter, long axis, short axis and azimuth angle are the basic parameters of standard deviation ellipses. The computation formulas viewed below are explained as follows, with geographic coordinate data longitude X_i , latitude Y_i and the corresponding economic or demographic weight W_p :

Mean Center:

$$\bar{X}_w = \frac{\sum_{i=1}^n W_i X_i}{\sum_{i=1}^n W_i}, \quad \bar{Y}_w = \frac{\sum_{i=1}^n W_i Y_i}{\sum_{i=1}^n W_i} \tag{1}$$

Azimuth Angle:

$$\tan \theta = \frac{(\sum_{i=1}^n W_i^2 X_i^2 - \sum_{i=1}^n W_i^2 \tilde{Y}_i^2) + \sqrt{(\sum_{i=1}^n W_i^2 \tilde{X}_i^2 - \sum_{i=1}^n W_i^2 \tilde{Y}_i^2)^2 + 4 \sum_{i=1}^n W_i^2 \tilde{X}_i^2 \tilde{Y}_i^2}}{\sum_{i=1}^{11} W_i^2 \tilde{X}_i^2 \tilde{Y}_i^2} \tag{2}$$

Standard Deviation Distance of X:

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^n (W_i X_i - \bar{W}_i X_i)^2}{\sum_{i=1}^n W_i X_i}} \tag{3}$$

Standard Deviation Distance of Y:

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^n (W_i \tilde{X}_i \cos \theta - W_i \tilde{Y}_i \sin \theta)^2}{\sum_{i=1}^n W_i^2}} \tag{4}$$

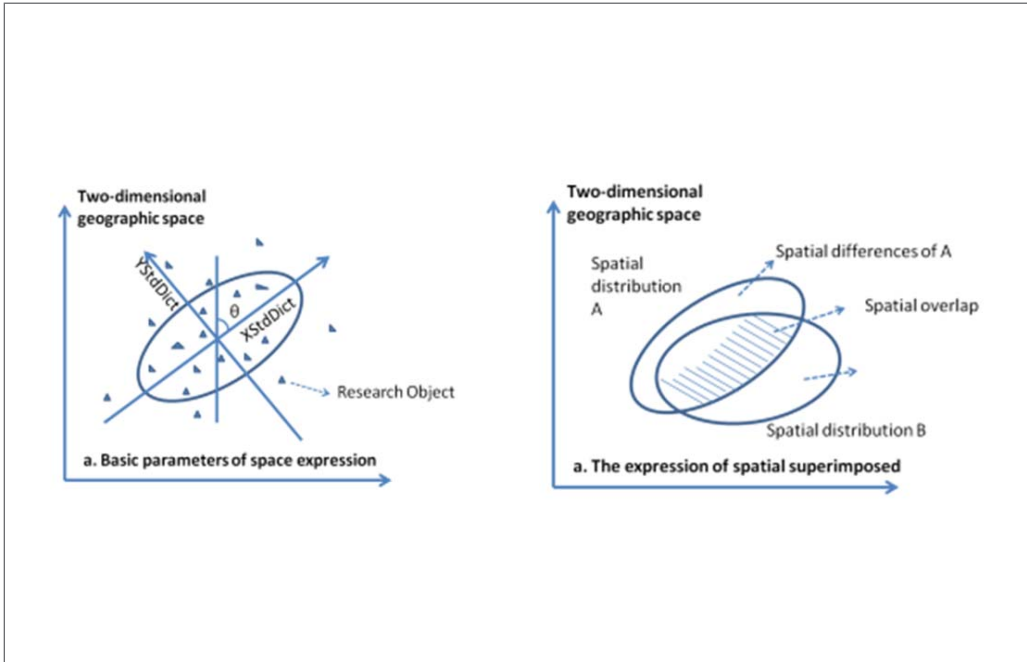


Figure 1. The pictorial view of standard deviational ellipse

A balanced economic spatial distribution should have the same spatial characteristics as a demographic distribution, and its spatial distribution should show the same standard deviational ellipse. Otherwise, the spatial distribution of both standard deviation ellipses will vary (Teller, 1995). The spatial unconformity of economic factors and the demographic distribution can reflect the imbalance of economic space directly. It will be defined as the space difference index, and the specific calculation method is as follows:

Space difference index:

$$SDI_{j,p} = 1 - \frac{Area(SDE_j \cap SDE_p)}{Area(SDE_j \cup SDE_p)} \quad (5)$$

SDE_j and SDE_p, respectively, represent the SDE area of economic elements and the demographic spatial distribution. SDI_{j,p} is the spatial difference index for economic factors and the demographic distribution, between 0 and 1, which reflects a greater discrepancy with a greater value.

This study uses the weighted standard deviational ellipse method based on the space and location of 11 countries, and it calculates the standard deviation of the spatial distribution ellipse. The 11 countries included are Estonia, Latvia, Lithuania, Poland, the Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Romania and Bulgaria (which joined the EU after the system transformation). We used national geographic location data including territory, a national economic factor (GDP) and a social factor (population). We obtained the national geographic latitude and longitude data from the GISCO database and other data from the Eurostat website.

The spatial calculation is performed using the ArcGIS10.2 platform and the spatial reference for Albers' projected coordinate system. Under the given plane coordinates, we calculated the standard deviational ellipse of the spatial distribution of economic factors. The maps of the 11 countries display the nations' location, GDP and demographic value. The different colors, from light to dark, represent the quantity, from low to high, in 2015.

Table 1a. The population of the studied countries

Population (unit: thousand persons)					
Country	1995	2000	2005	2010	2015
Estonia	1448.1	1401.3	1358.9	1333.3	1313.3
Latvia	2485.1	2367.6	2238.8	2097.3	1977.3
Lithuania	3629.1	3499.5	3322.5	3097.3	2904.9
Poland	38275.0	38256.0	38161.0	38517.0	38455.0
Czech Republic	10330.8	10272.5	10234.1	10517.3	10542.9
Slovakia	5363.4	5400.7	5387.1	5430.0	5422.3
Hungary	10329.0	10211.0	10087.1	10000.0	9839.3
Slovenia	1988.7	1989.4	2000.8	2048.8	2063.3
Croatia	4658.9	4425.7	4311.7	4296.0	4201.5
Romania	22681.0	22435.2	21319.7	20246.8	19819.7
Bulgaria	8406.1	8170.2	7659.0	7395.6	7197.5

Source: "Eurostat-Data Explorer: Population and employment" by Eurostat (2016). Available from <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do>

Table 1b. The GDP of the studied countries

Country	1995	2000	2005	2010	2015
Estonia	2902.3	6170.8	11262.3	14718.5	20460.9
Latvia	4134.5	8606.2	13710.6	17772.4	24377.7
Lithuania	5124.1	12491.3	21002.4	28027.7	37123.6
Poland	108715.7	186375.9	246201.3	361744.3	427737.4
Czech Republic	45541.7	66648.8	109394.0	156369.7	166964.1
Slovakia	15259.4	22346.8	39219.9	67387.1	78070.8
Hungary	35296.2	51185.8	90543.0	98198.4	108747.9
Slovenia	16279.8	21923.5	29235.4	36252.4	38570.0
Croatia	17326.6	23582.0	36508.4	45004.3	43897.0
Romania	28763.0	40796.8	80225.6	126746.4	160352.8
Bulgaria	11029.9	14300.5	24001.6	37723.8	44162.3

Source: "Eurostat - Data Explorer: GDP and main components (output, expenditure and income" by Eurostat (2016). Available from <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do>

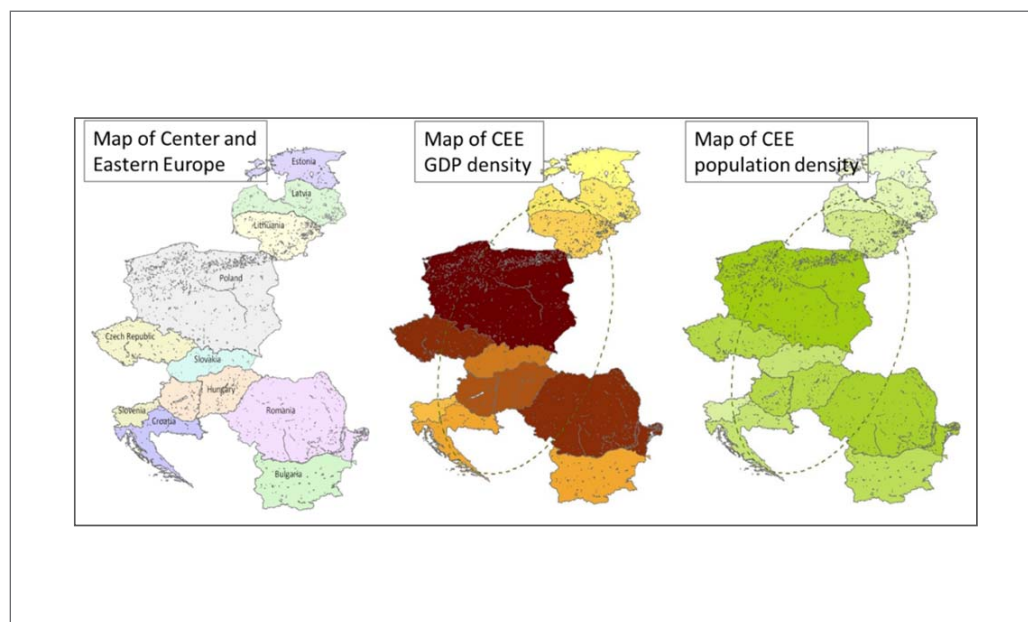


Figure 2. The map of CEE, GDP density and demographic density in 2015

3. Central and Eastern European economic spatial evolution trend

By means of a comparative analysis of the above economic factors from 1995 to 2015, we drew a standard deviational ellipse to find the distribution of the weighted parameters. The Central and Eastern European economic spatial ellipses can be observed in Figure 3, and detailed information is provided in table 2-3, which summarizes the evolution trend in four aspects.

3.1 The barycenter of the economy moving northeast

By comparing the standard deviation ellipses in different years, we found that the GDP spatial distribution ellipses barycenter has a northeastward moving track from 1995 to 2015. The detailed movement record of the GDP ellipses' barycenter for Central and Eastern Europe is shown in Figure 4. The total displacement of the GDP barycenter is 42.71 km, including a move eastward of 10.6 km and northward of 40.7 km, of which the movement has a small southeast callback in 2000-2005 and from 2005 to 2015, a smooth move to

the northeast. The GDP barycenter moves from Slovakia in 1995 to Poland in 2015. In the picture, we can see the ellipses' moving track clearly pressing closer to the demographic ellipse.

The demographic spatial distribution ellipses barycenter (Figure 4) has a southwestward moving trend overall. The barycenter moves 13 km in total, including 11 km westward and 7 km southward. The demographic barycenter's moving direction is clear and stable. There is no back folding during the whole route, which reflects the Central and Eastern European migration direction within the last long period and a definite moving tendency in the future. The moving distance between 2000 and 2005 is the largest (22 km); after that, the moving distance is reduced, but there is no change in the direction. From the moving trace, we can conclude that the dynamic of a northward-moving tendency is weaker now, but the westward moving momentum is still strong. These days, the demographic ellipses' barycenter of gravity is located in Slovakia.

As observed from the space, shown in figure 5, economic ellipses' barycenter (represented by GDP and the total demographic ellipses barycenter) are con-

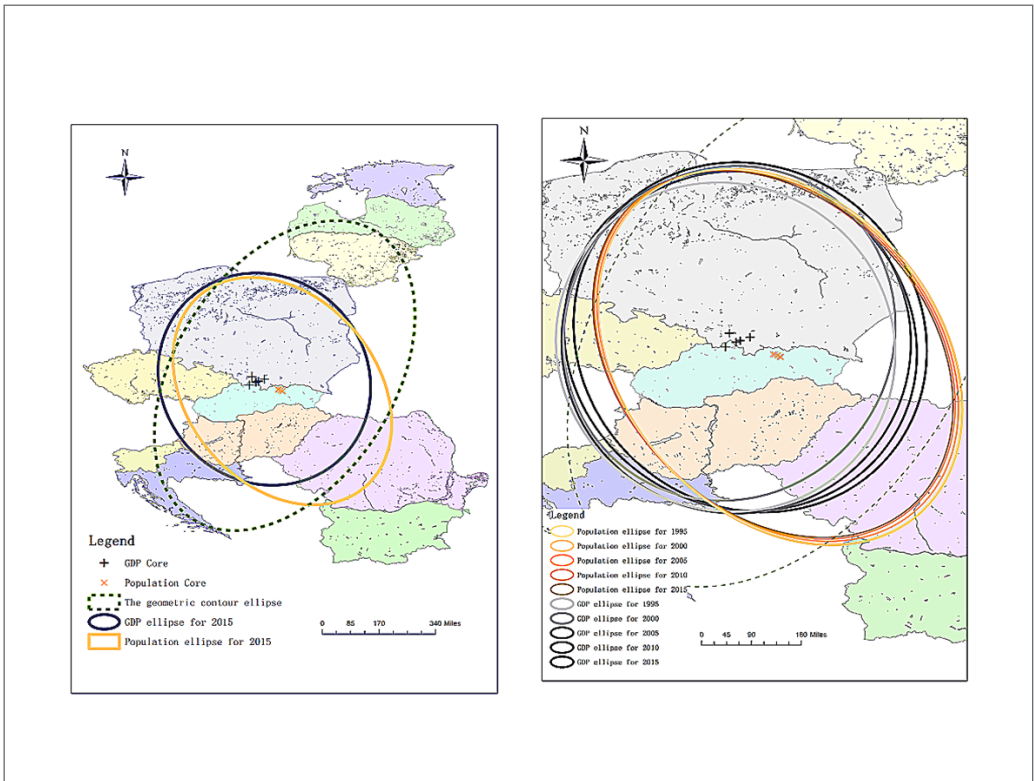


Figure 3. The contrast between GDP and demographic ellipse of CEE in 2015 and the variation tendency of double ellipses of CEE from 1995 to 2015

stantly approaching each other in space. The regional economic development and demographic distribution incline towards an equilibrium.

3.2 Economic spatial orientation

The Central and Eastern European demographic spatial distribution trend during the 1995-2015 period is shown in Figure 6. The standard deviational ellipse length of the X axis and the Y axis are reduced year after year, which means that the whole ellipse area is shrinking, moving gradually towards the center. Compared with the change in the economic spatial distribution, the demographic tendency is so unremarkable that to the naked eye, it is virtually microscopic. However, we are able to quantify it using numerical digits, where we can always find a smooth, stable variation towards one target. This

variation indicates a partiality that can conduct the demographic movement

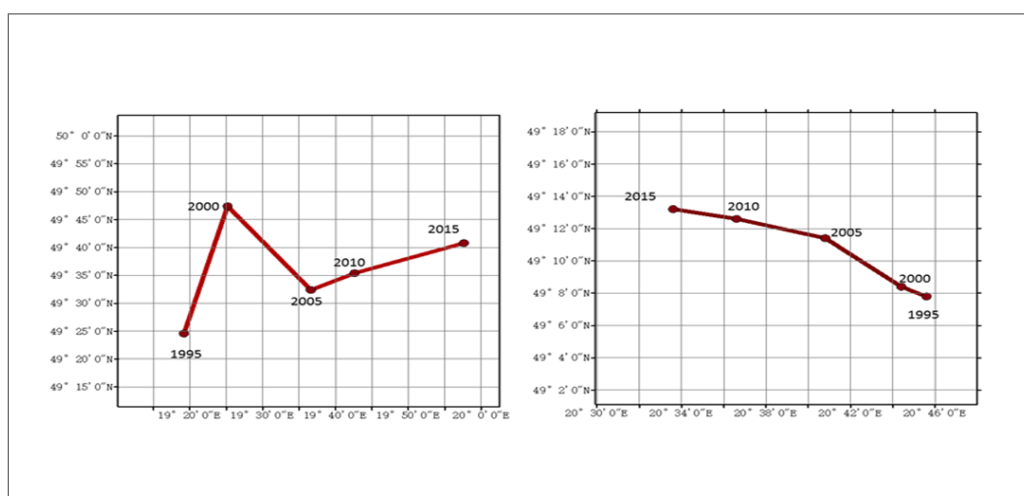
For the Central and Eastern European GDP spatial distribution, we can see a directionally stretched ellipse with small fluctuations. As shown in Figure 6, the standard deviation ellipse X axis in GDP increased every year after 2000, which indicates that the CEE economy remained along the north-south longitudinal extension from 2000 to 2015 and continued the trend of elongation. Among the process of shape-changing ellipses, the countries in the south of CEE play a bigger role than those in the central region and will stabilize the momentum. Although the GDP standard deviational ellipse is volatile, the length of the Y axis relatively stable, which indicates there is not much change in the east-west direction, as the economy has become stable. During the growth process for the length of the

Table 2. Standard deviation ellipse data of GDP

GDP Barycenter					
Feature	centerX	centerY	XStdDist	YStdDist	Rotation
ellipseGDP2015	19.969308	49.688798	4.933588	4.504663	150.648344
ellipseGDP2010	19.713476	49.59088	4.829346	4.468308	142.178839
ellipseGDP2005	19.603397	49.549298	4.727685	4.559695	178.303605
ellipseGDP2000	19.42821	49.795691	4.296936	4.655131	17.912925
ellipseGDP1995	19.325826	49.417404	4.596867	4.380448	151.444012

Table 3. Standard deviation ellipse data of demographic

Demographic Barycenter					
Feature	centerX	centerY	XStdDist	YStdDist	Rotation
ellipsePop2015	20.56432	49.223501	5.549827	4.119539	142.45571
ellipsePop2010	20.605509	49.215271	5.569524	4.14771	143.064694
ellipsePop2005	20.687748	49.19087	5.609377	4.151724	143.491456
ellipsePop2000	20.749103	49.143508	5.655776	4.169084	143.612027
ellipsePop1995	20.764892	49.142754	5.667183	4.195824	144.145527

**Figure 4.** The moving tendency of GDP and demographic barycenter

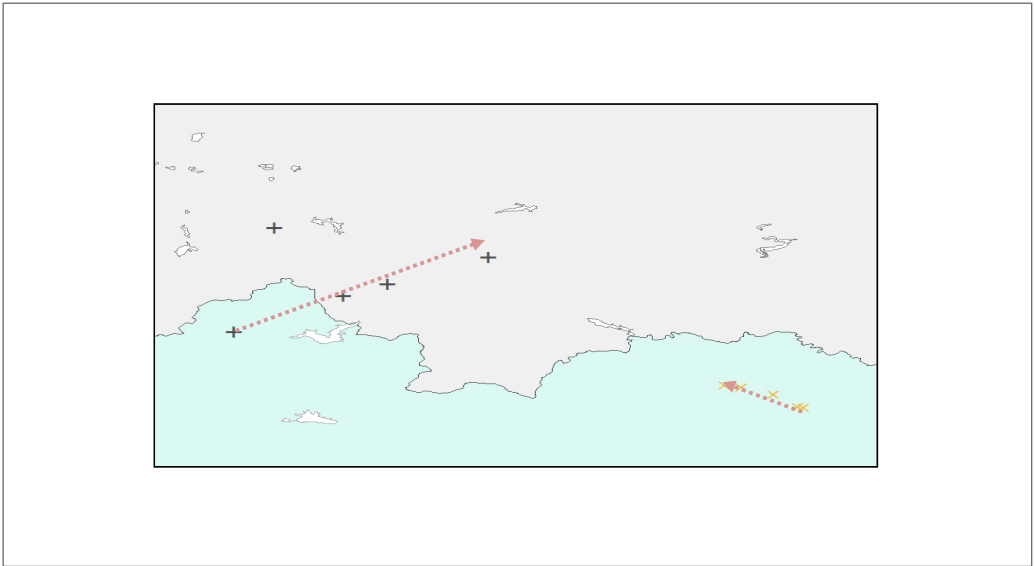


Figure 5. The tendency of approaching for barycenter

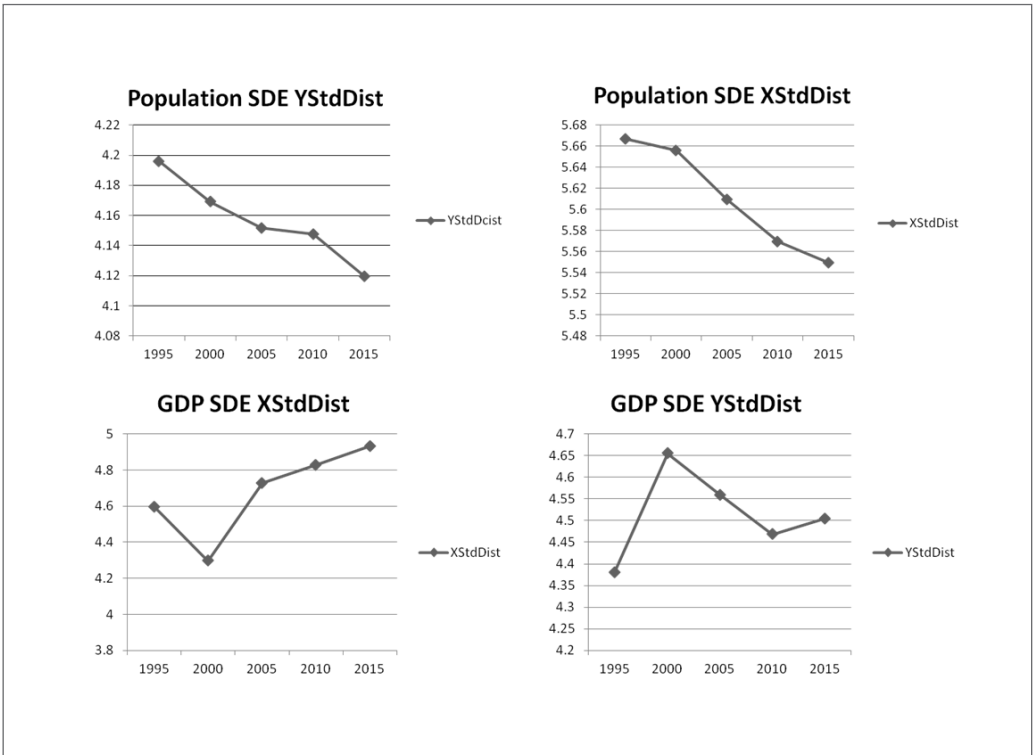


Figure 6. The change in spatial distribution range for demographic and GDP

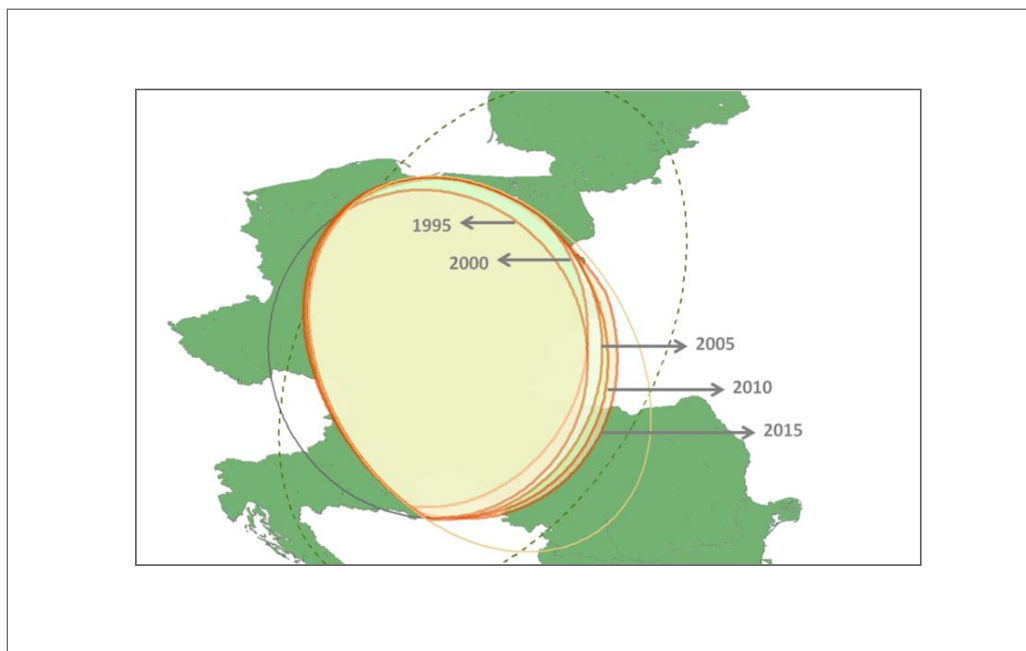


Figure 7. Ellipses intersect area from 1995 to 2015

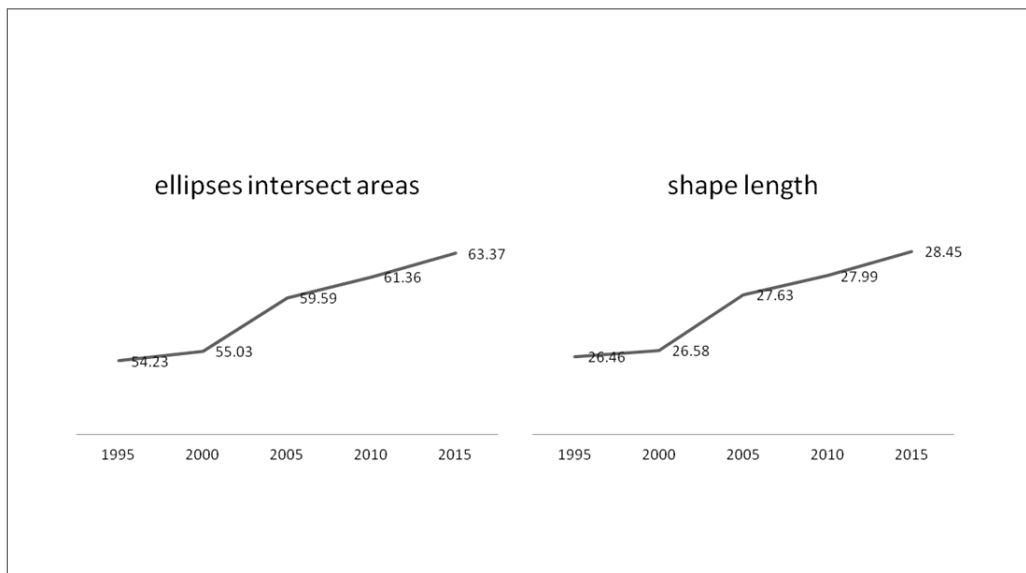


Figure 7a. Ellipses intersection area from 1995 to 2015

Table 4. The area and length of ellipses intersection

	1995	2000	2005	2010	2015
ellipses intersect areas /km ²	54.23	55.03	59.59	61.36	63.37
shape length /km	26.46	26.58	27.63	27.99	28.45
SDI	0.29	0.27	0.21	0.18	0.14

Y axis, the largest growth was registered from 2000-2005. From 2005-2010 and from 2010- 2015, the economic crisis caused the growth trend to significantly decrease.

For GDP ellipses, the current standard deviational ellipse X axis distribution ranges between 4.30 and 4.93. The Y axis distribution ranges between 4.38 and 4.65. The X axis and Y axis have similar lengths, so the standard deviation ellipses have a similar “round” shape, different from the Central and Eastern European geography distributional ellipses and demographic distributional ellipses. The larger the value of the discrepancy between the two axes, the more obvious the direction indicated by the ellipses. From the data, we can conclude that the land and population ellipses have a distinct orientation, while the economic ellipses do not and are consequently not reasonable for a mature economic system. It is sensible to note the different spatial discrepancies of the economy and the population. Considering the length of both the X and Y axes and the ratio of both standard deviational ellipses, the length of the Y axis of the GDP standard deviational ellipse still shows a larger growing trend.

3.3 Axis of rotation

The long axis of the Central and Eastern Europe GDP standard deviation ellipses move in a clockwise motion and fluctuate between 150.65° and 179.13°. They are located on a small scale and travel back and forth with no clear trend. There appears to be no structural change for the whole CEE. The corresponding azimuth of the demographic standard deviational ellipses decreases from 144.15° in 1995 to 142.46° in 2015. The demographic distribution rotation has a continuous change that is obviously north-westward;

the GDP standard deviational ellipse center is located in the north-west of the demographic, as the demographic moving trace continues to travel in that direction. This illustrates the attraction controlled by the demographic distribution given by a certain economic situation. Economic factors are especially important for migrant workers in the process of labor migration.

3.4 Economic spatial differentiation is on the decline

There is a contrast in the overlap area formed by the economic output SDE and the demographic distribution SDE, where an economic spatial differentiation evolution tendency can be observed. As shown in Figure 6, from 1995-2000 in Central and Eastern Europe, the standard deviational ellipse GDP and the demographic standard deviation ellipse created a larger and larger overlap area. As shown in Figure 7, during this same period, the distance between the economic ellipse barycenter and the demographic ellipse barycenter (shortened in waves), the spatial differentiation of GDP and the population distribution show an overall downward trend. This can be explained in terms of shortened distances. The demographic ellipse barycenter is moving towards the economic ellipse barycenter, which shows the natural law of population flowing to the intensive capital place. The GDP barycenter moving towards the population indicates that population migration provides abundant labor and a larger consumer market, which can stimulate economic vitality. After a series of measures, the economic and demographic ellipses of the reforming European Union system gradually converge, but so far, there still exists a large degree of differentiation for the standard devia-

tion ellipse, denoting a clear mobile trend in economic and demographic distributions.

The economy and demographic standard deviation ellipses indicate that the northwest boundary of the GDP ellipses is close to the boundary of population ellipses but still generates large differentiation in the southeast direction. The results show that the southeast countries in Central and Eastern Europe, including Romania and Bulgaria, have a high population and a large consumer market, which are unfortunately are not able to fulfil that role. As a result, there is considerable economic potential in these areas.

4. The main conclusions and policy recommendations

After institutional reforms, Central and Eastern European economic patterns suffered complex and diverse changes. The standard deviation ellipse method can reveal and visualize the changes in different ways. The Central and Eastern European economic spatial evolution mechanism provides a quantitative basis for the future, for both economic development as well as strategies for native land development, ensuring the effectiveness of the development strategy and target.

In comparing the standard deviation ellipses, the change in Central and Eastern Europe's demographic center is not so obvious. The lack of cash flow directly reflects the European labor migration feature, and to a large extent, it can also reflect the European nations' emotional dependence on their birthplace because of the language and cultural differences among European Union countries. It can also become one of the barriers for labor mobility. The demographic standard deviation ellipse moves only a short distance but with a strong regularity, shrinkage and direction to the west while year after year remaining close to the economic ellipse barycenter. Although labor mobility is influenced by social psychological factors, the drive of economic variables is also an important factor in the change in the labor force spatial distribution. In view of the present trend of population migration, countries at different stages of development need to adjust the corresponding policy according to their developing circumstances. Southeast countries, such as Romania and Bulgaria, should be particularly aware of their demographic surplus situation in the

Central and Eastern European area, taking into account that "labor outflow impact on regional economic performance has a significant nonlinear relationship with a 'U' shape", before reaching the peak. By studying a stimulated labor outflow, we can utilize new technology and new ideas, which can result in an active domestic market.

The Central and Eastern European economic barycenter moves towards the northeast, with an elongated distribution scale towards the north-south direction. The distance stretches larger and has obvious trends of getting close to the demographic distribution standard deviation ellipse. According to this trend, the future economy will continue to stretch along the north-south direction; therefore, more investments in southeastern European countries, such as Romania and Bulgaria, can be the most effective way to improve efficiency and development universally. Promoting the use of southeast surplus labor can reduce the unemployment rate and decrease the degree of economy and the demographic spatial differentiation. Countries such as Romania and Bulgaria, which are neighboring Asian countries and have a central location between Asia and Europe, should be able to make full use of capital investments from Asia. For example, they could actively participate in the "One belt and One Road" project, which is driven by China's government and taps into the existing potential of the transportation industry, processing industry, service industry and other labor-intensive industries to promote economic development with endogenous power. The project can make the area of Central and Eastern Europe a connection "between developed countries in the west and connect developing countries in the east" and promote a two-way drive development pattern.

There are two main policy recommendations that could be considered by the Romanian and Bulgarian governments and by other CEE countries. One is to access foreign investments from Western European countries, to develop strategies to determine the employment of the existing workforce and to stop its migration to the West. European Union funds should also be considered for the development of infrastructure. A second option, as we mentioned, is to access investments from other regions, such as the Asian market, especially China, to reindustrialize and create

sufficient jobs and economic growth. Romania could look for investments from the US as well because of its strategic position, long-term cooperation and contribution as part of the NATO.

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