POLYCENTRICITY MEASURES AND REGIONAL DISPARITIES

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Abstract
The concept of polycentric development at multinational, national and regional level is broadly used in academic research of regional development and spatial planning. It is also reflected in the normative agenda by the European Union. However, polycentricity has been considered a fuzzy concept, and it still lacks commonly accepted definition or measurement methods. Albeit a plethora of researchers and policy makers favors polycentric development as a tool for reduction of regional disparities, these statements are not based on empirical foundations. The research objectives are twofold and consecutive. The first objective is to define the morphological measures of polycentricity and apply these measures at country level. The second objective is to empirically test the following hypotheses: regional disparities in countries with polycentric urban system are less pronounced than in countries with monocentric urban system; income distribution in countries with polycentric urban system is more equal than in countries with monocentric urban system. The hypotheses stated by the objective of the study can be rejected: regional disparities in countries with polycentric urban system are not less pronounced than in countries with monocentric urban system; income distribution in countries with polycentric urban system is not more equal than in countries with monocentric urban system. The research results clearly suggest the polycentric development cannot be considered a tool for diminishing regional disparities and providing more cohesion between regions.

Key words: regional development, polycentricity measures, regional disparities, non-parametric tests.

Introduction
According to the European Union Treaty, the concept of territorial cohesion assumes fair access for citizens and economic operators to Services of General Economic Interest (SGEI), irrespective of the territory to which they belong. SGEI include important issues such as transport networks, energy and communications. Generally, cohesion means balanced distribution of human activities in territorial terms. The European Spatial Development Perspective (ESDP) was adopted by EU ministers responsible for spatial planning in 1999. One of the guidelines of ESDP is the promotion of polycentrism in the European Union. The concept of polycentrism is applied at community level, individual country level and regional level within the individual country. At community level, polycentrism means the establishing of alternative development centers to the existing ones, where the wealth and population are concentrated in a relatively small geographic areas. At national level, polycentrism means the development of interdependent networks of towns as alternatives to the large cities. At regional level, polycentrism means the integration of the rural areas with small and medium-sized towns. The promotion of territorial cohesion has to be based upon the improving the factors of competitiveness. The factors of competitiveness are constituted by the territorial imbalances besides the major imbalances in the EU, such as distribution of population and wealth and the geographical handicaps affecting certain areas. The imbalances identified are between centre and periphery at a larger, EU scale; gaps between towns in the centre and those in the periphery at a smaller, individual country scale; relationship between towns and the countryside with the growing suburbanisation of the countryside or even complete isolation of the most scarcely populated areas. Geographically handicapped areas include islands, peripheral mountain areas and the most remote regions with problems of market access and integration into their economic surroundings. Expanded capacity of research and innovation in the least-favored regions, improved accessibility via road, rail and air transport, improved telecommunications via broad-band networks are the main factors of competitiveness which could correct the identified imbalances. ESDP concludes that more polycentric regional shape provides more equal income distribution in the region. The idea of polycentricity as an important policy goal was supported in the “Territorial Agenda of the European Union” agreed in 2007. A guiding document for EU new cohesion policies prepared by Barca (2009) “An Agenda for a Reformed Cohesion Policy” stressed the role of networked polycentric regions in order to promote balanced territorial development and to overcome the disadvantages arising from big urban agglomerations. Research studies favoring polycentric development view network of evenly spread cities and towns as regional strength. Moreover, retained explicit centre - periphery division is considered a threat to a region. In many European countries, polycentric development is seen as a tool for diminishing regional disparities presumably created by monocentric urban system. Monocentric or polycentric urban systems
often are associated with divergence or convergence between the regions. The extent of regional disparities is considered lower in polycentric systems. Bacic and Sisinacki (2007) simply state that monocentric development of Croatia (the city of Zagreb) has produced more negative effects than positive ones without providing any empirical foundation of this or specifying these effects. Moreover, it is a priori assumed that Croatia is monocentric. Haite (2012) analyzes the performance of Latvian socio-economic indicators, such as GINI index, general unemployment level, GDP and poverty risk. Her study concludes that Baltic States in general, and Latvia in particular, are explicitly monocentric countries. A necessity of internal model of polycentric development in Latvia is stressed. Metropolitan planning in Copenhagen and Stockholm areas, on the contrary, is based upon the expectations of annual population increase in these capital cities over one per cent between now and 2030. Office of Regional Planning, Stockholm County Council (2010) in Stockholm’s regional plan assumes the metropolitan core alone cannot handle the anticipated growth, and focus is on seven or eight suburbs with relatively dense mix of jobs and housing. Municipal Plan, The City of Copenhagen (2011), on the other hand, focuses attention on increasing density and job growth in the city center area. Thus, the regional planning in these countries does not view faster metropolitan growth as a threat.

The concept of polycentricity can be analyzed either from morphological or functional perspective. The morphological approach is structural and it focuses on the coexistence of more than one urban center, usually ranked by their population. The functional approach is based upon the interaction measures which usually include the movement of people, goods and information. The present study deals with the morphological aspects of polycentricity.

The objective of the study is to empirically test the following hypotheses: regional disparities in countries with polycentric urban system are less pronounced than in countries with monocentric urban system; income distribution in countries with polycentric urban system is more equal than in countries with monocentric urban system.

**Materials and Methods**

Data on city sizes and their locations within the regions in 188 countries were retrieved from Thomas Brinkhoff’s online database which contains latest available information provided by governmental statistical institutions in every country. Using a larger number of countries to calculate the morphological measures would provide for a more unbiased scales in comparison with only 27 European countries used by Meijers and Sandberg (2006). Information on regional GDP per capita and regional unemployment was retrieved from OECD Statistical extracts database. Out of the 188 countries, data on GDP per capita in regions were available on 50 countries. Data on regional unemployment were available on 43 countries. The income disparities within a country are represented by GINI index. It is defined as follows (Gini, 1912):

$$\sum_{i=1}^{n} \sum_{j=1}^{n} |y_i - y_j|$$  \hspace{1cm} (1)

where n - sample size, $y_i$ - income of the i-th individual in the sample, $\bar{y}$ - arithmetic mean income of the sample. The Gini coefficient takes on values between 0 and 1 with zero interpreted as no inequality and one as total inequality. Data on GINI index were retrieved from The World Bank data collection. Data on GINI index were available on 158 countries.

For every country, data on the latest year available were retrieved for socio-economic variables.

The methods used by Meijers and Sandberg (2008) are applied with some adjustments. Regional disparities in a country can be evaluated by the coefficient of variance of socio-economic variables, such as GDP per capita and the level of unemployment. Coefficient of variance CV is calculated by the following formula:

$$CV(x) = \frac{\sigma(x)}{\mu(x)}$$  \hspace{1cm} (2)

where x - array of data, $\sigma(x)$ - standard deviation of x, and $\mu(x)$ - mean of x.

In every country, urban system is characterized by a spatial distribution of cities and relative sizes of cities with the largest population. Rank-size distribution or Zipf’s Law characterizes the regularity in the distribution of city sizes. In an individual country, ten largest cities are ranked according to their population. Both logarithms of the ranks and city sizes are calculated. The values of the logarithms of city sizes are regressed on logarithms of city ranks in regression equation:

$$y_i = ax_i + b$$  \hspace{1cm} (3)

where $y_i$ - decimal logarithm of i-th largest city in a country, $x_i$ - decimal logarithm of the rank of i-th largest city in a country, $a$ - regression slope, $b$ - regression intercept. If plotted on a diagram, regression line shows the “centricity” of the urban system. In monocentric countries line is steeper. In polycentric countries line is flatter. A single measure of rank-size distribution is the regression slope. Spatial distribution of cities over the country territory is measured by the spread of ranked largest cities across the regions in the country, where number of cities equals to the number of regions. A single measure of spatial distribution is...
the number of regions with at least one largest city divided to total number of regions. To compute the polycentricity score, a standardized scale has to be introduced depending on z-scores of both measures. Z-scores for i-th country are calculated by the following formula:

\[ Z = \frac{x_i - \mu}{\sigma} \]

where \( x_i \) - calculated measure for i-th country, \( \mu \)- mean of calculated measure for all countries, \( \sigma \) - standard deviation of calculated measure for all countries. A value of 100 is attributed to a z-score of 0. A value of 20 is attributed to standard deviation from mean. Standardized values of both measures are computed for every country. A single polycentricity score for the country i is calculated as an average of these two standardized values.

Results and Discussion

The regression slopes for rank-size distribution of cities and measures of spatial distribution of cities across the regions were calculated for 188 countries. The values of calculated regression slopes varied from -1.99 in Congo (the most pronounced dominance of the major city) to 0.49 in Malaysia (the least differences in the population of ten largest cities) (Figure 1).

The scores for spatial distribution varied from 0.29 in Argentina (concentration of the largest cities in a few regions in the country) to 1.00 in Iraq (at least one of the largest cities is located in every region). Distribution of cities in EU countries (excepting Malta) according to their in rank-size and spatial spread is shown in Figure 2. Countries with both marked dominance of major cities and uneven spatial distribution of cities are plotted at the lower left quarter of the diagram. Only Greece can be considered monocentric by both measures. Countries with marked dominance of major cities and more even spread of cities over the regions are plotted at the lower right quarter of the diagram. These countries include Baltic states, Hungary, Bulgaria, Slovenia, Czech Republic, Finland, Denmark, Austria and Ireland. Countries with less pronounced dominance of major cities and uneven spread of cities are plotted at the upper left quarter of the diagram. These countries include Portugal and Luxembourg. Countries that are polycentric by both measures are plotted at the upper right quarter of the diagram. These countries include Slovakia, Romania, Poland and Belgium. Germany, Cyprus, UK, Spain, the Netherlands, Sweden, Italy and France can be considered neither monocentric or polycentric by both measures.

Countries with both marked dominance of major cities and uneven spatial distribution of cities are plotted at the lower left quarter of the diagram. Only Greece can be considered monocentric by both measures. Countries with marked dominance of major cities and more even spread of cities over the regions are plotted at the lower right quarter of the diagram. These countries include Baltic states, Hungary, Bulgaria, Slovenia, Czech Republic, Finland, Denmark, Austria and Ireland. Countries with less pronounced dominance of major cities and uneven spread of cities are plotted at the upper left quarter of the diagram. These countries include Portugal and Luxembourg. Countries that are polycentric by both measures are plotted at the upper right quarter of the diagram.

Figure 1. Rank-size distribution of the largest cities in Malaysia and Congo.
Source: research findings, Brinkhoff (2012).
Figure 2. Rank-size distribution of the largest cities in Malaysia and Congo.
Source: research findings.

### Polycentricity scores and socio-economic variables of EU-27 countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Spatial distribution score</th>
<th>Rank-size score</th>
<th>Polycentricity score</th>
<th>GINI index</th>
<th>CV of regional GDP</th>
<th>CV of regional unemployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>110.7</td>
<td>79.9</td>
<td>95.3</td>
<td>29.1</td>
<td>0.20</td>
<td>0.42</td>
</tr>
<tr>
<td>Belgium</td>
<td>104.6</td>
<td>126.0</td>
<td>115.3</td>
<td>33.0</td>
<td>0.37</td>
<td>0.56</td>
</tr>
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<td>Bulgaria</td>
<td>124.5</td>
<td>98.6</td>
<td>111.5</td>
<td>45.3</td>
<td>0.42</td>
<td>0.60</td>
</tr>
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<td>Cyprus</td>
<td>89.4</td>
<td>119.1</td>
<td>104.3</td>
<td>29.0</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>120.2</td>
<td>96.7</td>
<td>108.4</td>
<td>18.8</td>
<td>0.38</td>
<td>0.40</td>
</tr>
<tr>
<td>Denmark</td>
<td>113.4</td>
<td>85.5</td>
<td>99.4</td>
<td>21.8</td>
<td>0.25</td>
<td>0.37</td>
</tr>
<tr>
<td>Estonia</td>
<td>97.4</td>
<td>79.0</td>
<td>88.2</td>
<td>36.0</td>
<td>0.48</td>
<td>0.52</td>
</tr>
<tr>
<td>Finland</td>
<td>119.4</td>
<td>94.0</td>
<td>106.7</td>
<td>26.9</td>
<td>0.18</td>
<td>0.43</td>
</tr>
<tr>
<td>France</td>
<td>88.3</td>
<td>109.3</td>
<td>98.8</td>
<td>29.1</td>
<td>0.36</td>
<td>0.43</td>
</tr>
<tr>
<td>Germany</td>
<td>84.9</td>
<td>115.9</td>
<td>100.4</td>
<td>28.3</td>
<td>0.23</td>
<td>0.44</td>
</tr>
<tr>
<td>Greece</td>
<td>85.9</td>
<td>73.1</td>
<td>79.5</td>
<td>34.3</td>
<td>0.24</td>
<td>0.42</td>
</tr>
<tr>
<td>Hungary</td>
<td>125.4</td>
<td>103.4</td>
<td>114.4</td>
<td>31.2</td>
<td>0.44</td>
<td>0.40</td>
</tr>
<tr>
<td>Ireland</td>
<td>107.4</td>
<td>77.1</td>
<td>92.2</td>
<td>34.3</td>
<td>0.36</td>
<td>0.17</td>
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<td>36.0</td>
<td>0.25</td>
<td>0.58</td>
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<tr>
<td>Latvia</td>
<td>117.4</td>
<td>88.6</td>
<td>103.0</td>
<td>35.7</td>
<td>0.52</td>
<td>0.18</td>
</tr>
<tr>
<td>Lithuania</td>
<td>125.4</td>
<td>85.3</td>
<td>105.3</td>
<td>37.6</td>
<td>0.38</td>
<td>0.30</td>
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<tr>
<td>Luxembourg</td>
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<td>22.9</td>
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<td>n.a.</td>
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<tr>
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<td>120.7</td>
<td>109.1</td>
<td>25.3</td>
<td>0.16</td>
<td>0.23</td>
</tr>
<tr>
<td>Poland</td>
<td>99.9</td>
<td>125.6</td>
<td>112.7</td>
<td>34.2</td>
<td>0.24</td>
<td>0.14</td>
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<td>Portugal</td>
<td>68.8</td>
<td>120.5</td>
<td>94.7</td>
<td>34.4</td>
<td>0.28</td>
<td>0.28</td>
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<tr>
<td>Romania</td>
<td>125.9</td>
<td>121.3</td>
<td>123.6</td>
<td>31.2</td>
<td>0.40</td>
<td>0.49</td>
</tr>
<tr>
<td>Slovakia</td>
<td>122.4</td>
<td>113.4</td>
<td>117.9</td>
<td>20.6</td>
<td>0.55</td>
<td>0.51</td>
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<tr>
<td>Slovenia</td>
<td>97.4</td>
<td>92.7</td>
<td>95.0</td>
<td>31.2</td>
<td>0.24</td>
<td>0.36</td>
</tr>
<tr>
<td>Spain</td>
<td>93.2</td>
<td>109.8</td>
<td>101.5</td>
<td>34.7</td>
<td>0.20</td>
<td>0.41</td>
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<tr>
<td>Sweden</td>
<td>97.4</td>
<td>112.6</td>
<td>105.0</td>
<td>25.0</td>
<td>0.12</td>
<td>0.15</td>
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<tr>
<td>UK</td>
<td>92.0</td>
<td>102.1</td>
<td>97.0</td>
<td>27.9</td>
<td>0.48</td>
<td>0.33</td>
</tr>
</tbody>
</table>

These countries include Slovakia, Romania, Poland and Belgium. Germany, Cyprus, UK, Spain, the Netherlands, Sweden, Italy and France can be considered neither monocentric nor polycentric by both measures. The values of polycentricity score ranged from 76.1 in Congo (the most monocentric country) to 123.6 in Romania (the most polycentric country). The median value of array of 188 countries is 99.7. Thus, of Baltic States only Estonia can be considered “explicitly” monocentric with polycentrity score of 88.2. Latvia and Lithuania scores 103.0 and 105.3, respectively. The dominance of Zagreb in Croatian city rank-size distribution is outweighed by rather even spatial distribution of cities, and Croatia can be considered polycentric with score of 106.5. The values of both measures for EU countries along with the values of respective socio-economic variables are shown in Table 1.

To test the null hypothesis H0: there is no significant relationship between the polycentricity score and selected socio economic variables, Spearman rank correlation coefficients Rho between polycentricity scores and corresponding values of coefficients of variance of regional GDP per capita, coefficients of variance of regional unemployment and GINI indexes were calculated. Computed values are provided in Table 2. The test results show that negative correlation between polycentricity score and GINI index in 158 countries is too low to be meaningful. Positive correlation between polycentricity score and coefficient of variance of regional unemployment level in 43 countries is too low to be meaningful. Positive correlation between polycentricity score and coefficient of variance of regional GDP per capita in 50 countries is low. None of the three computed Rho values exceed critical value. Null hypothesis cannot be rejected in each of three cases.

To further support the obtained results, the following null hypothesis H0: there are no significant differences in three variables between the countries with lower and higher polycentricity scores, was tested by Mann-Whitney U-test. For GINI index, data set of 158 countries was divided into two groups by median of polycentricity scores. For coefficients of variance of regional GDP per capita, data set of 50 countries was divided into two groups by median of polycentricity scores. For coefficients of variance of regional unemployment, data set of 43 countries was divided into two groups by median of polycentricity scores. Computed values for Mann-Whitney U-test are provided in Table 3. As the computed z-value does not exceed the critical value for the 5% confidence interval for all three variables, null hypothesis cannot be rejected.

The null hypothesis H0: there are no significant differences in socio-economic variables between countries divided into quartiles by polycentricity scores, was tested by Kruskal-Wallis test. For GINI

### Table 2

| Spearman Rank Correlation between polycentricity scores and socio-economic variables |
|-------------------------------|-------------|------------|--------------|
| Sample size                   | GINI index  | CV of regional GDP per capita | CV of regional unemployment |
| n=158                         | n=158       | n=50       | n=43         |
| Spearman’s Rho                | -0.096      | 0.230      | 0.064        |
| 2-sided p-value               | 0.230       | 0.108      | 0.682        |
| Rho critical value            | 0.156       | 0.279      | 0.301        |

Source: research findings.

### Table 3

| Mann-Whitney U-test results between polycentricity scores and socio-economic variables |
|----------------------------------------|-------------|------------|--------------|
| Sample size of the lower score         | GINI index  | CV of regional GDP per capita | CV of regional unemployment |
| n1=79                                  | n1=79       | n1=25     | n1=21        |
| Sample size of the higher score        | n2=79       | n2=25     | n2=22        |
| 2-sided p-value                        | 0.466       | 0.058     | 0.682        |
| Z computed value                       | 0.73        | 1.89      | 0.24         |
| Z critical value                       | 1.96        | 1.96      | 1.96         |

Source: research findings.
index, data set of 158 countries was divided into four quartiles of polycentricity scores. For coefficients of variance of regional GDP per capita, data set of 50 countries was divided into four quartiles of polycentricity scores. For coefficients of variance of regional unemployment, data set of 43 countries was divided into four quartiles of polycentricity scores. Computed values for Kruskal-Wallis test are provided in Table 4. As the computed z-value does not exceed the critical value for the 5% confidence interval for GINI index and variance of regional unemployment, null hypothesis for these variables cannot be rejected. For variances of regional GDP per capita, computed chi-squared value exceed the critical value for the 5% confidence interval and null hypothesis cannot be rejected. The alternative hypothesis H1: there exists marginal differences in variances of regional GDP between countries divided into quartiles by polycentricity scores, can be accepted.

Research results are in line with the findings of Meijers and Sandberg (2006) for the EU countries and Veneri and Burgalassi (2012) for Italian regions.

### Table 4

| Sample size of the 1st quartile | GINI index n1=40 | CV of regional GDP per capita n1=13 | CV of regional unemployment n1=11 |
| Sample size of the 2nd quartile | n2=39 | n2=12 | n2=10 |
| Sample size of the 3rd quartile | n3=39 | n3=12 | n3=11 |
| Sample size of the 4th quartile | n4=40 | n4=13 | n4=11 |
| P-value | 0.61 | 0.03 | 0.35 |
| Chi-squared computed value | 1.81 | 9.00 | 3.30 |
| Chi-squared critical value | 7.82 | 7.82 | 7.82 |

Source: research findings.

## Conclusions

1. The research results have not supported the existence of statistically significant differences in three socio-economic variables between countries with higher and lower polycentricity levels. Thus, higher polycentricity cannot be associated with less regional disparities.

2. Higher polycentricity score can rather be associated with more marked regional disparities in GDP per capita.

3. The hypotheses stated by the objective of the study can be rejected: regional disparities in countries with polycentric urban system are not less pronounced than in countries with monocentric urban system; income distribution in countries with polycentric urban system is not more equal than in countries with monocentric urban system.

4. The research results clearly suggest the polycentric development cannot be considered as a tool for diminishing regional disparities and providing more cohesion between regions.

## References


