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EVALUATION OF THE EUROPEAN UNION REGIONS CONVERGENCE REGARDING INNOVATION[1]

The paper presents an attempt to estimate sigma convergence (σ-convergence) occurring in the European space at NUTS 2 level with reference to innovation. Following sigma convergence hypothesis, assuming that the spatial diversification of European regional space for variables illustrating regional innovation presents a mitigating tendency, while in the distinguished, homogenous groups, regarding the level of attributes illustrating innovation, convergence processes will be much more noticeable than in the global regional space. The research objective was carried out in three stages covering Input and Output regional innovation indicators construction, classification of the European regional space into groups of regions with regard to values of Input and Output innovation indicators by means of positional statistics application, as well as measurement and estimation of sigma convergence processes at regional level.

The conducted analyses cover the period of 1999–2008, the research objects represent EU regions at NUTS 2 level (265 out of 271) and Eurostat data bases constitute the source of statistical data.

Keywords: innovation convergence, EU NUTS 2 regions

JEL: C 38, O 31, O 47, O 52

INTRODUCTION

European integration opens new opportunities for global European spatial development, both in the national and regional dimension. These opportunities are fundamentally dependent on a modern way of thinking, which facilitates innovation at different economy levels, i.e. enterprises, regions and metropolises. Convergence is one of crucial processes confirming the efficiency of certain activities carried out by creators and aimed at providing impulses for development. The article attempts to assess the convergence in regions of the European Union in terms of innovation. The discussion is limited to sigma convergence (σ-convergence) and an

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attempt to verify the assumption of an ongoing tendency towards balancing spatial diversification at NUTS 2 level regions (Regions, 2007) in EU countries with regard to innovation processes.

1. INTRODUCTION TO RESEARCH PROBLEMS

Convergence (Latin *convergere* – meet, unite) refers, in the economy, to the process aimed at reducing differences between entities featuring a diversified initial level of development. Convergence is understood in different ways. Frequently it is identified with macroeconomic convergence criteria included in the Maastricht Treaty (nominal convergence – convergence related to economies of other countries with reference to macroeconomic indicators, such as: inflation rate, interest rate (Michałek et al., 2007) and their dynamics (Malaga, 2004)). Another form of convergence is so called real convergence, i.e. actual processes observed in economies resulting in certain similarities of economies representing different areas of management (e.g. income level equalizing). There are numerous approaches to the problem of real convergence. It may be summarized that convergence is referred to as the phenomenon of national economies becoming similar in their level of growth called the level of equilibrium (Malaga, 2004; Fischer and Stirbock, 2006).

According to other authors, convergence reflects a long-term tendency towards equalizing income level per inhabitant or the size of production between rich and poor countries (Abramovitz, 1986; Rey and Montouri, 1999). The hypotheses referring to real convergence are most often presented from the perspective of neoclassical growth models: Solow-Swan or Mankiw-Romer-Weil models and endogenous growth (Rey and Montouri, 1999).

In economic theory, convergence is often defined as the process of approaching the steady state (β-convergence) by the economy. There are two types of β-convergence: absolute β-convergence, i.e. the one assuming that economies aim at obtaining the same state of equilibrium and relative β-convergence (it is assumed that economies converge at their individual states of equilibrium). Research is also conducted worldwide regarding economic phenomena dispersion in specified time periods and in defined groups of countries, which allows for distinguishing σ-convergence.

Another division, apart from distinguishing beta convergence which refers to balancing economic growth levels and informs about more dynamic growth of economies characterized by lower initial level of a given variable (e.g. GDP per capita, prices, costs, exchange rates), also recognizes sigma convergence which reflects shrinking differences within particular variables between certain regions (countries), and also gamma convergence referring to a situation when countries, regions and other studied entities change their ranking position regarding wealth in a specified time period (Wolszczak-Derlacz, 2007).

Convergence focused research applies different empirical strategies:

– based on time-series analysis – the most popular strategy (Cardenas and Ponton, 1995; Rey and Montouri, 1999; Terrasi, 1999; Malaga, 2004; Meliciani and Peracchi, 2006; Malaga and Kliber, 2007); allows for analyzing convergence in regions or countries in a specific time period,

– based on panel data, e.g. convergence of income level for such groups of countries as NONOIL, INTER, OECD (Islam, 1995).

The research on convergence is carried out at three spatial levels:

a) national, global (Baumol, 1986; Pritchett, 1997; Malaga, 2004),

b) regional (Barro and Sala-i-Martin, 1992; Carlino and Mills, 1993; 1996; Crown and Wheat, 1995; Malaga and Kliber, 2007; Olejnik, 2008),

c) local (Bukenya et al., 2002; Ying-Xia et al., 2005).

The literature also presents research-oriented sectors, consisting in e.g. convergence analysis of the salaries level in processing industry sectors in the analyzed countries (Socha and Wincenciak, 2007) or Gross Domestic Product convergence between eight sectors of the American economy (Barro and Sala-i-Martin, 1991).

While observing convergence processes in certain groups of countries economies, more and more often, take up the discussion regarding the so called convergence clubs. The concept of club convergence appeared at the beginning of the second half of the 1990s in studies by W. J. Baumol (Baumol, 1986), D. T Quah (Quah, 1993, 1996a, 1996b), S. N. Durlauf and P. A. Johnson (Durlauf and Johnson, 1995) and O. Galor (Galor, 1996). Following this concept countries (regions) featuring similar structural characteristics converge only if they are also similar with regard to their initial level of the analyzed characteristics (e.g. GDP per inhabitant). There are established groups of countries (regions) – clubs within which differences become smaller regarding the analyzed economic characteristic.

The analysis of convergence, both at the level of European Union regions and inside EU member states, has not yet confirmed the occurrence of economic convergence or divergence phenomena explicitly (see Barro and Sala-i-Martin, 1991; Barro and Sala-i-Martin, 1996a, 1996b, 2003; Gawlikowska-Hueckel, 2002; Gianetti, 2002; Quah, 1996a, 1996b, 1993).

Absolute beta convergence and sigma convergence at regional level have also not been observed in the research conducted by Polish authors.

Among interesting studies recognized as major input in the discussed subject matter in Polish literature, there are following publications worth mentioning. Gajewski et al (2004) reported that in recent years even divergence tendencies have been noticed, Wójcik (2008) found that between 1995 and 2006 both convergence and divergence tendencies were observed in Polish regional space. Tokarski et al (1999) reported β-conditional convergence in their research of the period between 1995 and 1999. Malaga (2004) examined sigma and beta unconditional and conditional convergence in OECD countries using aggregated growth models. D. Hübner – analyzed sigma convergence for EU countries based on GDP per capita variation coefficient (Hübner, 2004a, 2004b). Piech (2008) carried out research at both national and regional level with reference to Polish regions and analyzed the convergence of EU funds influence by means of HERMIN model (Piech, 2007) and MaMoR2 model (Kaczor, 2006). Kliber (2007) analyzed the problem of regional disproportions in Poland based on regional wealth growth factors such as capital and technical advancement. Bal-Domańska (2009a, 2009b, 2010a, 2010b, 2010c) analyzed sigma and beta conditional convergence in classes of NUTS 2 level regions of the European Union member states in the periods 1999-2004 and 1999-2007.

Among regional analyses referring to European space the results published in studies by Markowska and Strahl (2003) should be mentioned, since they focused on innovation related convergence estimation. The research was conducted in the following groups of regions: regions from the "old" 15 member states and regions from countries after the 2004 accession distinguished by industry and service oriented sectors. Research results allowed for concluding that in the analysed groups of countries interregional disproportions at NUTS 2 level become less noticeable, however, the EU accession generally weakened, for a short time, the rate of convergence. In the presented classes of regions where the share of workforce in market services sector or the share of workforce in industry were the dominating ones the interregional disproportions were observed to have grown smaller, along with increasing the maximum and minimum values of the studied innovation characteristics.

The article attempts at the continuation of the research mentioned and also at the integration of sigma convergence processes estimation in groups of regions distinguished, on the one hand, in relation to the EU integration process including EU 15 states, and on the other by distinguishing homogenous groups of regions with regard to tendencies in measures of regional innovation indicators.

2. RESEARCH PROCEDURE

European space is divided within the framework of the Nomenclature of Territorial Units for Statistics NUTS (Regions, 2007) into the following levels: NUTS 0 (27 countries), NUTS 1 (97 units) and NUTS 2 (271 regions).

The estimation of sigma convergence processes related to innovation at NUTS 2 level regions in European regional space was carried out in line with the following research stages:

– stage 1 – proposition of Input and Output regional innovation indicators,

– stage 2 – classification of European space, using order statistics application, into groups of regions with reference to tendencies of Input and Output innovation indicators values,

– stage 3 – sigma innovation convergence measurement at regional level.

2.1. Regional innovation indicators in the perspective of Eurostat

The sets of indicators prepared by the European Commission and aimed at illustrating important strategic areas (*Research Scoreboard, Enterprise Scoreboard, Innovation Scoreboard* and *Structural Indicators*), constituted the data source for Scoreboards. *European Innovation Scoreboard 2008* covered data referring to 29 indicators regarding innovation processes functioning in each member state (Arundel and Hollanders, 2006; European Innovation Scoreboard 2005; Hollanders, 2006a, 2006b; Hollanders et al., 2009).

It should be mentioned that in order to estimate innovation at national level another proposal was prepared, namely *Innovation Union Scoreboard 2011* and *Innovation Union Scoreboard 2012* indicators (Innovation Union Scoreboard, 2011, 2012). The list from 2009 was substituted in IUS 2010 set by a new one covering 25 indicators which, resulting from earlier criticism (Hollanders and van Cruysen, 2008), are supposed to capture the overall results of national research systems and innovation much more explicitly.

The abundant research conducted so far on preparing the list of indicators illustrating innovation at regional level has been comprehensively presented in studies by the team concentrated around Pro Inno Europe InnoMetrics. It was agreed that national level indicators are also to be applied at regional level, depending on statistical data collecting possibilities. Values of the regional innovation indicator, within the framework of RIS 2009, were calculated by means of applying adequate weights for particular groups of indicators. The following indicators were accepted for the purposes of *Regional Innovation Scoreboard 2009* specification (Hollanders et al., 2009):

1. innovation stimulators (4 indicators):

– human resources:

1.1. percentage of university graduates aged 25-64,

1.2. share in life-long learning per 100 people aged 25-64,

– financing and support for innovation:

1.3. share of public expenditure on R&D in GDP (in %),

1.4. broadband access to the Internet (as % of total households),

2. enterprises activities (5 indicators):

– investments:

2.1. share of enterprises expenditure on R&D in GDP (in %),

2.2. share of companies expenditure on innovation other than R&D in total expenditure,

– external relations and entrepreneurship:

2.3. share of SME implementing their own innovations in the total number of SME,

2.4. share of SME cooperating in innovation activities in the total number of SME,

– intermediary effects:

2.5. number of patents granted by EPO per 1 million of population,

3. enterprises performance results (7 indicators):

– innovators:

3.1. technological innovators (innovations related to products, services, processes) as % of total SME number,

3.2. non-technical innovators (marketing, organizational innovation) as % of total SME number,

3.3. innovators in company resources efficiency (mean of two indicators):

3.3.1. number of innovative companies responding that their innovative product or process exerted crucial influence on cutting labour costs per production unit as % of all enterprises,

3.3.2. number of innovative companies responding that their product or innovation process had a very important influence on cutting materials and energy consumption per production unit as % of all enterprises,

– economic effects of innovation – results:

3.4. share of workforce in mid-high and high-tech sectors in the total number employed in industry and service sectors, 3.5. share of workforce in services based on expert knowledge as % of total workforce,

3.6. share of new or modernized (marketwise) products' sales in total sales,

3.7. share of new or modernized (for enterprises) products' sales in total sales.

The study presents research covering only 265 out of 271 NUTS 2 level regions from EU countries due to the lack of complete data for four French overseas regions (Guadeloupe, Martinique, Guyane, Réunion) and two Spanish ones (Ciudad Autónoma de Ceuta, Ciudad Autónoma de Melilla). It was assumed that innovation processes may occur at different rate and therefore two innovation profiles were considered. Input type innovation, which illustrates regional input into innovative activities, and Output type innovation, which shows the effects accomplished as the consequence of incurred expenditure. Such diversification is based both on the applied research approaches and on the statistical data collecting system.

Among many approaches, which also consider Input and Output presentations may be listed:

1. While working on Global Innovation Index (GII) (Global, 2007, 2008, 2010) it was assumed that there is a distinction between an initial contribution, the component allowing for innovative activities to be stimulated by economy (Input) and the effect, i.e. the result of innovative activities within economy (Output), accompanied by innovation measurement in economy.

2. Economist Intelligence Unit Report (Innovation, 2007) defines innovation as "knowledge application in an innovative way, mainly for the purposes of obtaining economic profits" for the estimation of which two indices were calculated: innovation activities index and innovation input index.

3. NESTA organization (National Endowment for Science Technology and the Arts) suggested to define innovation as (First, 2010) "a change resulting from creating and adapting ideas which are new for the world, new for the country/region, new for industry, or new for a company". The underlying indicators were divided into the following categories: Input (innovative input regarded as activities taken up by the region, which facilitate innovation practices and establish the climate for innovation and entrepreneurship), relations (refer to indicators measuring all factors responsible for bringing people together, or economic units involved in innovation, including their cooperation and supporting infrastructure

aspects) and Output (refers to these indicators which reflect the scope of success obtained as the result of innovative practices implementation regardless of whether they are patent applications, forms implementing new products and processes, innovative knowledge or long-term change in Gross Value Added *per capita*).

4. In the process of National Innovation Initiative work (Innovate America, 2005) 7 components were recognized within the innovation Input block in regional environment: human capital (10 variables), research and development (2), financial indicators of capital (2), metrics of industrial base (2), infrastructure (2), legal environment regulators (4), life quality (3); and within the framework of Output block: ideas generation (1), ideas development (4), commercialization (2), productivity (1), welfare (6).

5. In other American research and analyses the possibility of regional innovation measurement was also noticed. The Tri-Cities (Tri-Cities 2004) project is carried out, including one of its presentations (Regional Innovation Index^{TM} project) prepared in cooperation with employees of such institutions as Science Academy, Universities, The House of Representatives, banks of ideas, scientific and research organizations and companies, and is related to Input-Output indicators based approach.

Referring back to Eurostat approach it should be indicated that out of indicators applied for the purposes of innovation estimation, within the framework of RIS, half of them referred to data from CIS (Community Innovation Survey) studies, i.e. surveys conducted in companies, however, not covering all EU member states and also with regard to selection algorithm referring to companies structure at national level therefore the results, only to a small extend may be transferred to NUTS 2 level and besides many of the indicators were not available for a significant number of regions (slightly less than 70% and therefore Eurostat analysis does not even refer to 200 out of 271 EU regions). It should also be pointed out that RIS study covers a one year period and data for RIS 2009 were collected in 2006 for 13 indicators, in 2005 for 2 indicators and in 2003 for one indicator (referring to patents).

The research presented in this paper refers to the European Union NUTS 2 level regions in a dynamic perspective, and even though within the framework of analyses carried out by Eurostat for NUTS 2 level regions 16 qualities were identified, it has to be pointed out that some of them result from surveys conducted as part of CIS (for listed by Eurostat indicators 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 3.6, 3.7, i.e. 50% of all) which reduces their availability in many countries and raises doubts about their application at the level of regions due to the need of unestimating them (it is also doubtful which criterion to apply). Additionally, many of the suggested data are available only at the country or NUTS 1 level and also if they are available at all, they are still unavailable for the majority of NUTS 2 level regions.

We suggest an approach in which data cover a 10-year period (1999-2008). Based on full data series availability (or ability to handle missing values), for the purposes of EU regions innovation analysis in a dynamic perspective, the listed below innovation characteristics were indicated:

Input type of innovation indicators:

– LLL – share of population aged 25-64 participating in life-long learning in a region,

– HRST – human resources in science and technology are people who fulfil one or other of the following conditions: successfully completed education at the third level in an S&T field of study or not formally qualified as above but employed in a S&T occupation where the above qualifications are normally required,

– EDUC – share of employed university graduates in the total workforce number in a region.

Output type of innovation indicators:

– MHTMANUF – workforce employed in high and mid-tech industry (as % of workforce),

– KIS – workforce employed in knowledge-intensive services (as % of workforce),

– EPO – patents registered in the European Patent Office.

Input and Output indices values – composite measures calculated as mean average of normalized, by means of zero unitarization method, innovation characteristics (Strahl, 1978) are included in the range of [0, 1]. Both indices allow for ranking regions by regional innovation level in the European scale with regard to outlays on innovation and innovation effects.

2.2. Classification of the European regional space into groups of regions with reference to tendencies of Input and Output innovation indicators

Positional classification method was selected from an abundant set of classification methods – since it provided the possibility of making direct comparisons based on classification results in specified moments of the study, but also owing to its estimation attributes related to the obtained classes of studied objects – positional classification method suggested by D. Strahl (Strahl, 2002; Markowska and Strahl, 2003). Attention should also be paid to the fact that this method defines classes and their properties, which turns out a useful approach while conducting analyses and comparisons in a dynamic perspective.

Considering the dynamic nature of convergence processes, estimation, a two-step European regional space positional classification method was applied.

The set of hierarchical objects was defined $P = \{P_1, P_2, \ldots, P_n, \ldots, P_N\}$ with sets of lower rank – p objects included, i.e.:

$$P_n = \{p_1^n \cup p_2^n \cup \ldots p_K^n\}, \tag{1}$$

where: p_k^n – lower rank k-th object ($k = 1, \ldots, K$) in n-th hierarchical object ($n = 1, \ldots, N$).

In the hereby study the EU countries represent hierarchical objects, while EU regions at NUTS 2 level represent lower rank objects, each of which is described by matrix of measures illustrating Input and Output innovation.

The suggested classification procedure refers to two examples. In the first one classification algorithm results in constructing, for each $t = 1, \ldots T$, $(m+1)$ moment, the classes marked by S_g symbol, where $g = 1, \ldots, G$ ($G = m+1$) when sets are described by m-variables. In the second case classification algorithm results in the construction of 2^m (i.e. $G = 2^m$) classes of possible combinations from m-variables for each $t = 1, \ldots T$ moment.

Let's discuss the ***first case***:

Regions from P_k set are included in the class S_1^t (for $t = 1,2,\ldots,T$) where values of all X_j^t i.e. m-variables are higher than the defined positional statistics (in the suggested procedure this statistics is represented by median (Me)).

●1° Therefore:

$$\forall\, j = 1,\ldots,m \;\; x_{kj}^t \geq Me\; x^t. \tag{2}$$

●2° Class S_2^t includes regions from P_k set, which values, of only $(m–1)$ variables, meet the following condition:

$$x_{kj}^{1t} \geq Me\; x^t \quad for \quad P_k \notin S_1^t. \tag{3}$$

●m° Class S_g^t ($g = m$) includes regions from P_k set for which the value of only X_j^t variable, from X set, meets condition (3).

●$(m+1)$° Class S_{g+1}^t ($g = m+1$) includes regions for which x_{kj}^t value of none X_j^t variable meets condition (3).

Second case:

●1° Class S_1^t for t = 1,2,…,T) covers these lower rank objects for which all m values of X_j^t variables meet the following condition:

$$x_{kj}^t \geq Me\ x^t \quad (4)$$

●2° Class S_2^t covers these lower rank objects for which only values of (m-1) variables constructing one of $\binom{m}{m-1}$ variables combinations meet condition (4).

●3° The third S_3^t class covers these lower rank objects for which variables values of the following combination, made up of (m – 1) elements, meet condition (4).

After using all (m–1) element combinations, the classes for (m – 2) element combinations are constructed and condition (4) is put forward.

●2^m Class S_g^t ($g = 2^m$) covers these lower rank objects for which x_{kj}^t values of all X_j^t variables do not meet condition (4).

Both cases refer to completely different classification assumptions; in the first one the same importance is assigned to all variables and classes of objects are distinguished only by means of the number of variables which meet the set conditions, while in the second case groups of objects are distinguished by identifying these variables which meet the defined classification conditions. D. Strahl's method becomes particularly useful in classification if a given phenomenon is described by means of several qualities. However, it seems difficult to apply if the number of features is large.

3. CONVERGENCE MEASUREMENT RELATED TO SIGMA INNOVATION AT REGIONAL LEVEL

The plane defined by aggregate Input and Output measures represents a classification space. The first level classification was performed for 265 European regions which allowed for constructing the following classes of regions. The classification procedure was repeated for each moment t = 1,2, …, T under study:

– 1 – regions with Input and Output measures assuming values bigger than median,

– 2 – regions which registered Input measure values higher than the median and Output measure values lower than the median,

– 3 – regions which registered Output measure values higher than the median and Input measure values lower than the median,

– 4 – regions which registered Input and Output measure values lower than the median.

At the second level of classification the following classes were constructed:

class 1 – covers regions which experienced Input and Output measure values higher than the median in each analyzed year (1999-2008) – innovative regions,

class 2 – covers regions which registered Input measure values higher than the median and Output measure values lower than the median in each analyzed year – innovative regions regarding innovation outlays,

class 3 – covers regions which registered Output measure values higher than the median and Input measure values lower than the median in each analyzed year – regions presenting significant results regarding innovation,

class 4 – covers regions which in the period of 1999-2008 experienced different tendencies related to Input and Output measure values regarding the median value – this class includes regions which were not listed in any of the other classes, i.e. class 1, 2, 3 and 5,

class 5 – covers regions which did not register Input and Output measure values higher than the median in any of the analyzed years (1999-2008).

As the result of the conducted two-stage classification, the classes of regions presented in tables 1 and 2 were obtained.

The classes at the opposite extremes are the most numerous ones, i.e. class 5 which includes 80 European regions and covers 30.2% of the analyzed regions total number, where Input and Output regional innovation values were not higher than the median in any of the studied years. Class 1, made up of 72 regions, included these regions which may be regarded as innovative since both Input and Output regional innovation indicator values in each of the studies years (1999-2008), were permanently higher than the median values. Classes 2 and 3 are smaller. About 14.7% of all European regions presented persistent, above the median, ranking position regarding values of Input regional innovation indicator. On the other hand, the regions included in class 3 (12.8% of all regions) always registered higher than the median values of Output regional innovation indicator in each analyzed year. Therefore, these are the regions accomplishing significant effects in the field of innovation.

While analyzing regions included in particular classes and countries it has to be emphasized that class 1 (i.e. the class covering regions which registered Input and Output measure values higher than the median in each year of analysis; innovative regions) includes regions from 7 countries and these are only the old 15 member states, i.e. Belgium, Germany, Denmark, Finland, France, The Netherlands and Sweden (all regions) and also Great Britain.

The 2nd class covers regions from 13 countries, however, apart from the old 15 member states there are also regions from the recent accessions which took place after 2004: Bulgaria, The Czech Republic, Estonia, Hungary, Slovenia and Slovakia. Class 3 includes regions from 6 countries only, which proves that the concentration by countries is definitely more important in this particular class, where only one Hungarian region was included together with the old 15 ones. Class 5, covering regions which do not present innovative attributes, includes regions from as many as 15 countries, also the old 15 ones, where 14 out of 21 Italian regions are listed, two Austrian regions and 2 Spanish ones. Having analyzed regional structure by classes and countries it becomes noticeable that the majority of class 1 regions, i.e. innovative ones, are listed in Sweden (all regions), Denmark and Finland.

More than half of class 1 regions, apart from the already mentioned countries, are also listed in Belgium, The Netherlands and Great Britain. All Belgian regions are included in innovative classes, in the case of Austria it is only 3 regions out of 9, while over 90% of German and French regions are covered by pro-innovative classes.

The results for Italy are quite poor because only 7 of its regions are included in pro-innovative classes. Very poor results are observed in Portugal, since all its regions are included in class 5, but also in Poland, Romania and Greece where all regions are listed in class 5, apart from just one region (including the capital city). Class 5, as has already been mentioned, includes regions characterized by Input and Output regional innovation indicators which did not present values higher than the median in any of the analyzed years within the 10 year period. While reviewing the list of regions included in table 2 it should be noticed that capital regions most often take better ranking positions than the other regions in a given country. Class 1 and 2 list 8 capital regions each, class 3 only Vienna, class 4 covers 7 capital regions and class 5 three of them (Malta, Lisbon and Lazio in Italy).

4. MEASUREMENT OF SIGMA CONVERGENCE IN INNOVATION IN THE EUROPEAN REGIONAL SPACE AND IN THE CLASSES OF REGIONS

It has been assumed that a convergence analysis of economies should be performed in a long-run perspective with GDP *per capita* as the measure of country or region economic growth estimation and, in general, this measure is also applied for sigma convergence phenomenon assessment, i.e. the diversification level of a group of countries or regions development.

Dispersion measure represents the analytical tool for measuring convergence of this type – natural logarithm standard deviation of these measures in the analyzed $t = 1,2, \ldots, T$ moments. Sigma convergence in innovation occurs when in the consecutive observation moments of a particular property illustrating the phenomenon subject to convergence estimation (e.g. regional innovation), natural logarithm standard deviation of the analyzed objects (groups of objects) are characterized by a downward tendency. In our research the natural logarithm standard deviation formula of Input and Output innovation measures takes the following form (5):

$$S_t^r = \sqrt{\frac{\sum_{i=1}^{k} (\ln y_{it}^r - \ln \bar{y}_t^r)^2}{k}}, \tag{5}$$

where: i – regional index (for $i = 1, \ldots, k$),
r – innovation measure number ($r = 1, 2$)

y_{it}^r – logarithm value of r-th innovation measure in i–th region in year t,

$\bar{y}_t^r$ – logarithm average level of r-th measure in the analyzed group of regions in year t.

If the formula (6) is satisfied that there is a phenomenon of sigma convergence in innovation.

$$\forall\ t_1, t_2 \in T:\ t_2 > t_1, \quad S_{t_1}^r > S_{t_2}^r \tag{6}$$

Values of natural logarithm standard deviations referring to calculated indicators of both Input and Output regional innovation for particular regions covered by the distinguished classes illustrate quite diversified tendencies. Fluctuations of the accepted interregional dispersion measure values are quite noticeable, which suggests the occurrence of both convergence and divergence processes (see table 3).

The EU NUTS 2 level regions are evaluated with regard to Input and Output innovation in the following groups:

– globally – EU 27 – all 265 regions for which data were available,

– EU 15 regions – 209 “old” EU regions,

– EU 12 regions – 56 regions from countries of the recent two accessions.

As may have been noticed, divergence and convergence tendencies are quite visible in the regions of the EU member states. However, it may be stated that in recent years the decreasing tendency in interregional differences regarding Input and Output regional innovation indicator values, in global European regional space and in the old 15 counties, was experienced. In the case of countries integrated with the EU after 2004, a noticeable increase in interregional differences was observed regarding both Input and Output innovation indicators, represented by the variation measure values (natural logarithm standard deviation of Input and Output regional innovation indicator).

It has to be emphasized that natural logarithm standard deviation highest values of Input and Output regional innovation indicator occurred in class 5, i.e. the class concentrating regions in which case values of measures illustrating Input and Output innovation were not higher than the median in any of the analyzed years. In class 1 and 3, however, dispersion measure values are lower for both Input and Output innovation indicators (see table 4 and fig. 1 and 2).

Therefore it may be inferred that regional diversification is higher in the class grouping regions of pro-innovative orientation. Generally while analyzing values of dispersion measure and its dynamics, it may be assumed that convergence is more difficult to accomplish in regions focused on innovation related effects.

The next step of the study consisted in calculating the variation coefficient (VC) values of Input and Output regional innovation indicators as the ratio of standard deviation to mean value in the group, and also the (max/min) range as the ratio of maximum measure value to its minimum value in the group which has been illustrated in table 5.

The basic characteristics of Input regional innovation indicator variation allow for concluding that convergence processes are noticeable in the studied period. In spite of the growing distance between regions presenting extreme values of regional innovation indicator in the case of both global European space, as well as in the regions of the old 15 and 12 countries of 2004 accession, the variation coefficient value indicates that the average deviation of an indicator value from the mean value is slightly smaller in all the distinguished groups of regions, however, it is most visible in the regions of the old 15 countries.

On the other hand, while analyzing variation measures for Output regional innovation indicator, it was noticed that the spread between regions in EU global space measured by range keeps growing but the variation coefficient presents a slightly decreasing tendency. In the case of the EU 15 regions, the spread between regions keeps fluctuating and the variation coefficient presents a stable level. The regional spread in EU 12 regions shows a small upward trend, but the variation coefficient value is slightly lower.

In the classes of regions it was observed that the highest spreads between Input regional innovation indicator values occur in class 5 and the lowest in class 2. These spreads, in a 10-year period, became smaller only in classes 3 and 4 and grew significantly bigger in class 5. However, variation coefficient values are stable in class 1 and 5 and slightly smaller in class 2, but became higher in class 3. Therefore convergence processes are not noticeable in the group of regions characterized by a persistent tendency in presenting lower than Weber's median values of Input regional innovation indicators values.

The output regional innovation indicator spread decreased in classes 2, 3, 4 and increased in classes 1 and 5 with a relatively significant upturn in class 5. With reference to variation coefficient values, in the course of the analyzed 10-year period slight fluctuations were registered (major ones in class 3), but the decreasing trend in average variation between regions in classes 1 and 5 became quite noticeable and were accompanied by a growing distance between regions presenting minimum and maximum values of Output regional innovation indicator.

The significance analysis of trends in natural logarithm standard deviations (see fig. 1 and 2) presents unique results. Insignificant trends usually have p values definitely higher, not only than 0,05, but also than 0,10. The significant diversification trends are characterized by:

– growing diversification in O1 ($p = 0.0136$, $R^2 = 0.5$)

– decreasing diversification in I3 class ($p = 0.0491$, $R^2 = 0.33$)

– parabolic trend in I5 class (diversification growth since 2003, later decrease) which may be explained, among others, by the influence of pre-accession funds. At the same time smaller support was provided for the poorer EU 15 regions (e.g. Greece, Italy, or Portugal).

In other variation characteristics, no significant trends were observed.

CONCLUSIONS

In the analyzed period (10 years, 1999-2008) the decreasing tendency regarding differences between regions in the global European space and in the old 15 countries was observed with reference to values of Input and Output regional innovation indicators values, and was accompanied by a sharp increase of spread between regions presenting extreme values of indicators. It was only in the case of the 2004 EU accession countries that a noticeable growth of differences between regions for both Input and Output innovation indicators was registered and confirmed by variation measure values (natural logarithm standard deviation of Input and Output regional innovation indicator). It was accompanied by a moderate spread growth between the extreme regions with regard to the analyzed phenomenon. However, in the case of the distinguished regional classes, Input and Output innovation convergence was observed in four out of five classes, i.e. in class 2, 3, 4 and 5. As far as class 1, concentrating regions characterized by a persistent tendency for pro-innovative performance is concerned, it was noticed that the differences between regions, measured by variation coefficient and natural logarithm standard deviation from the calculated indicators, were higher and the spread between regions presenting extreme Input and Output values of regional innovation indicators was bigger.

The practical use of the results of analyzes may be related to the EU regional policy, the policy of the regions of individual countries, modification of the Regional Innovation Strategy, the designation of institutional norms in the field of regional innovation.An interesting continuation of the study may be the presented analysis of the impact level of innovation in different regions where sigma real convergence occurred. For this purpose, the concept of conditional convergence can be used, in which the role of control variables would have the indicators assessing costs and effects of innovation.

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APPENDIX

Table 1

Number of regions in classes

Country	Total number of regions	Number of regions in a class				
		1	**2**	**3**	**4**	**5**
Austria	9			3	4	2
Belgium	11	7	3	1		
Germany	39	15	5	16	3	
Denmark	5	5				
Spain	17		5		10	2
Finland	5	4	1			
France	22	3		6	11	2
Greece	13				1	12
Ireland	2				1	1
Italy	21			6	1	14
Luxemburg	1			1		
The Netherlands	12	7	5			
Portugal	7					7
Sweden	8	8				
Great Britain	37	23	13		1	
Bulgaria	6		1			5
Cyprus	1		1			
The Czech Republic	8		1		3	4
Estonia	1		1			
Hungary	7		1	1	1	4
Lithuania	1				1	
Latvia	1				1	
Malta	1					1
Poland	16				1	15
Romania	8				1	7
Slovenia	2		1			1
Slovakia	4		1			3
Total (%)	**265 (100%)**	**72 (27.2%)**	**39 (14.7%)**	**34 (12.8%)**	**40 (27.2%)**	**80 (30.2%)**

Source: authors' calculations

Table 2

Regions in classes of regions

Class (number of regions)	Country (number of regions)	Regions
1 (72)	BE (7), DK (5), DE (15), FR (3), NL (7), FI (4), SE (8), UK (23)	**Région de Bruxelles** (BE), Prov. Antwerpen (BE), Prov. Limburg (BE), Prov. Oost-Vlaanderen (BE), Prov. Vlaams Brabant (BE), Prov. West-Vlaanderen (BE), Prov. Brabant Wallon (BE), **Hovedstaden** (DK), Sjælland (DK), Syddanmark (DK), Midtjylland (DK), Nordjylland (DK), Stuttgart (DE), Karlsruhe (DE), Freiburg (DE), Tübingen (DE), Oberbayern (DE), Mittelfranken (DE), **Berlin** (DE), Bremen (DE), Hamburg (DE), Darmstadt (DE), Gießen (DE), Hannover (DE), Köln (DE), Rheinhessen-Pfalz (DE), Dresden (DE), **Île de France** (FR), Midi-Pyrénées (FR), Rhône-Alpes (FR), Groningen (NL), Gelderland (NL), Utrecht (NL), **Noord-Holland** (NL), Zuid-Holland (NL), Noord-Brabant (NL), Limburg (NL), **Etelä-Suomi** (FI), Länsi-Suomi (FI), Pohjois-Suomi (FI), Åland (FI), **Stockholm** (SE), Östra Mellansverige (SE), Småland med öarna (SE), Sydsverige (SE), Västsverige (SE), Norra Mellansverige (SE), Mellersta Norrland (SE), Övre Norrland (SE), Tees Valley and Durham (UK), Northumberland, Tyne and Wear (UK), Cheshire (UK), Merseyside (UK), Derbyshire and Nottinghamshire (UK), Leicestershire, Rutland and Northants (UK), Herefordshire, Worcestershire and Warks (UK), Shropshire and Staffordshire (UK), West Midlands (UK), East Anglia (UK), Bedfordshire, Hertfordshire (UK), Essex (UK), **Inner London** (UK), **Outer London** (UK), Berkshire, Bucks and Oxfordshire (UK), Surrey, East and West Sussex (UK), Hampshire and Isle of Wight (UK), Kent (UK), Gloucestershire, Wiltshire and Bristol (UK), Dorset and Somerset (UK), East Wales (UK), Eastern Scotland (UK), South Western Scotland (UK)
2 (39)	BE (3), BG (1), CY, CZ (1), DE (5), EE, ES (5), FI (1), HU (1), NL (5), SI (1), SK (1), UK (13)	Prov. Liège (BE), Prov. Luxembourg (BE), Prov. Namur (BE), **Yugozapaden** (BG), **Cyprus** (CY), **Praha** (CZ), Brandenburg - Nordost (DE), Brandenburg – Südwest (DE), Chemnitz (DE), Leipzig (DE), Thüringen (DE), **Estonia** (EE), Pais Vasco (ES), Comunidad Foral de Navarra (ES), Aragón (ES), **Comunidad de Madrid** (ES), Castilla y León (ES), Itä-Suomi (FI), **Közép-Magyarország** (HU), Friesland (NL), Drenthe (NL), Overijssel (NL), Flevoland (NL), Zeeland (NL), **Zahodna Slovenija** (SI), **Bratislavský kraj** (SK), Cumbria (UK), Greater Manchester (UK), Lancashire (UK), East Yorkshire and Northern Lincolnshire (UK), North Yorkshire (UK), South Yorkshire (UK), West Yorkshire (UK), Cornwall and Isles of Scilly (UK), Devon (UK), West Wales and The Valleys (UK), North Eastern Scotland (UK), Highlands and Islands (UK), Northern Ireland (UK)
3 (33)	AT (3), BE (1), DE (16),	**Wien (AT),** Oberösterreich (AT), Vorarlberg (AT), Prov. Hainaut (BE), Kassel (DE), Niederbayern (DE), Oberpfalz (DE), Oberfranken (DE), Unterfranken (DE), Schwaben (DE), Braunschweig (DE), Lüneburg (DE), Weser-Ems (DE), Düsseldorf (DE), Münster (DE), Detmold (DE), Arnsberg (DE), Koblenz (DE), Saarland (DE),

	FR (6), HU (1), IT (6),	Schleswig-Holstein (DE), Haute-Normandie (FR), Centre (FR), Basse-Normandie (FR), Lorraine (FR), Alsace (FR), Franche-Comté (FR), Közép-Dunántúl (HU), Piemonte (IT), Valle d'Aosta (IT), Lombardia (IT), Veneto (IT), Friuli-Venezia Giulia (IT), Emilia-Romagna (IT)
4 (41)	AT (4), CZ (3), DE (3), ES (10) FR (11), GR (1), HU (1), IE (1), IT (1), LT, LU, LV, PL (1), RO (1), UK (1)	Niederösterreich (AT), Kärnten (AT), Steiermark (AT), Salzburg (AT), Strední Cechy (CZ), Jihozápad (CZ), Severovýchod (CZ), Mecklenburg-Vorpommern (DE), Trier (DE), Sachsen-Anhalt (DE), Galicia (ES), Principado de Asturias (ES), Cantabria (ES), La Rioja (ES), Extremadura (ES), Cataluña (ES), Comunidad Valenciana (ES), Andalucia (ES), Región de Murcia (ES), Canarias (ES), Picardie (FR), Bourgogne (FR), Nord - Pas-de-Calais (FR), Pays de la Loire (FR), Bretagne (FR), Poitou-Charentes (FR), Aquitaine (FR), Auvergne(FR), Languedoc-Roussillo (FR), Provence-Alpes-Côte d'Azur (FR), Corse (FR), **Attiki** (GR), Nyugat-Dunántúl (HU), **Southern and Eastern** (IE), Liguria (IT), **Lithuania** (LT), **Luxembourg** (LU), **Latvia** (LV), **Mazowieckie** (PL), **Bucuresti – Ilfov** (RO), Lincolnshire (UK)
5 (80)	AT (2), BG (5), CZ (4), IE (1), GR (12), ES (2), FR (2), IT (14), HU (4), MT, PL (15), PT (7)	Burgenland (AT), Tirol (AT), Severozapaden (BG), Severen tsentralen (BG), Severoiztochen (BG), Yugoiztochen (BG), Yuzhen tsentralen (BG), Severozápad (CZ), Jihovýchod (CZ), Strední Morava (CZ), Moravskoslezsko (CZ), Border, Midlands and Western (IE), Anatoliki Makedonia, Thraki (GR), Kentriki Makedonia (GR), Dytiki Makedonia (GR), Thessalia (GR), Ipeiros (GR), Ionia Nisia (GR), Dytiki Ellada (GR), Sterea Ellada (GR), Peloponnisos (GR), Voreio Aigaio (GR), Notio Aigaio (GR), Kriti (GR), Castilla-la Mancha (ES), Illes Balears (ES), Champagne-Ardenne (FR), Limousin (FR), Provincia Autonoma Bolzano-Bozen (IT), Provincia Autonoma Trento (IT), Toscana (IT), Umbria (IT), Marche (IT), **Lazio** (IT), Abruzzo (IT), Molise (IT), Campania (IT), Puglia (IT), Basilicata (IT), Calabria (IT), Sicilia (IT), Sardegna (IT), Dél-Dunántúl (HU), Észak-Magyarország (HU), Észak-Alföld (HU), Dél-Alföld (HU), **Malta** (MT), Małopolskie (PL), Łódzkie (PL), Śląskie (PL), Lubelskie (PL), Podlaskie (PL), Podkarpackie (PL), Świętokrzyskie (PL), Wielkopolskie (PL), Zachodniopomorskie (PL), Lubuskie (PL), Dolnośląskie (PL), Opolskie (PL), Kujawsko-pomorskie (PL), Warmińsko-mazurskie (PL), Pomorskie (PL), Norte (PT), Algarve (PT), Centro (PT), **Lisboa** (PT), Alentejo (PT), Região Autónoma dos Açores (PT), Região Autónoma da Madeira (PT), Nord-Vest (RO), Centru (RO), Nord-Est (RO), Sud-Est (RO), Sud – Muntenia (RO), Sud-Vest Oltenia (RO), Vest (RO), Vzhodna Slovenija (SI), Západné Slovensko (SK), Stredné Slovensko (SK), Východné Slovensko (SK)

EU capital regions or/and including the country's capital are marked in bold in the table

Source: authors' calculations

Table 3

Input and Output natural logarithm standard deviations measures in the regions of UE 27, UE 15 and UE 12

Year	Natural logarithm standard deviations measure					
	INPUT	OUTPUT	INPUT	OUTPUT	INPUT	OUTPUT
	UE 27		UE 15		UE 12	
1999	0,569	0,539	0,562	0,529	0,475	0,371
2000	0,580	0,534	0,536	0,514	0,546	0,418
2001	0,579	0,523	0,529	0,502	0,544	0,438
2002	0,611	0,546	0,582	0,533	0,535	0,416
2003	0,703	0,545	0,633	0,528	0,727	0,430
2004	0,594	0,534	0,507	0,508	0,645	0,418
2005	0,615	0,523	0,540	0,498	0,629	0,426
2006	0,609	0,525	0,534	0,497	0,622	0,432
2007	0,566	0,532	0,494	0,503	0,581	0,464
2008	0,526	0,522	0,474	0,497	0,509	0,449

Source: authors' calculations

Table 4

Input and Output natural logarithm standard deviations measures in classes of regions

Year	Natural logarithm standard deviations measure									
	INP	OUTP	INP	OUTP	INP	OUTP	INP	OUTP	INP	OUTP
	class									
	1		2		3		4		5	
1999	0,187	0,215	0,115	0,211	0,365	0,176	0,265	0,359	0,416	0,437
2000	0,194	0,205	0,134	0,198	0,254	0,156	0,247	0,355	0,463	0,463
2001	0,189	0,192	0,127	0,182	0,218	0,154	0,228	0,348	0,503	0,473
2002	0,192	0,213	0,134	0,201	0,231	0,163	0,241	0,347	0,569	0,481
2003	0,204	0,202	0,116	0,194	0,250	0,160	0,248	0,331	0,727	0,499
2004	0,196	0,226	0,111	0,206	0,249	0,173	0,235	0,380	0,576	0,459
2005	0,189	0,219	0,132	0,192	0,252	0,156	0,290	0,352	0,594	0,468
2006	0,195	0,216	0,134	0,207	0,224	0,177	0,265	0,352	0,609	0,467
2007	0,186	0,232	0,135	0,210	0,215	0,181	0,254	0,365	0,553	0,492
2008	0,181	0,244	0,134	0,203	0,215	0,164	0,233	0,328	0,504	0,481

Source: authors' calculations

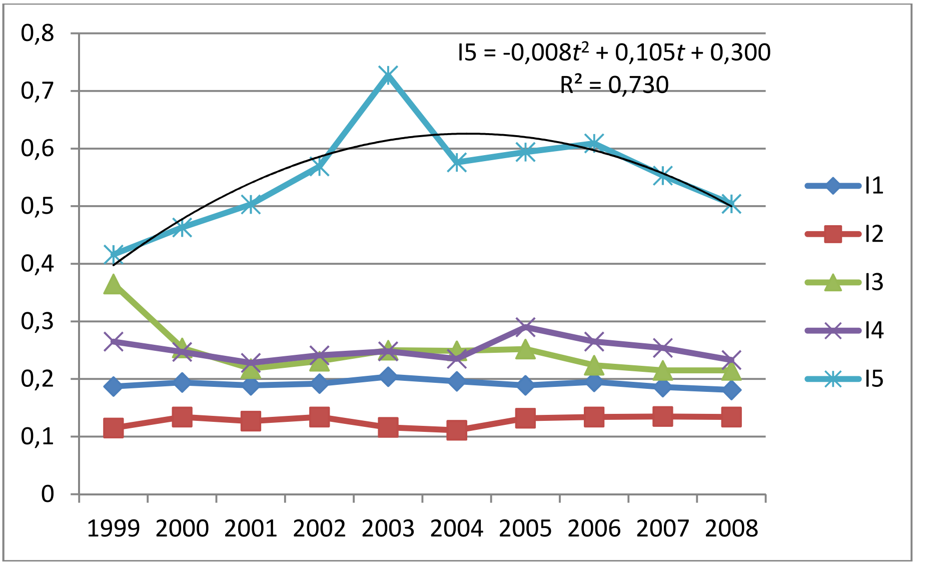

Figure 1. Input natural logarithm standard deviations measures in classes of regions

Source: authors' calculations

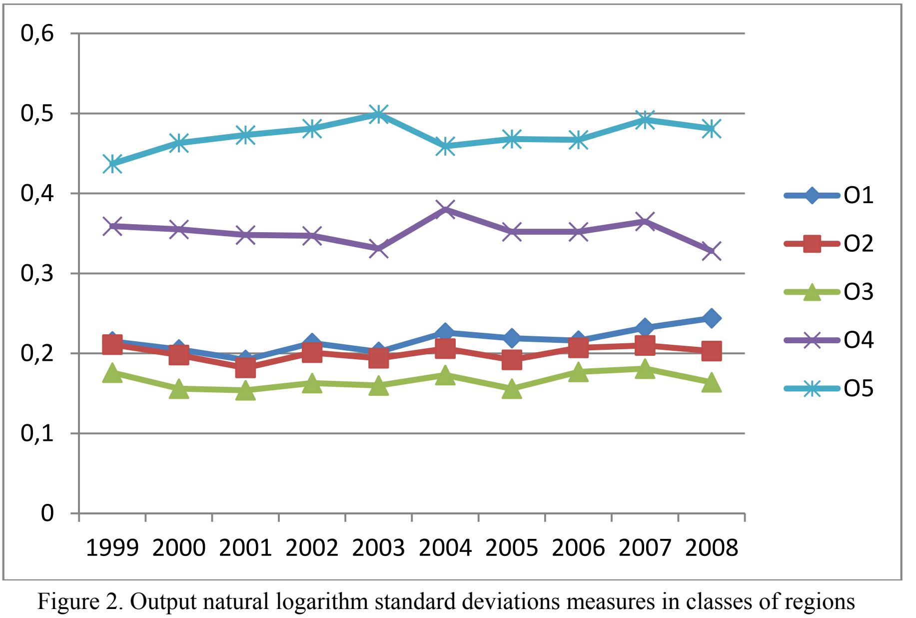

Figure 2. Output natural logarithm standard deviations measures in classes of regions

Source: authors' calculations

Table 5

Characteristics of Input and Output measures dispersion

Objects	Measure	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
		Input									
UE 27	max/min	19,83	31,69	28,49	31,74	68,74	36,01	45,49	50,17	39,19	55,5
	VC	0,48	0,48	0,47	0,48	0,50	0,45	0,46	0,45	0,43	0,42
UE 15	max/min	19,83	31,69	27,70	31,74	68,74	.27,07	45,49	50,17	39,19	55,58
	VC	0,45	0,43	0,42	0,42	0,44	0,39	0,40	0,39	0,37	0,36
UE 12	max/min	10,44	14,85	17,74	13,79	42,19	23,71	23,33	17,38	15,16	13,53
	VC	0,45	0,49	0,47	0,49	0,54	0,53	0,53	0,54	0,52	0,47
class: 1	max/min	2,32	2,47	2,50	2,51	2,44	2,20	2,32	2,49	2,37	2,34
	VC	5,17	5,06	5,08	5,03	4,83	4,92	5,14	4,97	5,15	5,21
2	max/min	1,56	1,64	1,64	1,7	1,6	1,55	1,85,	1,82	1,80	1,66
	VC	8,77	7,39	7,88	7,45	8,54	8,79	7,29	7,06	7,18	7,02
3	max/min	3,47	2,27	2,08	2,50	2,69	2,99	3,32	3,20	2,97	2,65
	VC	4,74	5,78	6,34	6,27	6,16	7,10	6,96	7,74	7,61	7,34
4	max/min	4,35	3,14	2,52	2,54	3,0	2,62	3,4	3,53	3,21	2,95
	VC	3,7	3,8	4,4	4,4	4,4	4,9	4,0	4,4	4,5	4,9
5	max/min	6,99	10,22	9,3	10,89	24,23	14,19	17,34	18,43	15,57	22,50
	VC	2,76	2,92	2,69	2,54	2,24	2,46	2,4	2,34	2,42	2,74
		Output									
UE 27	max/min	14,68	15,15	18,99	18,66	23,16	19,52	16,58	20,28	26,61	22,20
	VC	0,47	0,45	0,43	0,46	0,45	0,46	0,45	0,45	0,45	0,45
UE 15	max/min	14,68	14,93	17,81	13,45	19,53	15,97	13,16	15,78	13,89	14,28
	VC	0,43	0,41	0,40	0,42	0,41	0,42	0,41	0,41	0,41	0,42
UE 12	max/min	5,02	6,53	9,57	8,18	9,30	7,47	6,63	7,63	10,60	9,41
	VC	0,33	0,35	0,36	0,35	0,34	0,35	0,36	0,36	0,38	0,38
class: 1	max/min	2,56	2,57	2,50	2,67	2,5	2,67	2,55	2,65	2,71	2,75
	VC	4,33	4,49	4,75	4,28	4,5	3,97	4,15	4,09	3,81	3,6
2	max/min	2,82	2,68	2,63	2,72	2,55	2,65	2,44	2,73	2,52	2,84
	VC	5,57	5,85	6,25	6,02	6,03	5,95	6,12	5,76	5,63	5,62
3	max/min	2,17	1,81	1,85	1,84	1,86	2,02	1,86	2,01	2,02	1,84
	VC	8,62	8,65	8,88	8,41	8,63	8,33	8,65	8,00	8,09	8,25
4	max/min	3,59	3,6	3,45	3,68	3,06	3,96	3,61	4,36	4,12	3,52
	VC	3,31	3,34	3,44	3,44	3,54	3,13	3,30	3,30	3,27	3,30
5	max/min	5,39	5,66	7,11	6,44	8,02	6,85	6,03	7,20	9,48	8,04
	VC	2,58	2,5	2,48	2,42	2,44	2,49	2,45	2,47	2,39	2,45

Source: author’s calculations