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Convergence of the Standard of Living in Polish NUTS 2 Regions

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Abstract

The authors of the article made an attempt to verify the hypothesis that in 2006–2016 in Poland there was convergence of the standard of living of residents of voivodships (NUTS 2 regions). The values of the measure of the standard of living calculated by the authors by dynamic development pattern method were used to assess the standard of living in the analyzed period. Beta-convergence was verified by cross-section absolute and conditional spatial models of convergence of SAR and SARAR types. Sigma-convergence was verified by measures of dispersion and concentration of the standard of living in 2006–2016. The calculations made point to occurrence of beta- and sigma-convergence of the standard of living in Polish voivodships. However, the estimated values of index of convergence and yearly average rate of convergence of the standard of living seem to be quite high; in fact, much higher than expected. It may be a consequence of clustering phenomenon, which we probably observed.

Keywords: standard of living, convergence models, NUTS 2 regions in Poland (voivodships)

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Introduction

Observation of modern processes of development leads to the conclusion that the main aim of economic activity and policy should not be economic growth but rather an increase in people's standard of living. It is demonstrated not only by an increase in resources of material goods and their consumption but also in the development of the whole and wide range of intangible services, which contribute to an increase in the cultural level of the society, improvement of its health, quality of the natural environment, level of education, safety, etc. (Bywalec 1991, 191–194). Consequently, it is very important to reduce differences in the standard of living — i.e., convergence between the particular countries (regions in countries).

The concept of economic convergence ("catching-up effect") has its origin in the neoclassical theory of growth, represented mainly by the Solow-Swan model (Solow 1956; Swan 1956) and concerns a situation in which income per capita (measured as GDP per capita) in poorer countries (regions) grows faster than in richer countries (regions). As a result, in the long term poor countries (regions) move closer to rich countries (regions). The opposite process is called divergence. Intensive research into the phenomenon of real convergence conducted since the 1980s has led to defining different types of real convergence and different verification methods. There is sigma-convergence, beta-convergence and gamma-convergence as well as social, spatial, technological, sector or club convergence, among others (Kusideł 2013, 15).

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The tools which are used in analyses of economic convergence measured by changes in GDP per capita can also be used to analyze the convergence of the standard of living. The standard of living is a multidimensional category which is described by means of a whole range of individual indexes. In order to compare the standard of living in different countries (regions) it is necessary to adopt a synthetic index. There are several methods of establishing synthetic indexes. These methods can be divided into pattern and non-pattern ones.

In the case of non-pattern methods, synthetic index is a function of normalized (or at least standardized) values of individual (partial) indexes, which leads to comparability of partial indexes by eliminating different units used to measure them (Panek 2014, 147). In the case of pattern methods of construction of synthetic index the notion of a pattern (reference) object is used — i.e., an object which has the required ("best") values of individual indexes. The standard of living in the examined objects is determined on the basis of their distance from the pattern object. The method which is most often used is the distance method (Panek 2014, 148) proposed by Bennet (1937). One example of application of a modified distance method to build of synthetic index to measure the standard of living is Human Development Index (HDI), devised in 1990 by a Pakistani economist Mahbub ul Haq to the needs of United Nations Development Programme.[1] In Poland the pattern method of construction of synthetic index used most frequently to examine the standard of living is the method of development pattern proposed by Hellwig (1968).

When comparing the standard of living in different countries (regions) one should keep in mind the fact that geographical location may have an impact on the value of the particular indexes as well as the value of synthetic measure. This information is more relevant in the case of regions which are usually relatively small units functioning within the framework of the whole country on the basis of the same organizational and legal rules, which means that administrative borders do not have such a significant effect on the value of different indexes as in the case of neighboring countries. That is why there may be strong spatial dependencies between regions, which causes the fact that the value of examined phenomenon in the selected region is affected by other regions of the analyzed system.

The purpose of the article is an attempt to verify the hypothesis that in 2006–2016 in Poland there was a significant convergence in the standard of living of inhabitants of voivodships (NUTS 2 regions). In order to assess the standard of living in the analyzed term, the values of life-standard measures calculated by the authors by means of the model of dynamic development pattern (Bielak and Kowerski 2018) were used. Beta-convergence was verified by means of absolute and conditional spatial autoregressive model of order type (1) — for short SAR and spatial autoregressive model with autoregressive disturbances of order type (1, 1) — for short SARAR (for further details see: Fischer and Wang 2011, 32–35). Sigma-convergence was verified by means of measures of dispersion and concentration of the standard of living in 2006–2016.

1 Review of literature

The economists who study convergence of the standard of living have used the methodology applied in the case of analysis of economic convergence. Inspiration for this were, among others, the following studies by Baumol (1986), Barro (1991), Barro and Sala-I-Martin (1992), Mankiw, Romer and Weil (1992).

Beta-convergence occurs when values of analyzed index approach some common level; this type of convergence can be encountered in the literature in two variants: absolute and conditional convergence — the first one assumes that the regions of lower standard of living develop faster than the regions of higher standard, regardless of the initial conditions of growth; the latter occurs when this process relates to groups of regions which are relatively homogenous; as a result, the regions and countries with comparable income or structural factors become similar to each other. To verify

1. See: Human Development Indices and Indicators. 2018 Statistical Update. By Selim Jahan and others, Published for the United Nations Development Programme (UNDP), New York, 2018, [@:] http://hdr.undp.org/sites/default/files/2018_human_development_statistical_update.pdf.

beta-convergence of the standard of living cross-section regression model was applied; this model was also used to analyze economic convergence by means of GDP per capita:

(1) $$\ln\left(\frac{Y_{iT}}{Y_{i0}}\right) = a + b \cdot \ln Y_{i0} + \varepsilon_i,$$

where:
Y_{i0} —standard of living in i-th country (region) in the base year (0),
Y_{iT} —standard of living in i-th country (region) in the analyzed year (T).
For the phenomenon of convergence to take place, the assessed value of b parameter should be less than zero; otherwise we deal with divergence. The assessed model provides a possibility of calculating beta index:

(2) $$\beta = -\frac{\ln(1+b)}{T},$$

which is called the index of convergence rate and when multiplied by 100% provides information about average rate with which the economies (standard of living) of analyzed countries (regions) move closer.[2] To verify sigma-convergence of the standard of living the measures of dispersion and concentration of the analyzed phenomenon were used.

At first the convergence of individual indexes were examined separately. Hobijn and Franses (2001) examined the phenomenon of convergence of 150–160 countries (depending on the index) in 1965–1990 on the basis of four indexes: daily calorie supply, daily protein supply, infant mortality rates and life expectancy at birth. To verify the hypothesis of convergence, they applied cross-country regressions, distributional dynamics and cluster analysis. These authors built models based on all data as well as models in smaller groups based on GDP per capita, which, in their opinion, should prevent spatial autocorrelation. In the models assessed on the basis of all observations (all countries) beta-convergence occurred in the case of three variables: life expectancy at birth, infant mortality rate and daily calorie supply. Division into groups did not generally change the result (only life expectancy at birth in the poorest countries did not show convergence) and there also appeared convergence in daily protein supply in the groups of countries distinguished due to income. The studies led the authors to the conclusion that: “gap between the rich and poor apparently does not only manifest itself in real GDP per capita but also in living standards” and that, if anything, “there seems to be more convergence in per capita GDP levels than in life expectancy and infant mortality” (Hobijn and Franses 2001, 195).

Neumayer (2003) did not build a synthetic measure of the standard of living, either. He analyzed the following proxy variables for the standard of living: life expectancy at birth, infant survival rates, literacy rates among the adult population, the combined primary, secondary and tertiary educational enrolment ratio as well as telephone mainlines and television set availability per capita. He built cross-section models using 5-year mean arithmetic values of the particular proxy variables of the standard of living in 1960–1999. The number of observations (analyzed countries) differed depending on the term and ranged from 74 in 1965–1970 to 164 in 1960–1965. Neumayer has demonstrated that beta-convergence exists for a wide range of proxy variables for the standard of living, namely life expectancy, infant survival, educational enrolment, literacy as well as telephone and television availability. His results therefore indicate that countries with poor performance at the start period of the analysis have improved more in percentage terms than countries with strong performance. In other words, a process of catching up was observed (Neumayer 2003, 283).

Human Development Index (HDI) devised by Mahbub ul Haq had a significant impact on the development of the study of convergence of the standard of living; HDI was considered to be a very good synthetic measure of the standard of living by many authors. In the models of beta-convergence HDI “replaced” the individual indexes of the standard of living analyzed earlier.

2. However, when the assessed value of b parameter is smaller or equal to -1, coefficient β cannot be calculated and the achieved results cannot be interpreted reasonably.

A good example may be here the study of Mazumdar (2002), who examined the HDI convergence for a sample of 91 countries in 1960–1995 and also for three groups of countries according to their level of human development. He tested the beta-convergence regressions with Ordinary Least Square (OLS) method. Applied tests showed that in almost all the cases divergence was observed. Divergence was also observed for per capita real gross domestic product for all types of sample. Sutcliffe (2004) examined HDI trend for a sample of 99 countries over a period of 1975, 1980, 1985, 1990, 1995, and 2001. The author tested beta-convergence using cross-section model estimated by OLS. The results indicated convergence in terms of human development for the considered periods. Noorbakhsh (2007) analyzed a sample of 93 countries including 62 medium and 31 low human development countries in 1975–2001. To test the hypothesis of beta-convergence of the standard of living in its absolute and conditional forms, he built cross-section models of HDI, estimated by OLS method. He found weak absolute convergence of the standard of living for the analyzed countries in 1975–2001. Konya and Guisan (2008) tested sigma and beta-convergence in terms of worldwide human development, analyzing HDI trend values over a period of seven years (1975, 1980, 1985, 1990, 1995, 2000, and 2004) for a sample of 93 countries. Their results indicate that the world had been converging in the sense that relatively backward countries managed to increase their HDI faster on average than more developed countries, though this convergence process was rather slow.

When considering the level of GDP per capita and of HDI registered by EU states in 1995–2012, Bucur and Stangaciu (2015) tested the hypothesis of sigma and beta-convergence in terms of economic development and the standard of living. They applied cross-section models estimated by OLS. The results indicate a tendency for reducing divergence in both economic and social degree of development. A relatively strong process of sigma-convergence became evident while beta-convergence indicated a slower process for HDI convergence compared with GDP per capita among EU countries.

Recently there have been studies of regional convergence of the standard of living both in one country and in groups of countries. The authors of these studies often built their own synthetic measures of the standard of living which were the functions of different (sometimes very numerous) indexes describing the standard of living.

Muszyńska and Müller-Frączek (2014) used three synthetic measures to analyze the convergence of the standard of living in Polish voivodships in 1999–2012: (1) Cieślak's non-pattern measure of development (Cieślak 1974), (2) Strahl's synthetic measure of development (Strahl 1978), and (3) Pluta's modified measure of development (Pluta 1976). Synthetic measures were calculated on six variables: X_1 — share of expenditures of households on food in total expenses, X_2 — share expenditures of households on education in total expenses, X_3 — share of expenditures of households on leisure and culture in total expenses, X_4 — percentage of households without working family members, X_5 — deaths of infants per 1 000 of live births, and X_6 — number of passenger cars per 1 000 population. On the basis of the results of estimation with Generalized Method of Moments (GMM), dynamic panel models for all considered measures beta-convergence of the standard of living in Polish voivodships were verified. Also the regions which had a positive or a negative impact on the speed of the process were indicated.

In regional studies attention was drawn also to a possibility that location of the region in relations to other, particular neighboring regions, may have an impact on the results, which may cause spatial autocorrelation affecting the final estimation of convergence models. This problem can be solved in two ways. The first solution consists in correcting the individual indexes describing the standard of living or synthetic measures of the standard of living with the coefficient of spatial autocorrelation. The studies of Pietrzak (2014, 2016) can be a good example of this approach. He developed a proposal for the construction of a spatial taxonomic measure of development. This measure can be used to build the synthetic index of the standard of living. Such approach was also applied by Kuc (2017), who by using six variables (i.e., X_1 — unemployment rate, X_2 — percentage of young people neither in employment nor in education and training, X_3 — participation rate in education and training (last 4 weeks, people aged 25–64), X_4 — households income at purchasing power standard based on the final consumption per inhabitant, X_5 — crude death rate for tuberculosis per 100 000 inhabitants, X_6 — crude death rate for neoplasms per 100 000 inhabitants), calculated spatial taxonomic measure of the standard of living in 2004–2014 for 27 EU states and for 35 NUTS 2 regions of the Visegrad Group and then estimated cross-section regression models of the rate of growth of the standard of living. In all cases, b parameter was statistically insignificant so the null hypothesis regarding lack of beta-convergence cannot be rejected. Thus, sigma-convergence will not occur, either. However, the author found that, unlike in other Visegrad countries, sigma-divergence of the standard of living can be observed in Poland. It means that during the analyzed period, regional inequalities in Poland increased. Internal inequalities in Poland are almost four times higher than those at the national level in the European Union or at the regional level within the Visegrad Group countries (Kuc 2017, 59). The second solution consists in implement to cross-section model of beta-convergence of neighborhood matrix and assessment of spatial autoregressive model.

2 Methods

The definition of the standard of living proposed by Bywalec was adopted in the study; according to the definition, the standard of living is a multidimensional phenomenon, determined not only by the value of material resources and their consumption but also by the level of health, the quality of the natural environment and the level of education and safety (Bywalec 1991, 191–194). The study was carried out for Polish voivodships (NUTS 2) in 2006–2016. Dynamic measure of the standard of living[3] calculated by Hellwig's pattern of development method (Hellwig 1968) was adopted as the measure of the standard of living of the residents of voivodships. The following variables, selected by the method based on a condition number of a correlation matrix (Malina and Zeliaś 1996, 86), were adopted to build a dynamic measure of the standard of living:

- X_1—consumption of gas in households per year per capita (m^3)
- X_2—doctors authorized per 10 000 population
- X_3—suicides per 10 000 population
- X_4—passenger cars per 1 000 population
- X_5—infant deaths per 1 000 live births
- X_6—life expectancy of males (years)

The results of the studies show that in 2006–2016 there was an increase in the standard of living in all voivodships; however, the rates of increase were slightly different and depended on a voivodship. Beta-, sigma- and gamma-convergence were considered in the article.

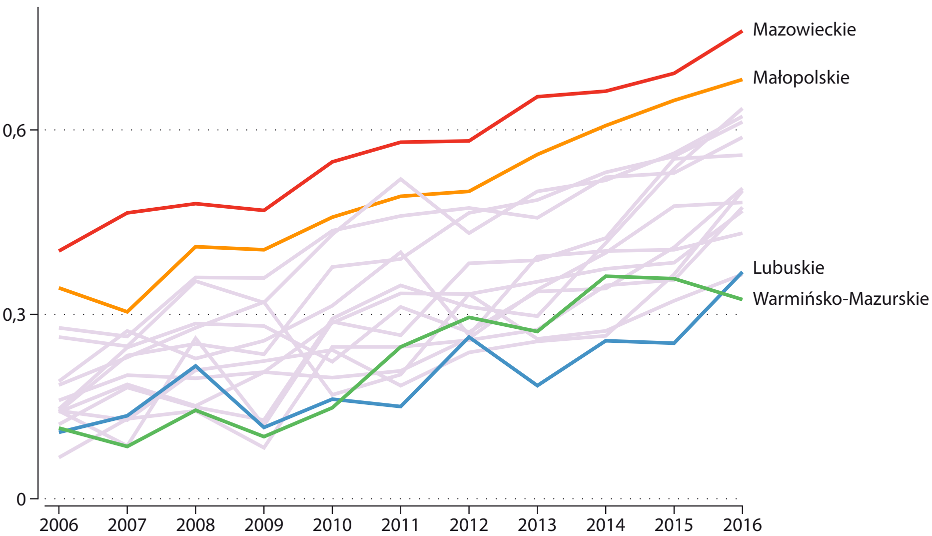


Fig. 1. Economic development measures of Polish voivodships in the years 2005–2016

Source: Bielak and Kowerski (2018)

3. Description of construction of this measure and the manner of selection of variables are included in the study by Bielak and Kowerski (2018).

2.1 Beta-convergence

The study started with estimation of the "standard" linear model on cross-section data for absolute beta-convergence, according to the formula

$$\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) = a + b \cdot \ln Y_{i2006} + \varepsilon_i \quad \text{for} \quad i = 1, 2, 3, \ldots, 16, \tag{3}$$

and conditional convergence models based on cross-section data, according to the general formula

$$\begin{aligned}\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) &= a_0 + b \cdot \ln Y_{i2006} + a_1 X_{1i2016} + a_2 X_{2i2016} + \cdots + a_j X_{ji2016} + \cdots \\ &+ a_k X_{ki2016} + \varepsilon_i \qquad \text{for} \quad i = 1, 2, 3, \ldots, 16 \text{ and } j = 1, 2, 3, \ldots, k\end{aligned} \tag{4}$$

where:
Y_{i2006} — value of the standard of living index in i-th voivodship in 2006,
Y_{i2016} — value of the standard of living index in i-th voivodship in 2016,
Y_{ij2016} — value of j-th conditional variable in i-th voivodship in 2016.

As conditional factors (for conditional beta-convergence) following variables were proposed:

- average monthly disposable income per capita, Poland = 100
- expressways and highways per 10 000 km^2 (in km)
- gross domestic product per capita, Poland = 100
- unemployment rate — on the LFA basis (in %)

The above models do not take into account spatial aspects of development of the standard of living; therefore a number of tests were used to verify the hypothesis about occurrence of spatial effects not captured by linear models. These tests were applied to residuals of model 3 and 4.[4] The following tests were used:

- Global Moran I statistic, of general formula

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(e_i - \bar{e})(e_j - \bar{e})}{\left(\sum_{i=1}^{n}(e_i - \bar{e})^2\right) \cdot \left(\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}\right)}, \tag{5}$$

where:
w_{ij} — an element of the spatial weights matrix W (which is in row-standardized form),
e_i — residual for i-th voivodship.

The positive value of I statistic indicates clustering of similar values, whilst negative value of I statistic indicates clustering of dissimilar values; a value of zero indicates zero spatial autocorrelation.

- Global Geary C contiguity ratio, of general formula

$$C = \frac{(n-1) \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(e_i - e_j)^2}{2\left(\sum_{i=1}^{n}(e_i - \bar{e})^2\right) \cdot \left(\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}\right)}, \tag{6}$$

where small values of C ratio indicate positive spatial autocorrelation, while large values of C ratio indicate negative spatial autocorrelation.

- Local Moran I statistic, of general formula

$$I_i = (e_i - \bar{e}) \sum_{j=1}^{n} w_{ij}(e_i - \bar{e}) \quad \text{where} \quad i \neq j. \tag{7}$$

Usually, non-zero weights are assigned only to the nearest neighbors (Lloyd 2011, 80–89).

4. Moran I test, additionally used to the value of the index of the standard of living and GDP, confirmed the occurrence of negative spatial autocorrelation — see tables 3, 4, 5.

Lagrange multiplier diagnostics for omitted spatial lag and error dependence, of general matrix formulas

(8) $$LM(\text{lag}) = \left(\frac{e^T W y}{e^T e\, n^{-1}}\right)^2 \cdot \frac{1}{H},$$

(9) $$LM(\text{error}) = \left(\frac{e^T W e}{e^T e\, n^{-1}}\right)^2 \cdot \frac{1}{tr[W^T W + W^2]},$$

where tr stands for the trace operator (the sum of the diagonal elements of a matrix), and $e^T e\, n^{-1}$ represents the error variance (for more details see: Fischer and Wang 2011, 36).

Occurrence of significant spatial autocorrelations led to construction of spatial models of beta-convergence. Finally two models were chosen:

- for estimating absolute beta-convergence—model SARAR, with two sources of spatial autocorrelation: dependent variable and residuals, and
- for estimating conditional beta-convergence—model SAR, with one source of spatial autocorrelation: dependent variable.[5]

2.2 Sigma-convergence

Sigma convergence means decreasing dispersion (diversity) in the standard of living level in analyzed regions (Kusideł 2013, 45–76). In order to verify the hypothesis on the existence of sigma-convergence one has to following measures were used:

- measures of dispersion
  - variance
  - maximum/minimum ratio
  - coefficient of variation
  - standard deviation of logarithm
  - average standard deviation (which makes it possible to avoid a foremost disadvantage of the first three measures, which is sensibility to outlier observations)
- measures of concentration
  - Gini coefficient
  - Atkinson's measure
  - Kolm's measure
  - Ricci-Schutz coefficient
  - Theil's entropy measure

As proposed by Friedman (1992) linear trend models for every measure, calculated for all consecutive years, were estimated

(10) $$y_t = a_0 + a_1 t + \varepsilon_t \quad \text{for} \quad t = 1, 2, 3, \ldots, 11$$

and significance of α_1 parameters were verified.

2.3 Gamma-convergence

Gamma-convergence occurs when the ranks (based on selected standard of living index) of surveyed regions in compared years are changing. Existence of gamma-convergence was tested using Spearman Rank correlation coefficient (Kusideł 2013, 70–71).

3 Results

3.1 Beta-convergence

Estimation results of "standard" model on cross-section data for absolute beta-convergence according to the formula

5. In the model for conditional beta-convergence the spatial error parameter occurred insignificant, thus we assumed that spatial autocorrelation of residuals in that model did not exist.

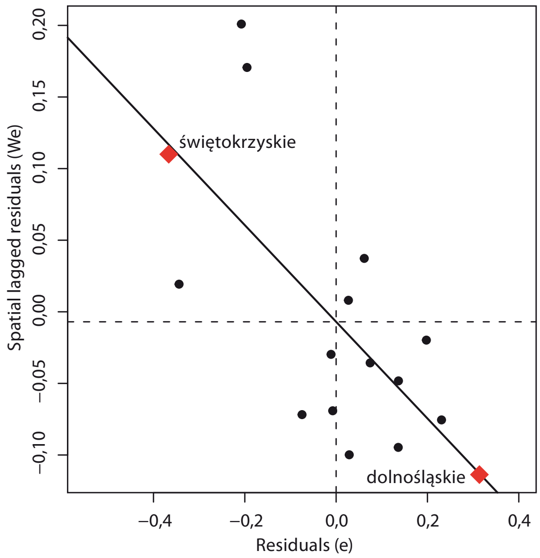
(11) $$\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) = a + b \cdot \ln Y_{i2006} + \varepsilon_i \quad \text{for} \quad i = 1, 2, 3, \ldots, 16$$

are presented in table 1. Despite the fact that b parameter is significant, carried out the test for spatial effects showed negative spatial autocorrelation in residuals. Similar results were obtained for spatial effect tests applied to standard of living measure values (see tab. 3 and 4). The Moran scatterplot reveals that Mazowieckie Voivodship has an exceptionally high value of standard of living relative to its neighbors (which is also noticeable on the maps). Points generally are gathered in the upper left quadrant (low-valued points with high-valued neighbors) and the lower right quadrant (high-valued points with low-valued neighbors) of the plot, which shows negative spatial correlation (LeSage and Pace 2009, 11).

Tab. 1. "Standard" model on cross-section data (OLS estimation) for absolute beta-convergence and tests for spatial effects in residuals

	Estimate	*P*-value
Intercept	−0,138	0,523
$\ln(Y_{i2006})$	−0,702	$<$ 0,001

$N = 16$
Residual standard error: 0,203
Adjusted R-squared: 0,711
Moran I statistic (alternative hypothesis — less) for model residuals: −0,338; $p = 0,023$
Geary C statistic (alternative hypothesis — less) for model residuals: 1,275; $p = 0,033$
Lagrange multiplier diagnostics for spatial dependence
- against spatial lag dependence: 2,128; $p = 0,145$
- against spatial error dependence: 3,704; $p = 0,054$

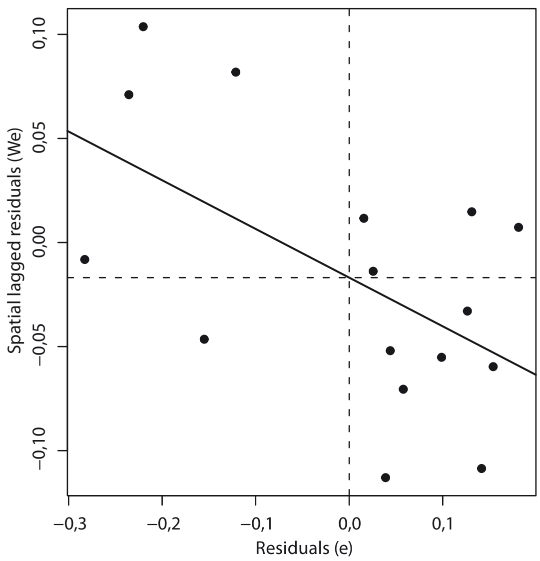


Note: [In the journal European practice of number notation is followed — for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). — Ed.]

Tab. 2. "Standard" model on cross-section data (OLS estimation) for conditional beta-convergence and tests for spatial effects in residuals

	Estimate	*P*-value
Intercept	−0,975	0,012
$\ln(Y_{i2006})$	−0,851	$<$ 0,001
GDP_{2016}	0,006	0,012

$N = 16$
Residual standard error: 0,164
Adjusted R-squared: 0,810
Moran I statistic (alternative hypothesis — less) for model residuals: −0,234; $p = 0,116$
Geary C statistic (alternative hypothesis — less) for model residuals: 1,151; $p = 0,156$
Lagrange multiplier diagnostics for spatial dependence
- against spatial lag dependence: 4,315; $p = 0,038$
- against spatial error dependence: 1,779; $p = 0,182$

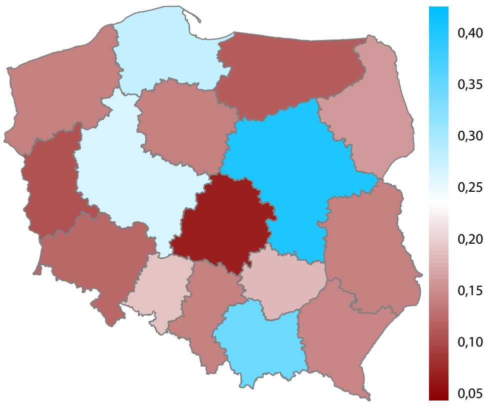


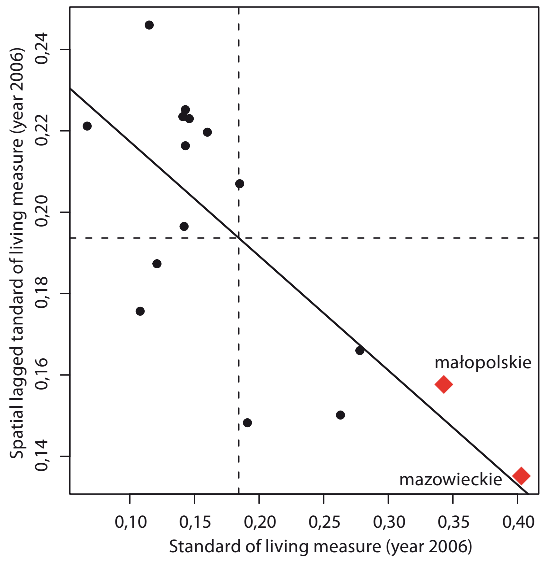
During estimation and verification of conditional convergence models, only the GDP per capita occurred statistical significant. Estimation result of "standard" model on cross-section data for conditional beta-convergence, according to the formula

$$\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) = a_0 + b \cdot \ln Y_{i2006} + a_1 \mathrm{GDP}_{i2016} + \varepsilon_i \quad \text{for} \quad i = 1, 2, 3, \ldots, 16 \tag{12}$$

Tab. 3. Moran statistics (alternative hypothesis — less) for spatial correlation of standard of living measure in the year 2006

	Statistic	*P*-value
Global Moran *I*	−0,281	0,068
Local Moran *I*[a]		
Łódzkie	−0,551	0,062
Mazowieckie	−1,370	< 0,001

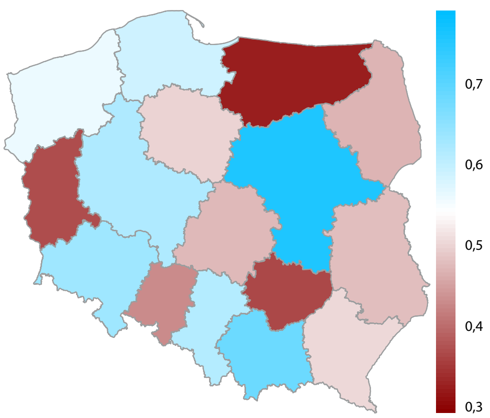


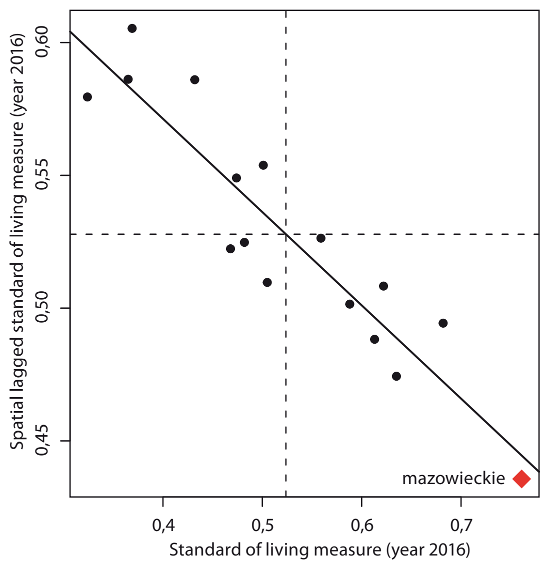


[a]Only voivodships with significant (at 0,1 level) Local Moran statistic are listed.

Tab. 4. Moran statistics (alternative hypothesis — less) for spatial correlation of standard of living measure in the year 2016

	Statistic	*P*-value
Global Moran *I*	−0,351	0,029
Local Moran *I*[a]		
Świętokrzyskie	−0,713	0,022
Warmińsko-Mazurskie	−0,801	0,043
Mazowieckie	−1,504	< 0,001
Lubuskie	−0,908	0,051





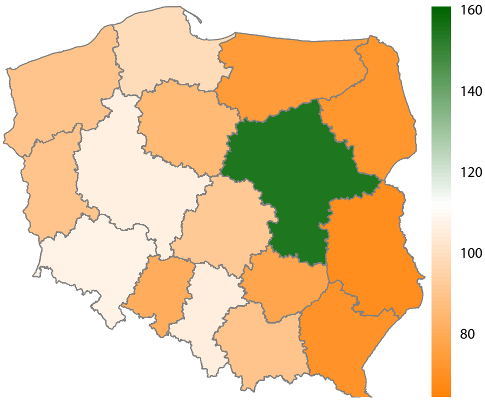
[a]Only voivodships with significant (at 0,1 level) Local Moran statistic are listed.

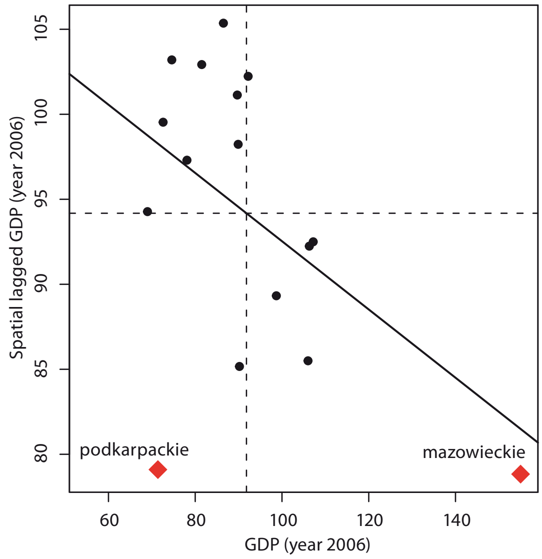
are presented in table 2. Despite the fact that all parameters are significant, carried out the test for spatial effects suggest negative spatial autocorrelation in residuals. Additionally we concluded, that Global Moran I tests applied to GPD per capita values did not show significant spatial correlation, nevertheless according to Local Moran I tests, level of GDP per capita in two voivodhips, in both years 2006 and 2016, are the most distinctive influential points (see tab. 5 and 6). Mazowieckie Voivodship has an extremely high value relative to its neighbors, while very low value in Podkarpackie Voivodship is surrounded by neighbors with low values of GDP per capita as well.

Going back to the absolute beta-convergence model (11), Lagrange multiplier tests indicate that residuals are spatial dependent (see tab. 1). However in model with two sources of spatial autocorrelation, both the and parameters are significant; additionally the SARAR model has got better Akaike's Information Criterion (–10,009 against –5,941 in SEM model).[6] Thus, finally, the model

Tab. 5. Moran statistics (alternative hypothesis — less) for spatial correlation of GDP per capita in the year 2006

	Statistic	*P*-value
Global Moran I	−0,201	0,141
Local Moran I^{a}		
Mazowieckie	−1,980	< 0,001

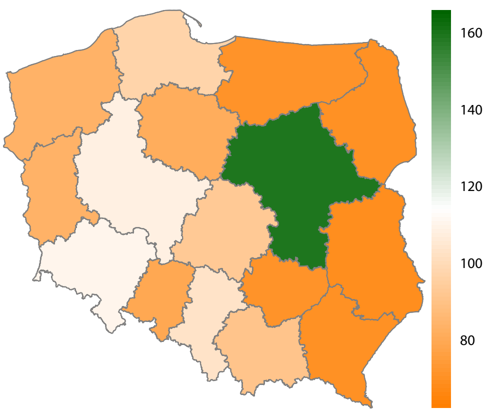


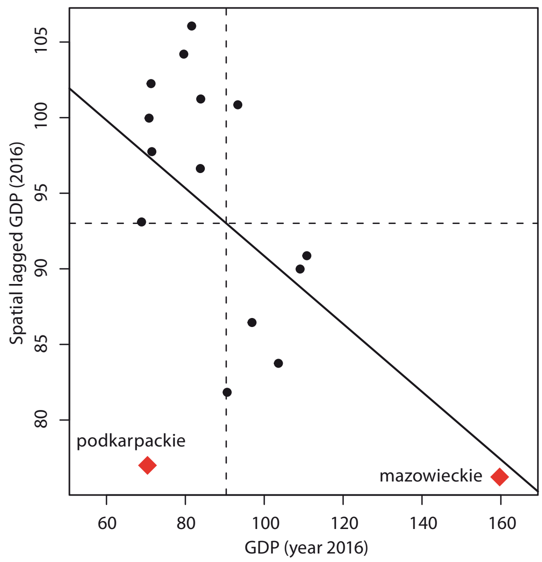


[a] Only voivodships with significant (at 0,1 level) Local Moran statistic are listed.

Tab. 6. Moran statistics (alternative hypothesis — less) for spatial correlation of GDP per capita in the year 2016

	Statistic	*P*-value
Global Moran I	– 0,224	0,105
Local Moran I^{a}		
Mazowieckie	−1,949	< 0,001





[a] Only voivodships with significant (at 0,1 level) Local Moran statistic are listed.

6. AIC estimates the relative amount of information lost by a given model: the less information a model loses, the higher is the quality of that model (Hill, Griffiths, and Lim 2011, 238).

(13)
$$\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) = \rho\sum_{i=1}^{16}\sum_{j=1}^{16} w_{ij}\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) + a + b\cdot\ln Y_{i2006} + \varepsilon_i$$
$$\varepsilon_i = \lambda\sum_{i=1}^{16}\sum_{j=1}^{16} w_{ij}\varepsilon_i + \nu_i$$

was estimated, where:
ρ — spatial lag parameter,
λ — spatial error parameter,
w_{ij} — elements of spatial weight matrix W based on neighborhood, normalized by rows.
All parameters are significant at 0,001 level. The reported LR test proved that the addition of the spatial lag was an improvement. Moran I and Geary C tests confirm that spatial correlation in the residuals of the model was removed (tab. 7). Therefore, based on estimated parameter b we could obtain yearly average rate of absolute beta-convergence, and according to formula $\beta = -\ln(1-b)/10$, in the years 2006–2016, it equals 14,6%. Further, time needed to cover half the distance to a balance, according to formula $\tau = -\ln(0{,}5)/\beta$, equals 4,76 years.

Tab. 7. SARAR model for absolute beta-convergence estimation results and tests for spatial effects in residuals

	Estimate	*P*-value	Tests
Intercept	−0,781	< 0,001	$N = 16$
$\ln(Y_{i2006})$	−0,767	< 0,001	LR test value[a]: 12,293; $p = 0{,}002$
ρ	0,477	< 0,001	Moran I statistic (alternative hypothesis — less): −0,210; $p = 0{,}161$
λ	−1,461	< 0,001	Geary C statistic (alternative hypothesis — less): 1,179; $p = 0{,}112$

[a] The LR test is a test of the model with and without the spatial lag.

As far as conditional beta-convergence is concerned, the SAR model was estimated

(14)
$$\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) = \rho\sum_{i=1}^{16}\sum_{j=1}^{16} w_{ij}\ln\left(\frac{Y_{i2016}}{Y_{i2006}}\right) + a_0 + b\cdot\ln Y_{i2006} + a_1\mathrm{GDP}_{i2016} + \varepsilon_i,$$

where the only conditional variable was gross domestic product per capita.[7] All parameters (except intercept) are significant at 0,05 level. The LR test proved that the addition of the spatial lag was an improvement. Tests confirm that spatial correlation in the residuals of the model was removed (tab. 8). Therefore, based on estimated parameter b we could obtain yearly average rate of conditional beta-convergence in the years 2006–2016: 15,1%; and time needed to cover half the distance to a balance equals 4,60 years.

Tab. 8. SAR model for conditional beta-convergence estimation results and tests for spatial effects in residuals

	Estimate	*P*-value	Tests
Intercept	−0,351	0,371	$N = 16$
$\ln(Y_{i2006})$	−0,778	< 0,001	LR test value[a]: 4,440; $p = 0{,}035$
GDP_{i2006}	0,006	< 0,001	Moran I statistic (alternative hypothesis — less): 0,032; $p = 0{,}756$
ρ	−0,455	0,041	Geary C statistic (alternative hypothesis — less): 0,932; $p = 0{,}673$

[a] The LR test is a test of the model with and without the spatial lag.

3.2 Sigma-convergence

It is assumed that if dispersion (or concentration) of surveyed index of development among regions decreases significantly over time, and is lower in the last year (in comparison to first year), we deal with sigma-convergence. All tested parameters — see section 2.2 of article — were significant

7. Other potential considered variables, in all tested types of models, occurred insignificant.

and their values were below zero (except two — for models based on the variance and the Kolm's measure of concentration) (tab. 9). That may allow us to come to conclusion that sigma-convergence occurs indeed. But it is well-known that values of all the enumerated indexes (besides variance and Kolm's, precisely) decrease when average of the measured variable increase — i.e., only variance and Kolm's, if one adds the same absolute amount to every y_i, remain unaltered (see: Cowell 2011, 165). Taking into consideration the fact that average standard of living measure was gradually increasing from 0,183 in 2006 to 0,524 in 2016, the results suggesting existence of "one-goal-point" sigma-convergence may be misleading. Figure 2, where standard of living index linear trends[8] and their extrapolations till year 2020 are presented, suggest that we deal with three groups of voivodships: with convergence within each group and with divergence between groups.

Tab. 9. Parameters of linear trend models for dispersion and concentration measures

Measure	Value in 2006	Value in 2016	a_1 estimate
Variance	0,0079	0,0139	0,0006**
Maximum/minimum ratio	6,0149	2,3488	−0,3368**
Coefficient of variation	0,4964	0,2325	−0,0248***
Standard deviation of logarithm	0,1220	0,0623	−0,0064***
Average standard deviation	0,3778	0,1894	−0,0172***
Gini coefficient	0,2664	0,1363	−0,0129***
Atkinson's measure	0,0506	0,0129	−0,0038***
Kolm's measure	0,0038	0,0069	0,0003**
Ricci-Schutz coefficient	0,1889	0,0947	−0,0086***
Theil's entropy measure	0,1047	0,0255	−0,0078***

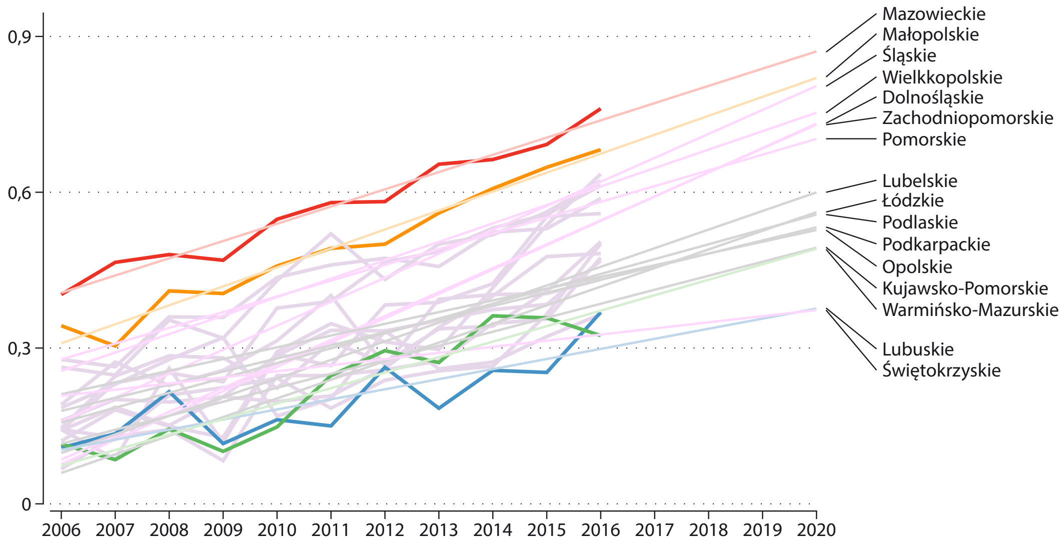


Fig. 2. Extrapolation of stadard of living linear trends for all voivodships

3.3 Gamma-convergence

Changes of rank positions of voivodships in the consecutive years described above imply that we probably deal with a gamma-convergence (Puziak 2009, 42–43). However according to conducted calculations there is not significant gamma-convergence of standard of living measure neither if "one-time change" from year 2006 to 2016 is taken into consideration nor if the consecutive year-to-year periods[9] are considered.

8. All parameters for time variable in the trend models were highly significant.
9. That is: 2006–2007, 2007–2008,..., 2015–2016.

Discussion and conclusions

The calculations made point to the occurrence of beta- and sigma-convergence of the standard of living in Polish voivodships in 2006–2016, which is compatible with the results of studies conducted by Muszyńska and Müller-Frączek (2014). However, estimated values of index of convergence and yearly average rate of convergence of the standard of living seem to be quite high, in fact, much higher than expected. Muszyńska and Müller-Frączek, based on panel data models, obtained values of yearly average rate of convergence of measures of development characterizing level of living in Polish voivodships in the years 1999–2012, between 6,8% and 13,5%. Our results — about 15% of yearly average rate of convergence — suggest that resembling of voivodships standard of living is much faster. However there is observed a phenomenon that voivodships with low value of the measure quickly (in a year or two) overtake voivodships with higher value of the measure, and the difference between them further increases. Next, standard of living of overtaken voivodships increase faster than the others, etc. Thus convergence changes to divergence in short

Tab. 10. Ranks of Polish voivodship, according to standard of living measure, in the years 2006 and 2016

Voivodship	Rank[a] in 2006	Rank[a] in 2016	Change in rank position
Dolnośląskie	13,0	3,0	10,0
Kujawsko-Pomorskie	9,5	9,0	0,5
Lubelskie	12,0	10,0	2,0
Lubuskie	15,0	14,0	1,0
Łódzkie	16,0	11,0	5,0
Małopolskie	2,0	2,0	0,0
Mazowieckie	1,0	1,0	0,0
Opolskie	5,0	13,0	−8,0
Podkarpackie	8,0	8,0	0,0
Podlaskie	7,0	12,0	−5,0
Pomorskie	3,0	6,0	−3,0
Śląskie	11,0	5,0	6,0
Świętokrzyskie	6,0	15,0	−9,0
Warmińsko-Mazurskie	14,0	16,0	−2,0
Wielkopolskie	4,0	4,0	0,0
Zachodniopomorskie	9,5	7,0	2,5

[a] Ranks generated following rules of Spearman Rank correlation procedure (hence 9,5 values).

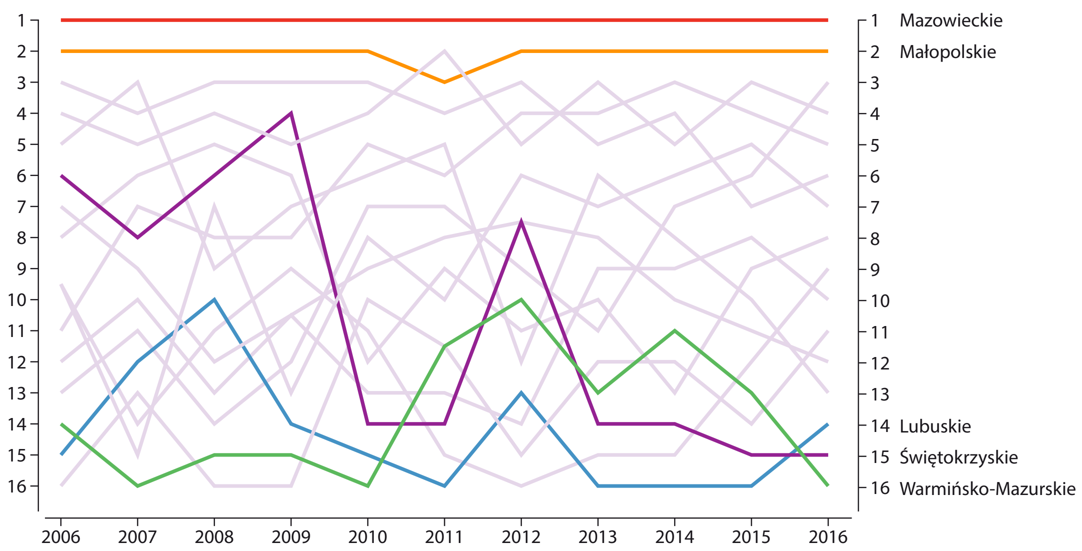


Fig. 3. Ranks of Polish voivodship, according to standard of living measure, in the years 2006 and 2016

periods of time. It is easily noticed when the voivodships are ranked according to value of standard living and the results are plotted (see tab. 10). Therefore it is possible that this phenomena is the source of some kind of "disturbance" that results in such a high measure of yearly average rate of convergence.

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