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## Conference Paper Parallel convergence of income and educational achievements on a local level in Poland - Joint distribution dynamics

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## Parallel convergence of income and educational achievements on a local level in Poland – joint distribution dynamics

Piotr Wójcik\*

#### Abstract

In the last decade, after accession to European Union, Poland has achieved a significant improvement of indicators relating to income on a national level. Polish GDP *per capita* (in PPP terms) increased from 49% of European Union average in 2004 to 67% in 2013 showing progress in each year (source: Eurostat). Simultaneously an impressive progress was achieved by Polish secondary schools pupils, which is confirmed by international comparisons of educational results (PISA). Empirical analyses of GDP *per capita* distribution and its dynamics on a regional level in Poland show that the above mentioned progress does not spread out proportionally on all regions and income convergence is not observed. Instead, relatively faster growth of initially richest regions (mostly large cities) introduces convergence of clubs which leads to polarization.

The purpose of this paper is to analyze the relationship between the local convergence of income and educational achievements on a local level in Poland in the period 2003–2013. We aim to verify if and how the convergence processes of these two phenomena are related to each other. The analysis is applied on the level of municipalities (LAU 2, former NUTS 5). Income is measured in terms of *per capita* revenue in municipality budget from the share in receipts from personal income tax. Educational achievements are measured by the median results of standardized lower-secondary school leaving exams. The evolution of the joint distribution of income and educational achievements is analyzed with the use of a transition matrix generalized for two-dimensional distributions.

**Keywords**: local convergence, parallel convergence, income, educational achievements, convergence of clubs, transition matrix, municipalities

**JEL Classification**: I25, O15, P25, R11

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## Introduction

In the last decade Poland has achieved a significant improvement of indicators relating to income on a national level. GDP *per capita* of Poland (in terms of purchasing power parity) increased from 49% of European Union average in 2004 (a year of Polish accession into UE) to 67% in 2013 showing progress in each year. Simultaneously the impressive progress was achieved by Polish secondary schools pupils, which is confirmed by international comparisons of educational results, namely Programme for International Student Assessment (PISA) repeated every three years under OECD auspices. In mathematics literacy test Polish pupils climbed from 25. place in the world in 2000 into 13. place in the world in 2012. In the reading test (which verifies if pupils are able to "construct, extend and reflect on the meaning of what they have read across a wide range of continuous and non-continuous texts") they started in 2000 from 25. place in the world, to achieve 10. place in 2012. In the science test the results improved from 22. place in 2000 to 9. place in 2012.

Empirical analyses of GDP *per capita* diversification on a regional level in Poland show that the above mentioned impressive progress does not spread out proportionally on all regions. Therefore it is very interesting to investigate how the convergence process of income and educational achievements looks on a regional and on a local level – what patterns of convergence are observed there. Does the dynamics of income convergence process on a local level replicate patterns observed on a regional level (sigma divergence, convergence of clubs, polarization) or follows a totally different scheme? What are the patterns of regional and local convergence of educational achievements? And last but not least – if and how the convergence processes of income and educational achievements are related to one another on a local level.

The research hypothesis in this article assumes that in Poland one can observe a parallel convergence process of income and educational achievements on the level of municipalities, i.e. increase in the relative income is accompanied by increase of educational achievements in the same regions and vice versa.

The measure of income considered on the level of municipalities is *per capita* revenue in municipality budget from the share in receipts from personal income tax. Educational achievements in turn will be measured by the median result of lower-secondary school leaving exams. These exams provide detailed, standardized and comparable data on educational achievements of Polish secondary schools pupils on all regional levels year-by-year since 2002. Median is used instead of a mean to minimize the impact of potential outliers on the municipality representative exam score.

The remaining part of the article is organized in the following way. Section 1 brings a short theoretical and empirical literature review concerning economic and educational convergence processes. Section 2 explains the methodology of modelling the whole distribution dynamics and mobility within the distribution. Section 3 describes the framework of empirical research, research aim and hypothesis, empirical data and includes interpretation of all results. The last part of the article summarizes main conclusions.

## 1. Convergence literature review

In economic and regional research the term convergence is most often referred to a relatively faster development of poorer countries (regions) as compared to richer countries (regions), causing the reduction of distance between them. The opposite phenomenon – increasing disparities – is called divergence. Analyses of convergence most often relate to the measure of income, for example gross domestic product per inhabitant, but can also apply to other measurable economic or social phenomena, for example quality of life, education or unemployment rate (see e.g. Tyrowicz and Wójcik, 2010).

Neoclassical growth theories (e.g. Solow 1956, Swan 1956, Mankiw et al. 1992, Nonneman and Vanhoudt 1996) predict that in case of perfect competition and unrestricted mobility of production factors the levels of development of countries or regions should equalize (converge) – the process of equalization is called convergence. Convergence will be resulting from capital flows into countries or regions with lower costs of production factors and flows of employees to countries or regions with higher wages. Endogenous growth models (e.g. Romer 1986, Lucas Jr. 1988), depending on the assumptions formulated, may predict convergence or divergence (the process of increasing disproportions). Polarized development theories in turn univocally predict that regions specializing in innovative activities should grow faster, creating growth poles (e.g. Perroux 1955, Paelinck 1965), which accompanied by limited spatial spill-over effects and washing out of development resources from other regions will lead to divergence.

When related to educational achievements or human capital in a broader sense, the existence of convergence would mean equalization of the level of human capital between countries or regions, while divergence would indicate further diversification and polarization of countries or regions with respect to that phenomenon. Despite the lack of economic theories predicting convergence or divergence of human capital between countries or regions, there are empirical analyses which undertake the analysis of convergence of this phenomenon as a crucial growth factor and one of important social indicators measuring widely understood level of development (Sab and Smith 2004, Gadomski and Gabryjelska-Basiuk 2004, 2006, Berry and Glaeser 2005, Cuaresma 2005, Südekum 2008).

Based on numerous empirical research conducted for European Union countries and regions (e.g. Tondl 2001, Badinger et al. 2004, Fisher and Stirböck 2004, Magrini 2004, Corrado et al. 2005, Geppert and Stephan 2008, Heidenreich and Wunder 2008 and recently Cavenaile and Dubois 2011, Borsi and Metiu 2013) one can generally conclude that neoclassical theories explain to some extent income convergence process observed in some periods on a national level, while the development patterns observed on a regional level of a particular country closer reflect predictions of the polarized development theories.

Empirical analyses of convergence of GDP *per capita* in Poland conducted on a regional level for different periods indicate that the initially poorest voivodeships (provinces, NUTS2 regions) and subregions (NUTS3 regions) on average do not grow faster than richer regions. On the contrary, the fastest growth is observed for the initially richest regions. Income disparities between regions do not decrease and even increase with time. Only in subperiods of economic slow-down one can observe a short-term decrease of interregional income inequalities (Wójcik 2008).

The substantial majority of Polish research of income convergence processes is limited to using so called classical approach to convergence analysis (see e.g. Sala-i-Martin 1996). It consists of analyzing beta convergence which concentrates on the analysis of a representative country or region and verifies the relationship between an average growth rate and the initial income (regression analysis) and sigma convergence which verifies the dynamics of a single descriptive statistic – a synthetic measure of dispersion (usually a standard deviation or a coefficient of variation) in subsequent years (eg. Gajewski and Tokarski 2004, Próchniak 2004, Markowska-Przybyła 2010). These methods do not allow for the examination of the whole distribution of the analyzed phenomenon and its dynamics in time. Whereas the analysis of the entire distribution is widely recognized as the most appropriate method of convergence processes research (Quah 1993, 1997, Magrini 2009), in particular when one expects to observe convergence of clubs which leads to polarization. And indeed, empirical analyses examining the whole distribution of GDP *per capita* and its dynamics in time for Polish voivodeships indicated the existence of convergence of clubs – equalization of income separately for the richest and the poorest regions (Wójcik 2004, 2007). In addition, the dispersion of *per capita* income on the level of voivodeships and subregions increased shortly after Polish accession to EU (Wójcik 2008).

Empirical analyses devoted to income convergence on a local level are rare. The common measures of income on a local level are based on revenues from personal income tax, e.g. *per capita* revenue of the local administrative unit from the share in receipts from personal income tax. Andrade et al. (2004) analyze the dynamics of the whole distribution of such *per capita* income of almost 4000 Brazilian municipalities in 1970–1996 and observe lack of convergence for all municipalities. The only observed pattern is convergence of clubs. Higgins et al. (2006) make use of data about local income and 41 variables potentially conditioning convergence (including

different measures of education) for 3058 US counties for the period 1970–1990. They verify the existence of the classical beta convergence and find that only conditional convergence is observed. Among significant conditioning variables a high share of population with secondary education positively influences a growth rate of a local income. Young et al. (2008) also verify beta and sigma convergence on a local level for US counties in 1970–1998. They observe a significant relationship between a growth rate of a local income and an initial income (i.e. absolute beta convergence), which is however accompanied by stable or even in some states increasing variability of a local income (i.e. sigma divergence). Viegas and Antunes (2013) using spatial econometric models analyze convergence of local incomes for 278 continental municipalities of Portugal in 1998–2009 and find strong and significant beta convergence and strong and significant impact of spatial relationships on the local convergence process. The analyses of income convergence on a local level in Poland were not performed so far.

Education or human capital is widely recognized as one of the most important factors of economic development (e.g. Benhabib and Spiegel 1994, Barro 1999, Krueger and Lindahl 2001, Pritchett 2001, Herbst 2012, Jabłoński 2012, Gennaioli et al. 2013, Delgado et al. 2014) and was repeatedly analyzed in empirical convergence research as a conditioning factor of convergence between countries or regions (e.g. Mankiw et al. 1992, Smętkowski and Wójcik 2009). The influence of human capital on growth is held through its impact on labor productivity (Lucas Jr., 1988) or through the total factor productivity (TFP), thanks to increasing innovativeness of the economy (Nelson and Phelps, 1966). Empirical research on importance of human capital for economic development usually makes use of a simple Barro-type growth regression. The most important works devoted to this issue were published by Mankiw et al. (1992), Benhabib and Spiegel (1994), Krueger and Lindahl (2001), Barro (1999), Barro and Barro and Sala-i-Martin (2003), Chen and Dahlman (2004), and recently Ciccone and Papaioannou (2009), Arnold et al. (2011).

In the 1990s the influence of human capital on economic growth was a subject of a tempestuous scientific debate. However, most of the current research both applied to national level data and regional level data confirms that human capital strongly and positively affects economic growth, i.e. high level of human capital plays a major role in the success of countries and regions. Education is an important factor of economic and also social exclusion in many dimensions, which was corroborated for Poland in recent research conducted by Instytut Badań Edukacyjnych (Institute of Educational Research, Chłoń-Domińczak 2015, Rószkiewicz and Sawczuk 2015). In addition, the results of recent research suggest that what really matters for growth is not the level of human capital/education, but its quality – not educational attainment but educational achievement. Schoellman (2012) and Delgado et al. (2014) show that educational achievements, measured by mean test scores, provide a more reliable measure of human capital as compared with the average number of years of schooling. Significant differences in the quality of schooling across countries imply that economic growth rates are more highly correlated with educational achievements than attainment.

The examination of human capital convergence on a regional level leads to ambiguous conclusions. Wheeler (2006), Hammond and Thompson (2010) show tendencies to divergence of human capital measured by the share of highly-skilled employees between US cities and states. In turn, Südekum (2008) analyzing regions of West Germany in 1977–2002 finds robust evidence of human capital convergence – regions with a large initial share of highly-skilled employees had higher total employment growth, but lower growth of highly-skilled jobs. The analyses of human capital or educational achievements convergence on a regional or local level for Poland have not been performed yet.

Only in recent years there appeared empirical works verifying the existence of a relationship between convergence of income and convergence of human capital or education (which is different from using human capital or education as a conditioning factor explaining convergence!). The conclusions are again ambiguous. Wolff (2000) finds convergence of the levels of education between 24 OECD countries in the period 1950–1990 accompanied by the convergence of labour productivity. Berry and Glaeser (2005) confirm the divergence of human capital between US cities and suggest that it is related to the decline of income convergence process. Rattso and Stokke (2014) discover a separate convergence of income and education for 89 Norwegian NUTS4 regions and do not find a statistically significant relationship between these two processes – education level increases in large cities with a limited increase of income in these regions, while the fastest income growth is observed in regions with relatively low and stable education level.

The purpose of this article is to apply the methodology of the analysis of the whole distribution to seek for similarities in convergence processes of income and educational achievements in Poland on a local level (municipalities). We want to verify the research hypothesis that one can observe a parallel convergence process of income and educational achievements on a local level in Poland, i.e. an increase in the relative income is accompanied by the increase of educational achievements in the same regions and vice versa.

### 2. Methodology

The methodology of convergence analysis that allows to observe the dynamics of the whole distribution was proposed by Quah (1993, 1997) and bases on transition matrices (used in Markov chains) and conditional kernel density estimation. Both methods allow to analyze the whole distribution of the analyzed variable and its dynamics in time. Within this alternative framework it is also possible to test for convergence of clubs and polarization.

A discrete variant of the methodology uses transition matrices (Markov chains). The initial distribution of relative *per capita* income (or any other analyzed variable) is divided into several intervals called income groups (classes). Based on that division the transition matrix (M) is estimated. It shows how the whole distribution of relative GDP *per capita* (d) evolves over time<sup>1</sup>:

$$d_t = M \times d_{t-1} \tag{1}$$

The estimated elements of a transition matrix M are interpreted as probabilities of transition between different income groups. One can infer about the percentage of countries or regions which being initially (t1) in a particular income class, stay in it or move to other groups in the next period  $(t2)^2$ .

$$p_{ij} = P(X_{t2} = j | X_{t1} = i) \tag{2}$$

Transition matrix also allows to estimate the long-run evolution of income distribution (ergodic vector)<sup>3</sup>. In convergence analysis the ergodic vector should not be treated as a long-run forecast for income distribution. It is hardly rational to assume that the dynamics of convergence process will be unchanged in the long run. Ergodic vector should be rather interpreted as a synthetic "one number" indicator of the tendencies in the analyzed period and a kind of summarization of transition probabilities.

Convergence will take place if the estimated probabilities in an ergodic vector tend to move towards the group including the average value. If probability mass is concentrating in extreme income groups, there are tendencies to polarization and convergence of clubs. High probabilities on the diagonal of a transition matrix mean strong persistence of the distribution. The limitation of transition matrices is an arbitrary selection of interval boundaries – different divisions may lead to different results and conclusions. To get rid of that limitation Quah proposed to use in addition conditional kernel density estimation of the whole density function of relative income distribution, which is behind the scope of this paper.

In this paper we use an approach which is a simple generalization of the transition matrix. Each group in the initial period and the final period will be defined by two characteristics: a relative income and educational achievements. That would allow to directly observe the joint

 $<sup>^{-1}</sup>$ This method can be compared to the first order autoregression in time series analysis.

<sup>&</sup>lt;sup>2</sup>Therefore all the values in a transition matrix are nonnegative and sum of probabilities in each row equals unity.

<sup>&</sup>lt;sup>3</sup>Transition matrix M raised to power s with  $s \to \infty$  converges to a matrix with rank equal to 1, called an ergodic matrix or an ergodic vector. However, it is not always possible to calculate such an ergodic vector – it depends on the distribution of estimated probabilities within a transition matrix.

two dimensional distribution dynamics. One can therefore think about a transition matrix depicting a final distribution conditioned on the initial distribution as a four dimensional structure. However, it can be easily depicted in a two dimensional contingency table, but requires slightly different interpretation than a simple transition matrix.

### 3. Empirical research framework and results

The empirical research will be based on the data on the level of municipalities<sup>4</sup> from two different public statistics databases. In particular the article will make use of the data on: (1) *per capita* revenue in municipality budget from the share in receipts from personal income tax for the period 2003–2013 (Bank Danych Lokalnych GUS / Local Data Bank, Central Statistical Office) and (2) median results of standardized lower-secondary school leaving exams in Poland (Centralna Komisja Edukacyjna / Central Examination Board) for the period 2003– 2013. Median is used instead of the mean to minimize the impact of outliers on the municipality representative exam score. We base our analyses on the data on exam results transformed by Instytut Badań Edukacyjnych / Institute of Educational Research (see Szaleniec et al., 2015). In case of income data we calculate relative income *per capita* for each municipality by relating the original value of the revenue in municipality budget from the share in receipts from personal income tax to the country average. Therefore we somehow loose information of the overall progress in economic or educational achievements, but instead we concentrate on the analysis of year-by-year mobility within the univariate and joint distributions.

In the first step of the empirical analysis we look on the spatial distribution of both phenomena in the initial (2003) and final (2013) year of our sample. Figure 1 shows the distribution of exam results while Figure 2 represents relative incomes in municipalities.

<sup>&</sup>lt;sup>4</sup>There are 2479 municipalities in Poland, which are grouped in 16 provinces called voivodeships.

Figure 1: Spatial distribution of median exam results on the level of municipalities in 2003 (left) and 2013 (right)



On each map municipalities are divided into 10 equal sized decile groups with respect to the presented variable. Regions with the lowest values are shown in light yellow (the lighter the lower), while the highest values are observed in municipalities colored in red (the darker the higher). In 2003 higher exam results are generally observed in Central, Eastern and South-Eastern regions, while lower values are found in the North-East, West and South-West (see the left map on Figure 1). In 2013 there is no such clear division. The distribution is more diversified, but still more often high exam results are found in the Southern, South-Eastern and Central Poland (see the right map on Figure 1). The spatial distribution of relative income seems to show a different pattern. At the first sight one may conclude that it is very stable over time – the comparison of maps for year 2003 and 2013 does not reveal any significant differences (see Figure 2). In both cases higher values of relative income are observed (in line with expectations) for large cities (e.g. Warszawa, Łódź, Poznań, Wrocław, Gdańsk, Szczecin) and their surroundings, but also for the whole Silesian voivodeship and the Western and South-Western regions of Poland. Figure 2: Spatial distribution of relative income on the level of municipalities in 2003 (left) and 2013 (right)



The initial comparison of distribution dynamics of the two phenomena is presented on Figure 3, which shows a spatial distribution of a change (difference) in relative income and a change in median exam results between the ends of the sample (the value in 2013 minus the value in 2003). Regions with a positive change (increase) are filled in green (the darker the higher the increase) and regions with a negative change are presented in red (the darker the stronger the decrease). There does not seem to be any clear relationship between the two maps. One important observation is that municipalities generally improved in terms of a relative income value (more green units on the left map), while in much more cases the decrease in exam results was observed (much more red on the right map).

The observation about no clear relationship between the distributions is corroborated by a simple Pearson's correlation coefficient between the values presented on the maps – the change in relative income and the change in exam results between 2003 and 2013. The coefficient is equal to -0.01 and is not statistically significant. However, the correlation coefficient between values of relative income and exam results is relatively stable over time and amounts in the analyzed period to about 0.30-0.35 with few exceptions, especially at the beginning of the period – see Table 1.

Figure 3: Spatial distribution of a change in relative income (left) and a change in median exam results (right) on the level of municipalities between 2003 and 2013



Table 1: Pearson's correlation between *per capita* income and exam results on the level of municipalities in the period 2003-2013

year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
correlation	0.08	0.2	0.24	0.35	0.32	0.33	0.32	0.35	0.24	0.31	0.29
Note: all values are statistically significant.											

Figure 4: Coefficient of variation of relative income and median exam results on the level of municipalities in the period 2003 and 2013



The next step of looking for similarities of the two distributions is comparing a single

measure of their dispersion and its dynamics over time (i.e. so called sigma convergence). As the two phenomena have different distributions, we use the coefficient of variation (CV), which is depicted on Figure 4. In general, for both relative income and exam results one can observe a decrease in the level of disparities – CV for income decreases from 67.5 in 2003 to 56.9 in 2013 (scale on the left vertical axis), while CV for exams decreases from 5.4 in 2003 to 4.3 in 2013 (scale on the right vertical axis). This means that one could observe absolute sigma convergence process for educational achievements and for relative income on a local level in Poland. What is more, the lines seem to follow very similar trends, mainly between 2004 and 2010 (in this period they are almost parallel) – correlation of both CVs in this period is equal to 0.8, which reduces to 0.31 for the whole sample.

Having found similarities in convergence process indicated by a single dispersion measure, we move forward to analyzing potential similarities in transition matrices, which depict mobility within the whole distribution over time. The starting point of this part is the analysis of distribution dynamics for each of the phenomena separately. We estimated and compared transition matrices for a relative income and for exams results, which related to a direct transition, i.e. distribution dynamics just between extreme years of the sample period – 2003 and 2013, without taking into account distributions in intermediate years.

At first we estimated a transition matrix for a relative *per capita* income. The full range of values was divided into five groups (classes) and the borders between groups were based on quintiles of the initial relative income. Therefore, initially (in 2003) the groups were equal-sized. Estimation results are shown in Table 2 – row headers inform about the initial group (and also initial size of each group), while column headers include information about final groups (and intervals defining groups – which were kept fixed). For example the lowest group 1 included initially 20% of the poorest municipalities (496 administrative units), which had relative income lower or equal to 29.45% of the country average. The richest group 5 in turn included initially 496 (20%) municipalities with a relative *per capita* income above 73.86% of the country average. Values in table cells sum up to 100 in each row and are interpreted as the probability of stability of the distribution or mobility between groups for a particular initial class of income<sup>5</sup>.

For example for municipalities that were initially in the poorest group 1 the probability of staying in the same group in the final period (having *per capita* GDP lower than 29.45% of the average also in 2013) was equal to 49.6%, while the probability of moving to the second group was equal to 39.1% and with the probability of 0.4% the relative income of such municipality could increase above 73.86% of the country average. Generally values on the diagonal show relatively strong persistence of the distribution – here the average probability of staying in the

 $<sup>{}^{5}</sup>$ For ease of interpretation the background of each cell is filled with a color relating to its value – from dark red for the lowest to dark green for the highest.

	group 1	group2	group 3	group4	group 5
	<= 29.45%	(29.45%, 37.53%]	(37.53%, 49.14%]	(49.14%, 73.86%]	>73.86%
group 1 (496)	49.6	39.1	9.3	1.6	0.4
group 2 (496)	6.2	38.3	47.0	8.1	0.4
group 3 (495)	0.4	7.5	48.1	41.0	3.0
group 4 (496)	0.2	0.8	7.9	71.4	19.8
group 5 (496)	0.0	0.4	0.0	10.5	89.1
ergodic	0.4	1.9	6.7	32.2	59.5

Table 2: Transition matrix for relative per capita income distribution between 2003 and 2013

Note: division into groups based on quintiles of the initial distribution.

same group is equal to 59.3% and is the highest for the two richest groups. The results indicate relatively high probability of moving to upper (richer) classes for three lowest quintile groups on the relative income ladder. Together with the two richest groups being most stable, that produces the ergodic distribution which shows strong concentration of long term probabilities in two upper groups (above 90% in total). As the highest group includes the average value of the relative income, these results indicate convergence process for income on a local level.

Table 3 shows results of similar estimation of the transition matrix with five classes based on the quintiles of the initial distribution, but for educational achievements. One can observe much weaker persistence of the distribution of exam results - the probability of staying in the same group was on average equal to 28.8% and did not differ much across groups (relatively highest for the lowest group – municipalities with the worst exam results). Mobility between groups is higher than in the case of relative income distribution – all cells include non-zero probabilities, which means that mobility between all groups was observed in both directions. The highest probabilities concentrate along the diagonal, however not as strongly as in the previous transition matrix. But similarly as before, the probabilities to the right from the diagonal are higher than the ones to the left. This indicates a higher chance of improving than decreasing exam results during the analyzed period. However, keeping educational achievements on the highest level (above 102.86 – as in group 5) is not highly probable (23.8%). That is why the ergodic vector indicates that if such dynamics as described by the estimated transition matrix was observed in a long run, only groups 3 and 4 would relatively increase their size (to about 25.5% and 25.7% – while initially all groups were equal sized). As these two groups are located around the average value of the exam (100), estimation results suggest a convergence process (in the long run more municipalities will have their exam results close to the average, so the distribution will be more concentrated around the mean), which however is relatively weak and slow as these groups do not increase their size significantly.

After the analysis of dynamics of univariate distributions, the remaining part of the empirical

	group 1 <= 94.64	group 2 (94.64, 97.15]	group 3 (97.15, 99.49]	group 4 (99.49, 102.86]	group 5 > 102.86
group 1 (496)	35.5	23.6	23.4	13.7	3.8
group 2 (496)	20.6	22.0	29.2	22.4	5.8
group 3 (494)	15.2	16.6	29.1	27.9	11.1
group 4 (497)	12.1	13.5	23.7	33.8	16.9
group 5 (496)	13.9	13.9	20.2	28.2	23.8
ergodic	19.2	17.8	25.5	25.7	11.8

Table 3: Transition matrix for median exam results between 2003 and 2013

Note: division into groups based on quintiles of the initial distribution.

analysis will be devoted to the verification of potential co-movement of the distributions. One could observe indications of the convergence process for both phenomena – somehow stronger for income distribution, which was strongly persistent and weaker for educational achievements, where mobility within the distribution was much more pronounced. The analysis of the joint distribution was based on the division of each of the variables into five quintile groups based on their initial distribution (in 2003), in the same way as described above. Therefore considering these two partitions together introduces 25 classes with similar frequencies, but not necessarily exactly equal sized. The initial two dimensional distribution of relative income and educational achievements is presented in Table 4.

Table 4: Initial (2003) joint distribution for relative income and exam results

				income			
		group 1	group 2	group 3	group 4	group 5	
		<= 29.45%	(29.45%, 37.53%]	(37.53%, 49.14%]	(49.14%, 73.86%]	>73.86%	total
	group 1: <= 94.64	99	121	136	99	41	496
	group 2: (94.64, 97.15]	99	101	93	113	90	496
exams	group 3: (97.15, 99.49]	93	84	96	100	121	494
	group 4: (99.49, 102.86]	76	88	77	114	142	497
	group 5: > 102.86	129	102	93	70	102	496
	total	496	496	495	496	496	2479

Note: division into groups based on quintiles of the initial marginal distributions.

One can observe that in the highest income group exam results are also relatively high – there are just 41 municipalities in this group with the lowest educational achievements. In turn for low (but not the lowest) income groups (2 and 3) the frequencies of municipalities with low and the lowest exam results (row groups 1 and 2) are clearly higher than the ones with better educational achievements. An interesting distinction from this pattern is found for the poorest municipalities, where the frequency of a class with highest exam results is far above the numbers in remaining classes. The Chi-square test of independence applied on above results led to strong rejection of the hypothesis assuming no relationship between the distributions (test statistic = 113.77, p-value < 0.0001), but the relationship is very weak (Cramer's V = 0.107, Spearman's correlation coefficient = 0.054).

				income			
		group 1	group 2	group 3	group 4	group 5	
		<= 29.45%	(29.45%, 37.53%]	(37.53%, 49.14%]	(49.14%, 73.86%]	>73.86%	total
	group 1: <= 94.64	75	102	130	138	37	482
	group 2: (94.64, 97.15]	58	75	116	127	68	444
exams	group 3: (97.15, 99.49]	63	109	139	157	155	623
	group 4: (99.49, 102.86]	57	98	115	175	180	625
	group 5: > 102.86	27	43	56	60	119	305
	total	280	427	556	657	559	2479

Table 5: Final (2013) joint distribution for relative income and exam results

Note: division into groups based on quintiles of the initial marginal distributions.

The same comparison of the distributions was done for the final period (2013), which is summarized in Table 5. One can observe clear mobility towards higher income groups (total frequencies of groups 3, 4, and 5 increased in comparison with the initial distribution) and towards classes with exam results close to 100 (group 3 and 4), which was already observed in the univariate analysis. At the first sight the relationship between the two variables seems to be stronger in 2013 than in 2003, which is corroborated by the Chi-square test result (test statistic = 149.35, p-value < 0.00001), Cramer's V = 0.123 and Spearman's correlation coefficient = 0.195. The relationship is still relatively weak but stronger than before.

Finally we estimated a transition matrix for a two dimensional distribution – the division into above mentioned 25 groups defined by the quintile groups of relative income and independently calculated quintile groups of exam results. The results of the analysis are summarized in Table 6 (sorted by income classes). Groups with the same value of income are outlined with thicker lines and within each such group five additional classes related to exam results are distinguished. Based on estimation results one can observe clear concentration of transition probabilities within the same or similar income groups – most of low or zero transition probabilities are far away from the diagonal – either in top right or bottom left corner of the table and relatively high probabilities along the diagonal of the two dimensional table. This corroborates relatively high stability of income distribution. However, for a particular relative income (outlined 5x5 groups on the diagonal of the table) there might be almost any movements with respect to educational achievements – (almost) all cells within each diagonal income subgroup have non-zero transition probabilities. Therefore mobility within the joint distribution with respect to exam results is much higher than with respect to the values of income.

	4 e5													0.	.3 1.3	.1	.0 1.0	8.	.0 3.0	.3 2.6	.1 7.1	.6 2.4	.8 8.9	.9 10.7	.5 22.5	.5 51.0	0 16 1
le 5	8 e/	0.			e.		∞.	0.				6.	.1	1	1	1 1	.0 3.	.3 1	.0 11	.1 5	0 7	4 14	.2 17	.4 33	.4 41	.8 27	0
incom	e3	1			1		0	1				5 2	1		3	2 1	0 4	9 5	0 5	0 6	10	2 24	8 32	9 31	6 20	9 9	1
	e2											1.			1.	2.	4.	0	.9 (	7.		12.	17.	9.	5.	2.	
	e1																5.1	2.7	2.0	0.9		22.0	10.0	4.1	1.4	1.0	0 0
	е5				1.3		0.8		1.2	1.1		2.9	1.1	6.3	3.9	5.4		4.4	7.0	9.6	10.0		2.2	2.5	0.7	1.0	0 0
4	e4						3.3	1.0	1.2	3.4	3.9	2.9	12.9	9.4	13.0	14.0	9.1	20.4	18.0	28.1	21.4	9.8	2.2	1.7	3.5	3.9	00
JCOME	e3	1.0						2.0	2.4	3.4	3.9	14.0	14.0	7.3	14.3	4.3	13.1	15.0	23.0	14.0	17.1	2.4	3.3	3.3		2.0	C 2
Ŀ.	e2	1.0	1.0		1.3		0.8	3.0	3.6	1.1		8.1	5.4	6.3	3.9	4.3	18.2	23.9	13.0	10.5	14.3	2.4	1.1	1.7	1.4	1.0	U U
	e1	1.0	1.0			0.8		2.0		1.1	2.0	11.8	14.0	7.3	6.5	12.9	27.3	15.9	5.0	10.5	5.7	9.8	3.3	0.8	2.1		u u
	е5		1.0		2.6	1.6	2.5	1.0	4.8	5.7	9.8	2.2	2.2	5.2	9.1	8.6	1.0				2.9						
3	e4		3.0	4.3	1.3	2.3	5.0	9.6	11.9	8.0	9.8	4.4	9.7	13.5	15.6	16.1	3.0	0.9		0.9	1.4						, ,
come	e3	1.0	1.0	4.3	1.3	2.3	9.9	12.9	14.3	8.0	14.7	9.6	10.8	14.6	11.7	9.7	4.0	4.4	1.0	3.5	1.4						1
i	e2	3.0	3.0	2.2		1.6	16.5	9.9	6.0	11.4	4.9	12.5	11.8	14.6	1.3	9.7	3.0	0.9									, ,
	e1	3.0	3.0	2.2		1.6	16.5	5.9	16.7	10.2	8.8	17.6	7.5	8.3	10.4	4.3	4.0	2.7	4.0								1
	е5	1.0	1.0	1.1	7.9	8.5	1.7	4.0	4.8	5.7	4.9			2.1	1.3												,
2	e4	3.0	9.1	5.4	10.5	14.7	9.9	10.9	10.7	10.2	7.8	1.5	2.2		2.6	1.1							1.1		0.7		0
come	e3	10.1	15.2	10.8	10.5	5.4	6.6	11.9	13.1	9.1	10.8	0.7	3.2	1.0	2.6					0.9	1.4						N O
ine	e2	5.1	6.1	7.5	7.9	4.7	9.1	11.9		6.8	7.8	2.2				4.3		0.9									0
	e1	15.2	7.1	7.5	3.9	14.0	14.0	6.9	3.6	4.5	6.9	5.1	4.3	2.1					1.0								70
	е5	2.0	4.0	6.5	5.3	7.8				1.1																	00
	e4	8.1	9.1	12.9	13.2	9.3	1.7		1.2	1.1						1.1			1.0								6
ome 1	e3	12.1	13.1	10.8	10.5	8.5	0.8	1.0	1.2	3.4	2.0			1.0													0
inc	e2	11.1	8.1	11.8	7.9	10.9	0.8	3.0	1.2	2.3	1.0																0
	e1	21.2	14.1	12.9	13.2	6.2	2.5	2.0	2.4	2.3	1.0																0
		exams 1	exams 2	exams 3	exams 4	exams 5	exams 1	exams 2	exams 3	exams 4	exams 5	exams 1	exams 2	exams 3	exams 4	exams 5	exams 1	exams 2	exams 3	exams 4	exams 5	exams 1	exams 2	exams 3	exams 4	exams 5	,dic
		income 1						income 3					income 4					income 5			orac						

Table 6: Transition matrix for a joint distribution between 2003 and 2013 – sorted by income groups

ij					1.0	2.4					8.9				3.0	10.7			1.3	2.6	22.5				7.1	51.0	16.1
i4	5		0.8	2.9					1.1	4.4	2.2		1.2	6.3	7.0	2.5	1.3	1.1	3.9	9.6	0.7			5.4	10.0	1.0	2.9
i3	xams		2.5	2.2	1.0		1.0	1.0	2.2				4.8	5.2			2.6	5.7	9.1			1.6	9.8	8.6	2.9		0.5
i2	е	1.0	1.7				1.0	4.0				1.1	4.8	2.1			7.9	5.7	1.3			8.5	4.9				0.1
i1		2.0					4.0					6.5					5.3	1.1				7.8					0.0
i5					3.0	14.6				1.8	17.8			1.0	11.0	33.9			1.3	5.3	41.5			1.1	7.1	27.5	21.9
i4	4		3.3	2.9	9.1	9.8		1.0	12.9	20.4	2.2		1.2	9.4	18.0	1.7		3.4	13.0	28.1	3.5		3.9	14.0	21.4	3.9	8.6
13	xams 4		5.0	4.4	3.0		3.0	9.9	9.7	0.9		4.3	11.9	13.5			1.3	8.0	15.6	0.9		2.3	9.8	16.1	1.4		1.2
i2	e	3.0	6.6	1.5			9.1	10.9	2.2		1.1	5.4	10.7				10.5	10.2	2.6		0.7	14.7	7.8	1.1			0.5
i1		8.1	1.7				9.1					12.9	1.2		1.0		13.2	1.1				9.3		1.1			0.1
i5		1.0	0.8	2.9	4.0	24.4		1.0	1.1	5.3	32.2				5.0	31.4	1.3			6.1	20.4			1.1	10.0	9.8	15.3
i4	3	1.0		14.0	13.1	2.4		2.0	14.0	15.0	3.3		2.4	7.3	23.0	3.3		3.4	14.3	14.0			3.9	4.3	17.1	2.0	6.7
ij	xams	1.0	9.9	9.6	4.0		1.0	12.9	10.8	4.4		4.3	14.3	14.6	1.0		1.3	8.0	11.7	3.5		2.3	14.7	9.7	1.4		1.8
i2	e	10.1	6.6	0.7			15.2	11.9	3.2			10.8	13.1	1.0			10.5	9.1	2.6	0.9		5.4	10.8		1.4		0.4
i1		12.1	0.8				13.1	1.0				10.8	1.2	1.0			10.5	3.4				8.5	2.0				0.1
i5				1.5	4.0	12.2				0.9	17.8				6.0	9.9			1.3	7.0	5.6			2.2		2.9	6.0
i4	2	1.0	0.8	8.1	18.2	2.4	1.0	3.0	5.4	23.9	1.1		3.6	6.3	13.0	1.7	1.3	1.1	3.9	10.5	1.4			4.3	14.3	1.0	5.9
ij	kams 2	3.0	16.5	12.5	3.0		3.0	9.9	11.8	0.9		2.2	6.0	14.6				11.4	1.3			1.6	4.9	9.7			1.0
i2	e)	5.1	9.1	2.2			6.1	11.9		0.9		7.5					7.9	6.8				4.7	7.8	4.3			0.2
i1		11.1	0.8				8.1	3.0				11.8	1.2				7.9	2.3				10.9	1.0				0.1
ij					5.1	22.0				2.7	10.0				2.0	4.1				0.9	1.4					1.0	3.0
i4		1.0		11.8	27.3	9.8	1.0	2.0	14.0	15.9	3.3			7.3	5.0	0.8		1.1	6.5	10.5	2.1	0.8	2.0	12.9	5.7		5.5
ij	ams 1	3.0	16.5	17.6	4.0		3.0	5.9	7.5	2.7		2.2	16.7	8.3	4.0			10.2	10.4			1.6	8.8	4.3			1.5
i2	e	15.2	14.0	5.1			7.1	6.9	4.3			7.5	3.6	2.1	1.0		3.9	4.5				14.0	6.9				0.4
i1		21.2	2.5				14.1	2.0				12.9	2.4				13.2	2.3				6.2	1.0				0.1
				exams 1					exams 2					exams 3					exams 4					exams 5			dic
		income 1	income 2	income 3	income 4	income 5	income 1	income 2	income 3	income 4	income 5	income 1	income 2	income 3	income 4	income 5	income 1	income 2	income 3	income 4	income 5	income 1	income 2	income 3	income 4	income 5	ergo(

Table 7: Transition matrix for joint distribution between 2003 and 2013 – sorted by exam groups

Another observation indicates that there are much higher probabilities in the subgroups above the diagonal than below, which is in line with the previous findings showing higher probabilities of becoming relatively richer (moving to higher income groups), but this may be accompanied by any change (stability, increase or decrease) in educational achievements. The ergodic distribution shows strong concentration of long run probability in the two upper income groups – for all exam results they cover 92% of the probability mass. What is also interesting, the three top classes of educational achievements within the highest income group include above 53% of the ergodic probability mass, which suggests that together with increasing relative income, educational achievements might also improve.

Table 7 includes exactly the same information as Table 6, but the rows and columns are sorted differently – with respect to educational achievements. Groups with the same value of exam results are outlined with thicker lines and within each such group five additional classes related to relative income are distinguished. This form of the table clearly shows a different pattern of mobility within the marginal distribution of education as compared to income dynamics. Here one does not observe empty table corners (with zero probabilities) as seen in Table 6. Instead, those empty corners far from the diagonal are clearly observed in each subgroup related to particular quintile group of exam results. This corroborates previous findings that mobility within the distribution of income is much smaller than the movements between different educational results classes. In case of income a municipality can most probably stay in the same group or move to the adjacent class, while in case of exam results it may jump between the extreme ends of the scale. One of the explanations for that difference might be much smaller disparities of exam results between municipalities in comparison to relative income diversity (see again Figure 4).

To simplify the interpretation of estimated transition probabilities for a two-dimensional distribution we aggregated selected probabilities for each income-exams group. Table 8 shows probabilities of staying within the same group (% stable) with respect to income, exam results or both. It also presents how probable it is for a region from a particular group to improve (% increasing) or worsen (% decreasing) its relative income, exam result or both.

One can observe once again that income distribution is much more persistent than exam results distribution and the strongest persistence is observed for richer regions (income group 4 and 5). Keeping relatively stable both income and exam results is also much more probable in two highest income groups.

For poorer regions (income groups 1–3) with lowest exam results (exams 1 and 2) the probability of improving just the exam results (55-65%) is always slightly higher than the probability of becoming relatively richer (45–55%). The probability of improving with respect to both exam results and income is also relatively high in these groups and ranges to 30-40%.

For richer regions (income groups 4 and 5) with highest exam results (exams 4 and 5) the probability of decreasing just the exam results (30-80%) is always significantly higher than the probability of becoming relatively poorer (5-8%). Based on these results one can conclude that the increase in relative income was not accompanied by the increase of educational achievements in the same regions and vice versa.

The probability of increasing relative income is in all groups higher than the probability of decreasing (apart from extreme income groups when one of the probabilities cannot be calculated – highest income cannot further increase and vice versa). In case of exam results, the probability of increasing is higher in lower groups and lower in groups with higher initial educational achievements.

			% sta	able		% incre	easing	% decreasing			
initial	group	inc	exam	inc+exam	inc	exam	inc+exam	inc	exam	inc+exam	
income 1	exams 1	55%	40%	21%	45%	60%	26%	0%	0%	0%	
income 1	exams 2	48%	18%	8%	52%	57%	30%	0%	25%	0%	
income 1	exams 3	55%	26%	11%	45%	30%	11%	0%	44%	0%	
income 1	exams 4	50%	25%	13%	50%	17%	12%	0%	58%	0%	
income 1	exams 5	43%	18%	8%	57%	0%	0%	0%	82%	0%	
income 2	exams 1	38%	33%	14%	56%	67%	40%	6%	0%	0%	
income 2	exams 2	46%	28%	12%	49%	55%	28%	6%	17%	2%	
income 2	exams 3	32%	31%	13%	62%	36%	19%	6%	33%	4%	
income 2	exams 4	36%	23%	10%	53%	14%	7%	10%	64%	8%	
income 2	exams 5	38%	15%	5%	58%	0%	0%	4%	85%	4%	
income 3	exams 1	46%	35%	18%	44%	65%	32%	10%	0%	0%	
income 3	exams 2	42%	17%	12%	48%	57%	29%	10%	26%	4%	
income 3	exams 3	56%	24%	15%	38%	38%	17%	6%	39%	2%	
income 3	exams 4	48%	32%	16%	45%	16%	5%	6%	52%	3%	
income 3	exams 5	48%	14%	9%	45%	0%	0%	6%	86%	6%	
income 4	exams 1	68%	36%	27%	17%	64%	12%	15%	0%	0%	
income 4	exams 2	80%	27%	24%	11%	52%	7%	10%	21%	3%	
income 4	exams 3	66%	29%	23%	27%	40%	14%	7%	31%	5%	
income 4	exams 4	73%	34%	28%	22%	12%	3%	5%	54%	4%	
income 4	exams 5	69%	20%	10%	24%	0%	0%	7%	80%	4%	
income 5	exams 1	76%	32%	22%	0%	68%	0%	24%	0%	0%	
income 5	exams 2	87%	19%	18%	0%	68%	0%	13%	13%	3%	
income 5	exams 3	90%	35%	31%	0%	49%	0%	10%	17%	2%	
income 5	exams 4	92%	46%	42%	0%	23%	0%	8%	31%	4%	
income 5	exams 5	92%	52%	51%	0%	0%	0%	8%	48%	7%	

Table 8: Aggregated probabilities based on a two-dimensional transition matrix

Based on the ergodic probabilities from the transition matrix estimated for the two dimen-

sional distribution (Table 6 or Table 7) one can calculate the ergodic (long-run) distribution of municipalities between the assumed 25 income/education groups – see Table 9. This should not be treated as the long-run prediction, rather a kind of a simple summary of what would the joint distribution look like if its dynamics in the long run was the same as observed in the sample period (according to the estimated transition matrix).

				income			
			group2	group 3	group 4		
		group 1	(29.45%,	(37.53%,	(49.14%,	group 5	
		<= 29.45%	37.53%]	49.14%]	73.86%]	>73.86%	total
	group 1: <= 94.64	2	9	37	138	74	261
S	group 2: (94.64, 97.15]	2	6	26	145	148	327
хап	group 3: (97.15, 99.49]	2	11	45	165	378	601
ē	group 4: (99.49, 102.86]	3	12	29	214	543	802
	group 5: > 102.86	1	3	13	73	399	488
	total	11	42	149	735	1542	2479

Table 9: Ergodic joint distribution for relative income and educational results

Note: based on the estimated transition matrix. Division into groups based on quintiles of the initial marginal distributions.

One can clearly see that the largest frequencies concentrate in the highest relative income group (which includes an average income – the value of 100%) and the second highest and in terms of educational achievements the largest frequencies are observed for the three highest exam results groups – group 4 with the value of 100 and two adjacent groups 3 and 5. This can be even clearer when one compares the ergodic distribution with the initial one, which is depicted in Table 10.

Table 10: Long term mobility within the joint distribution – difference between the ergodic and initial distribution

				income			
			group2	group 3	group 4		
		group 1	(29.45%,	(37.53%,	(49.14%,	group 5	
		<= 29.45%	37.53%]	49.14%]	73.86%]	>73.86%	total
	group 1: <= 94.64	-97	-112	-99	39	33	-235
S	group 2: (94.64, 97.15]	-97	-95	-67	32	58	-169
xam	group 3: (97.15, 99.49]	-91	-73	-51	65	257	107
ê	group 4: (99.49, 102.86]	-73	-76	-48	100	401	305
	group 5: > 102.86	-128	-99	-80	3	297	-8
	total	-485	-454	-346	239	1046	0

Note: division into groups based on quintiles of the initial distribution.

Here one can observe a very clear vertical pattern – all numbers in the last two column groups (relatively highest incomes) are positive while the first three columns include only negative

numbers. And within these last two columns the largest differences are found in row groups 3, 4 and also 5.

## Conclusions

The purpose of that article was to analyze the relationship between convergence of income and educational achievements on a local level in Poland in the period 2003–2013. We wanted to verify if and how the convergence processes of these two phenomena are related to one another on the level of municipalities. Income was measured in terms of *per capita* revenue in municipality budget from the share in receipts from personal income tax. Educational achievements were measured by the median results of standardized lower-secondary school leaving exams. The evolution of the joint distribution of income and educational achievements was analyzed with the use of a transition matrix generalized for two-dimensional distributions.

The analysis showed that in regions with initially the highest relative income also initial educational achievements are usually equal to or higher than the average for the whole country. The joint distribution is relatively stable over time, but there are weak indications of convergence both for income and educational achievements. Mobility within the joint distribution with respect to exam results was much higher than with respect to the values of income. The largest mobility was observed for the groups with the lowest or low initial income or the highest educational achievements. In turn, the strongest persistence was found for the groups initially the richest or with high educational achievements. Joint distribution dynamics shows that for regions with the lowest exam results the probability of improving low exam results is equal to or higher than the probability of becoming richer (for all income groups). The three top classes of educational achievements within the highest income group included above 53% of the ergodic probability mass, which suggests that together with increasing relative income, educational achievements might also improve. However, as the comparison of probabilities shows, the increase in the relative income was not neccesarily accompanied by the increase of educational achievements in the same regions and vice versa.

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