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The impact of the regional price deflators on regional income convergence in Poland

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Abstract

This paper compares the impact of regional price deflators on the results of convergence analysis at different levels of territorial aggregation. We take as an example the evolution of income disparities between 16 NUTS2 and 66 NUTS3 Polish regions. We find that the real regional income disparities are lower than the nominal ones and that the difference is greater at the NUTS3 level. Also, the application of regional price deflators seems to have a certain impact on the results of the analysis devoted to the dynamics of the regional income distribution.

Keywords: regional income convergence, PPP deflators, spatial spillovers

JEL: E30, O10, R10

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1 Introduction

Many papers have focused on the evolution of regional income convergence between and within different countries, with the European Union being a particular focus of attention. The pioneering studies by Barro and Sala-i-Martin (1991, 1992) showed a negative relationship between economic growth rate and the initial level of income both across US states and across European regions. Their findings concerning the existence of an absolute β-convergence across both 73 Western European regions and the regions within particular countries raised a discussion about regional income dynamics.

The estimated 2% yearly speed of the convergence process reported by Barro and Sala-i-Martin (1991, 1992) has been the subject of particular controversies. Here, many other studies have revealed that the speed of convergence appears to depend on the estimation strategy applied by the researchers (e.g. Abreu, de Groot, Florax 2005; Arbia, Le Gallo, Piras 2008; Mur, López, Angulo 2010). Moreover, several papers show that although there is a clear convergence process at the EU Community level, at the same time regional income disparities are either stable or even increasing within particular countries. This applies particularly to the EU new member states that joined from 2004 onwards (e.g. Artelaris, Kallioras, Petrakos 2010; Paas, Schlitte 2007).

In the case of the European Union, the interest in the evolution of regional income disparities goes far beyond the typical scientific purposes. Articles 158–162 of the Treaty establishing the European Communities lay down that the Union should promote an overall harmonious development and strengthen economic and social cohesion by reducing development disparities between the regions. As a result, the EU cohesion policy, with its EUR 351 billion allocation, accounts for about a half of the Community budget between 2014 and 2020. The poorest regions and countries are considered an absolute priority under that policy. Hence, the analysis of the evolution of regional per capita GDP plays a crucial role, both at the time of determining the regional allocation of funding, and at the time of evaluating the long-term results of the cohesion policy.

This paper investigates the possible impact that the inclusion of regional PPP deflators may have on the results of the analysis of regional income disparities within a given country. In particular it compares the results of convergence analysis, in the case of Poland between 2000 and 2012 at the NUTS2 and the NUTS3 level, based on the real per capita GDP (nominal data deflated by regional PPP deflators) and nominal per capita GDP. We consider both β-convergence and σ-convergence approaches and apply different non-parametric techniques in order to show that the results of previous studies may overestimate the overall level of regional income disparities and may lead to slightly different conclusions concerning regional convergence patterns. This is due to the fact that the better developed regions tend to have higher regional prices. Hence, in nominal terms (or deflated using the national price average) they appear to be richer than they really are. At the same time, areas lagging behind seem to be doing relatively worse than they should.

The remainder of the paper is organized as follows. In the next section, we summarize the main findings concerning the evolution of regional income disparities between and within EU member states. Thereafter, we describe the research methodology and data used in our study. In Section 4, we discuss the results of empirical analysis based on the regression approach to convergence analysis at the NUTS2 and NUTS3 level regions. Section 5 shows the results of a non-parametric approach that applies a stochastic kernel to analyse convergence patterns at different levels of territorial aggregation. Finally, we summarize our findings in the concluding section.

2 Literature review

Two concepts of income convergence are usually distinguished in the literature: β-convergence and σ-convergence. The first one describes the catching up process that, according to the neoclassical growth model, should be experienced by poor economies. Still, it is necessary to remember that the neoclassical growth model predicts absolute convergence only in the case of identical economies. Thus, there is an absolute (unconditional) β-convergence where locations with low per capita income grow faster than the rich ones, irrespective of all other factors. On the other hand, σ-convergence occurs once the dispersion of per capita income among different regions diminishes over time. The two concepts of convergence are closely related as there cannot be σ-convergence without β-convergence. Still the presence of β-convergence is a necessary but not a sufficient condition for σ-convergence (see for example Sala-i-Martin 1996 for more details about two concepts of convergence).

Unfortunately, the results of empirical research for European regions are not exempt from controversy. In fact, the discussion about the patterns of convergence in Europe began after the publication of empirical studies by Barro and Sala-i-Martin in the early 1990s (Barro, Sala-i-Martin 1991, 1992; Sala-i-Martin 1996). They found that there was an absolute β-convergence both across all European regions and across the regions within particular countries. Surprisingly, the speed of convergence was very similar in all cases – about 2% yearly. Moreover, they claimed that the dispersion of per capita income within the five larger European countries (France, Germany, Italy, Spain and the UK) had declined between 1950 and 1990.

However, many other studies show that even if there is a convergence process at the Community level, at the same time regional income disparities are either stable or increasing within particular countries. Cappelen et al. (2003) investigate 105 European regions between 1980 and 1997 and show there is a weak σ-convergence between all of them. However, it turns out that there is a divergence once Greek, Portuguese and Spanish regions are excluded. Furthermore, there is no convergence within countries. Arbia and Paelinck (2003) analyse the dynamics of per capita income in 119 NUTS-2 European regions between 1985 and 1999 and find that that European regions do not converge to a common value in terms of income per capita. Fischer and Stumpner (2008) suggest that there is a tendency towards regional cohesion in Europe; however, they also find that the cross-section distribution of regional per capita income is likely to split up into two separate groups (richer metropolitan regions and the rest). Landesmann and Römisch (2006) focus on the EU NUTS2 and NUTS3 regions during the 1995–2002 period and find that regional income disparities have increased within all new member states and most of the old member states. Paas and Schlitte (2007) reveal an absolute β-convergence among all 861 EU NUTS3 regions with a speed of around 2% yearly between 1995 and 2003. On the other hand, they claim there is no convergence within most of the EU25 countries. Moreover, there is a divergence within the group of new member states (NMS). The ongoing regional divergence process within the NMS is particularly well documented in the case of Poland (e.g. Artelaris, Kallioras, Petrakos 2010; Czyż, Hauke 2011; Herbst, Wójcik 2012).

The criticism concerning the initial findings of Barro and Sala-i-Martin is also based on methodological issues. For instance, Cameron and Muellbauer (2000) claim that, because of statistical data inaccuracy, their results describing regional convergence within the UK are certainly biased. Abreu, de Groot and Florax (2005) use meta-analysis based on over 600 estimates taken from different growth studies to investigate whether there is substance to the “myth” of the 2%. They find that different specifications correcting for omitted variable bias, addressing endogeneity in the explanatory variables or using different estimators (e.g. GMM or LSDV) typically lead to estimations higher than the "legendary" 2% convergence rate. As a matter of fact, the average convergence rate resulting from their meta-analysis is 4.3%. Arbia, Le Gallo and Piras (2008) discuss the impact of different spatial specifications on convergence analysis. They show that using the same regional data in different specifications, we may obtain a convergence rate of between 0.13% and 2.54%. Generally, the inclusion of spatial effects leads to an increase in the convergence rate.

Abreu, de Groot and Florax (2005) point out another important issue concerning the results of convergence analysis. Their hypothesis is that the use of purchasing power parity (PPP) rates leads to higher estimates of the rate of convergence as compared to the use of market exchange rates. The latter makes poor countries appear poorer than they actually are. They claim that the use of PPPs raises the estimated rate of convergence by 1.8 percentage points. The above argument can also be applied in the case of the regional income convergence analysis within particular countries. Here, the use of average national price deflators may lead to serious biases, since it has been shown that higher nominal wages reflect to some extent higher regional prices (e.g. Tabuchi 2001). Hence, poorer regions with lower nominal wages and income per capita appear to be even poorer once the average price deflators are applied. Exactly the opposite happens with the better-off areas.

It would appear that the issue of differences in regional price indices may have an impact on the results of regional income convergence analysis within particular countries; however, this possibility has not been addressed in any study concerning EU member states.[1] Several papers try to take into account regional price differentials within the analysis of distribution or evolution of regional wages (e.g. Blien et al. 2009; Rokicki 2013). Blien et al. (2009) show that the application of imputed price levels significantly changes the results of the estimations concerning the agglomeration wage differentials. Rokicki (2015) claims that the applications of regional PPP deflators significantly decrease the overall level of wage dispersion, although the overall impact on the results of the convergence analysis is rather moderate.

This paper adds to the existing literature by demonstrating the impact of the regional PPP deflators on the analysis of regional income disparities within a given country. In particular, it compares the results of convergence analysis, in the case of Poland between 2000 and 2012 using both NUTS2 and NUTS3 level data, based on the per capita GDP deflated by regional PPP deflators and a nominal one. The existing studies tend to use nominal data deflated by national PPP deflators in order to express data in constant prices, which allows to conduct the analysis for different member states. Yet, the application of national PPP deflators has no impact on convergence analysis within a particular country, as compared to analysis based on data expressed in current prices (e.g. nominal per capita GDP). Our paper can be considered an extension of a recent study by Rokicki and Hewings (2016), who introduce regional price deflators into regional convergence analysis taking as an example the US states and Polish NUTS2 regions. In the present paper we aim to expand their analysis using different levels of territorial aggregation for the same country – NUTS2 vs. NUTS3 regions.[2] We also extend the time span by adding one more year (2000–2012 vs. 2000–2011). Finally, we apply a set of non-parametric tools that were not used in the aforementioned paper.

[1] With the exception of a recent study by Rokicki and Hewings (2016). They compare the impact of regional PPP deflators on income convergence across US states and Polish NUTS2 regions applying standard convergence analysis only.

[2] Also, regional price deflators at the NUTS3 level are based on different methodological approach that the ones for the NUTS2 level regions.

3 Research methodology and data

Most of the studies dealing with the regional convergence issues use cross-section analysis to verify the existence of either the β-convergence or σ-convergence process. These concepts rely on the neoclassical growth theory assumptions (e.g., Solow 1956) that lead to the conclusion that regions with similar technology, savings rate and population growth should eventually reach the same level of per capita income. The existence of absolute β-convergence suggests that lower income regions grow faster than the high income ones; this is a necessary but not sufficient condition for the reduction of regional income disparities (σ-convergence).

In this study, we verify the impact of regional price deflators on different specifications of β-convergence (absolute, conditional and spatial) and σ-convergence, using panel data over the 2000–2012 period. The baseline β-convergence regressions are based on panel estimation of the classical unconditional convergence equation:

$$\ln\left(\frac{y_{i,t}}{y_{i,t-T}}\right) = \alpha + \beta \ln(y_{i,t-T}) + \varepsilon_{i,t} \tag{1}$$

where $y_{i,t}$ stands for per capita income in region i at time t.

The above specification is then extended by including control variables (conditional convergence – equation 2) and spatial spillovers (spatial models – equation 3).

$$\ln\left(\frac{y_{i,t}}{y_{i,t-T}}\right) = \alpha + \beta \ln(y_{i,t-T}) + \gamma D_i + \varepsilon_{i,t} \tag{2}$$

$$\ln\left(\frac{y_{i,t}}{y_{i,t-T}}\right) = \alpha + \beta \ln(y_{i,t-T}) + \rho \sum_{i-1}^{n} w_{i,j} \ln\left(\frac{y_{i,t}}{y_{i,t-T}}\right) + \varepsilon_{i,t} \tag{3}$$

where $w_{i,j}$ is an element of a spatial weights matrix W, with n representing the number of regions and $\varepsilon_{i,t} = \lambda W \varepsilon_{i,t} + u_{i,t}$, where $u_{i,t} \sim Nid(0, \sigma^2)$.

In the case of the σ-convergence, we apply both traditional and weighted approaches (e.g., Petrakos, Artelaris 2009). The baseline coefficient of variation (σ-convergence) is expressed by the formula:

$$\sigma_t = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(\ln(y_{i,t}) - \ln(\bar{y}_t)\right)^2} \tag{4}$$

In the weighted version regional population share is used as a weight (see Abreu, de Groot, Florax 2005; Arbia, Le Gallo, Piras 2008) for more detailed surveys on different convergence analysis specifications and their functional forms).

In order to deal with the criticism concerning the possible reversion to the mean (e.g. Quah 1993), we also assess the impact of the regional price deflators on the convergence analysis using non-

-parametric methods. In particular, we follow the approach by Basile (2010), who applies a stochastic kernel in order to avoid the arbitrary discretization of the income space that might influence the results of the analysis (e.g. Reichlin 1999) see Fischer and Stumpner (2008) for details concerning the estimation of the stochastic kernel.

Our analysis for the NUTS2 level regions relies on the regional PPP deflators estimated in accordance with the common Eurostat/OECD methodology (see European Communities/OECD 2006). This approach is based on the expenditure side of the Gross Domestic Product and employs the EKS (Éltetö-Köves-Szulc) method that requires data concerning both the prices of representative goods and services and the structure of spending. The latter is required to weight price indices calculated for particular base categories. A detailed review of the methodology can be found in the recent paper by Rokicki and Hewings (2016). In this study, we use the data for Polish NUTS2 regions, where all the necessary data are available.

Yet, the minimum data requirements for applying the Eurostat/OECD methodology are not met when attention is directed to Polish NUTS3 regions. In this case, price deflators at the NUTS3 level are forecasted with the use of a multiple imputation approach proposed by Rubin (1978). Multiple imputation is a Monte Carlo technique based on a Bayesian approach, where missing values are replaced by $M > 1$ simulated versions (e.g. Schafer 1999). Observed data are used in order to construct a posterior distribution of the missing data. The imputation process is based on random draws from this posterior distribution that leads to the creation of *M* multiple-imputed datasets. Multiple-imputed datasets are analysed separately, yet the results of the analysis are combined in order to produce estimates and confidence intervals that incorporate missing-data uncertainty. For more details on the multiple imputation approach used to calculate price deflators for Polish NUTS3 regions see Rokicki and Hewings (2016).

The calculation of regional price indices is based on data on regional prices that cover the period between 2000 and 2012 and accounts for over 300 representative consumer goods and services. Most of the data on prices are unpublished and has been obtained courtesy of the Polish Central Statistical Office (see Rokicki, Hewings 2016 for more details about the price data). Almost all of the remaining data come from the different publications of the Polish Central Statistical Office, again for the 2000–2012 period. In particular, the data on regional per capita GDP,[3] agriculture employment, unemployment and population density comes from the Local Data Bank (the latest available data come from 2012), while data on expenditure come from the Household Budget Survey. All pecuniary data are expressed in Polish zloty. The data used to compute spatial weights matrices come from the ESRI shapefile data for Polish NUTS2 and NUTS3 regions.

4 Regression approach to convergence analysis – the impact of regional price deflators at the NUTS2 and NUTS3 level regions

In accordance with theoretical expectations, price levels can be expected to differ significantly between regions with different levels of economic development. In particular, the introduction of the housing sector into the New Economic Geography framework leads to results indicating that the core regions

[3] These data are compiled in accordance with the Polish Classification of Activities 2007 (PKD 2007) and the European System of National and Regional Accounts 2010 (the ESA 2010).

are on aggregate more expensive than the periphery (e.g. Suedekum 2006). As suggested by Tabuchi (2001), we should also expect that services would also be, on average, more expensive in the core areas due to higher nominal wages. Hence, the application of average national price deflators statistically makes poorer regions even poorer. Exactly the opposite happens with the better off areas. Hence, the inclusion of the regional PPP deflators should lead to a decrease of regional income differentials as measured by the coefficient of variation. On the other hand, the impact on the β-convergence analysis is unclear since it depends on the evolution of regional price indices over time. The introduction of regional PPP deflators would have a significant impact on β-convergence analysis only if the regional inflation rates were closely following regional growth rates of income.

As claimed by Rokicki and Hewings (2016), PPP deflators calculated in accordance with the Eurostat/OECD methodology confirm the existence of substantial price differentials between Polish NUTS2 regions. Moreover, they show that there have been significant changes in terms of the spatial distribution of PPP deflators between 2000 and 2012. In particular, in 2012 the group of regions with the lowest values of PPP deflators expands into all eastern border regions and the Wielkopolskie region. On the other hand, all western border regions constitute a group with the second highest level of PPP deflators after the capital (Mazowieckie) region. Rokicki and Hewings (2016) also show that the NUTS2 regions are very heterogeneous in terms of the price indices. From their analysis, regional price indices vary significantly within particular NUTS2 regions. The highest level of prices is found around the biggest cities such as Warsaw, Kraków, Gdańsk and Poznań. At the same time, the lowest average prices are observed mainly in agricultural areas located in central and eastern Poland. Further, there have been few significant changes between 2000 and 2012. That suggests that relative regional price levels are somehow “locked in” and on average remain constant over time.

The question is now whether the application of regional PPP deflators may significantly influence the results of regional income convergence analysis. Taking into account that the highest price indices are on average found in the more developed regions, we should expect that, after applying PPP deflators, the real per capita GDP would be on average relatively lower in high income regions and relatively higher in low income ones, as compared to the nominal values. Nevertheless, the spatial distribution of relative (to the national average) nominal and real per capita GDP at the NUST2 level in 2000 and 2012 is almost exactly similar, at least for given income categories (see Figure 1). Note that by nominal income we understand per capita income in constant 1999 prices. Real income is defined as per capita income in constant 1999 prices deflated using regional PPP deflators. In 2000, the application of regional price indices seems to have a significant impact only in Zachodniopomorskie, where real per capita GDP is lower than its nominal counterpart. The only visible exceptions in 2012 are Dolnośląskie and Wielkopolskie. In the case of the former, nominal per capita GDP is significantly higher than the real one. As a result, it falls to a lower income category. In the case of the latter region, the application of a PPP deflator improves its income class.

Figure 2 compares the spatial distribution of nominal and real per capita GDP at the NUTS3 level regions in 2000 and 2012. At first sight, there is hardly a difference between the two income measures, irrespective of the year of observation. In this sense we may conclude that there is no substantial difference between the NUTS2 and NUTS3 regions. In 2012 in the case of two subregions, the application PPP deflators leads to an increase of income level (Bielski and Pilski) and a decrease in the case of a further five (Kraków, Radomski, Rybnicki, Starogardzki, Wrocław). Similar conclusions can be drawn for the year 2000.

So as to more accurate evaluate the impact of PPP deflators on per capita GDP in particular regions, we calculate the indices showing the regional/national average ratio in 2012 before and after using the PPP deflators. Table 1 summarizes the results for the NUTS2 level regions. As expected, real per capita GDP is relatively lower (as compared to the national average) in the top three regions (Dolnośląskie, Mazowieckie, Śląskie). In the case of the richest Mazowieckie region, its per capita income decreases, as compared to the national average, by more than 9 percentage points. The difference between the nominal and real per capita GDP relative to national average is smaller for Dolnośląskie and Śląskie. Here it does not exceed 4 and 1 percentage points respectively. Note that Wielkopolskie, which occupies fourth place in terms of nominal income level, improves its position and replaces Śląskie in the top three of real per capita GDP. Its relative income improves by more than 3 percentage points.

Exactly the opposite results can be found for the low income areas such as Lubelskie, Podkarpackie, Podlaskie, Świętokrzyskie and Warmińsko-Mazurskie. Here, we find that the relative level of per capita income increases between 0.7 percentage points (Warmińsko-Mazurskie) and 2.7 percentage points (Podkarpackie). In this sense, the impact of PPP deflators seems to be smaller than for the better--developed regions. It is also on average smaller than the impact of PPP deflators on relative per capita income level in regions such as Pomorskie or Lubuskie. Due to the high price indices, their relative income levels decrease by over 4 and 2 percentage points respectively.

The comparison of the nominal and real per capita GDP in 2012 at the NUTS3 level also shows that the application of PPP deflators has a significant impact in terms of the regional/national average ratio (see Table 2). Similar to the NUTS2 regions, real per capita GDP is relatively lower (as compared to the national average) in the top five regions and relatively higher in the bottom five ones. The largest decrease in the relative income level is found in the case of the Warszawa subregion. Here, per capita income decreases, as compared to the national average, by almost 30 percentage points, followed by Legnicko-Głogowski (16 percentage points), Poznań (12 percentage points), Wrocław (11 percentage points) and Kraków (8 percentage points) subregions. In the case of the five poorest NUTS3 regions, we find that the relative level of per capita income increases over 3 percentage points in Nowosądecki, over 2 percentage points in Krośnieński and Chełmsko-Zamojski, more than 1 percentage point in Przemyski and less than 1 percentage point in Ełcki subregions. Clearly, the impact of PPP deflators is much smaller for the least than for the more developed subregions. Still, it is greater as compared with the poorest NUTS2 regions, especially for the top of the income distribution.

The above findings suggest that we might observe a reduction in dispersion of regional per capita GDP (σ-convergence) once we refer to the real instead of nominal values. In this sense, we can expect to find a greater impact at the NUTS3 level as compared to the NUTS2 level regions. Hence, following the more traditional un-weighted approach,[4] we calculate first σ-convergence for 2012 at the NUTS2 level. It falls from 0.246, calculated for nominal per capita income, to 0.229 computed using the data adjusted for regional prices. The impact is slightly larger once we apply the weighted approach proposed by Petrakos and Artelaris (2009). Here, the value of coefficient of variation decreases from 0.252 for nominal per capita GDP to 0.230 for the real one.

It appears, however, that the application of regional PPP deflators hardly affects the evolution of σ-convergence between 2000 and 2012 (see Figure 3). The evolution of the coefficient of variation for nominal and real per capita GDP looks very similar. In this sense, there is no difference between

4 Here, σ-convergence is defined simply as a coefficient of variation of per capita income.

an unweighted and a weighted approach, although it is clear that the PPP deflators have a greater impact on weighted σ-convergence when the whole period is analysed.

Not surprisingly, the application of regional PPP deflators also leads to a significant decrease in the dispersion of regional per capita GDP at the NUTS3 level. In the case of the unweighted approach, the σ-convergence in 2012 falls from 0.355 (nominal per capita income) to 0.331 (real per capita income). For the weighted approach, the coefficient of variation decreases from 0.401 for nominal per capita GDP to 0.351 for the real one. As expected, in both cases the difference is greater than the results obtained for the NUTS2 regions.

Again, though, the application of regional PPP deflators hardly affects the evolution of σ-convergence between 2000 and 2012 (see Figure 4). The evolution of the coefficient of variation for nominal and real per capita GDP looks very similar, regardless of which approach is used. This finding may suggest that the regional price levels evolve similarly across regions, both at the NUTS2 and the NUTS3 level.

Having examined the impact of regional PPP deflators on the σ-convergence analysis, we continue the analysis studying their impact on β-convergence. Here, we find that the introduction of the PPP deflators does not have a significant impact on the results of the absolute convergence analysis during the period between 2000 and 2012 (see Table 3). The results of the OLS panel regression based on nominal and real per capita GDP are very similar (Models 1 and 2). In both specifications, we find that the initial level of income is not statistically significant in explaining regional growth rates. Similar results are obtained for the LM spatial regressions (Models 5 and 6), which also indicate the lack of spatial dependence. In the case of spatial specifications we follow the approach by Arbia, Le Gallo and Piras (2008), who suggest to use spatial lag or spatial error specification while comparing with simple convergence models. The results in Table 3 and 4 are robust to different weights matrices and specifications (spatial lag and spatial error separately). Note that the above approach relies on demand side spatial spillovers. Alternative specification could be the spatial Durbin model as suggested by Ertur and Koch (2007), who derived a neoclassical model with supply-side spatial externalities. Finally, both nominal and real data regressions confirm the existence of conditional beta convergence (Models 3 and 4). Yet, while the coefficient for real per capita GDP is higher than its nominal counterpart (-0.289 versus -0.222), the difference is within the standard error. Here, apart from the specification based on fixed effects only, we also tested specifications including an additional control variable (population growth). They do not, however, influence the main results and conclusions. Still, many control variables usually used in convergence regressions (e.g. investment-to-GDP ratio) are not available at a regional level. Others, like human capital, are available at the NUTS2 level only. Therefore, we do not use them, in order to be able to compare the results at the NUTS2 and NUTS3 level. This in turn results in potential underspecification of our conditional convergence regressions (see Islam 2003) for more detailed discussion on different conditional convergence specifications).

The results of convergence regressions at the NUTS3 level confirm the lack of significant impact of regional PPP deflators on the β-convergence analysis. For the 2000–2012 period, we do not confirm the existence of either an absolute convergence or divergence process (Models 1 and 2). However, we do find that the conditional β-convergence (Models 3 and 4) using real per capita income generates a coefficient (-0.302) that is higher than the coefficient for nominal income (-0.276). Again, as in the case of NUTS2 regions, the difference is within the standard error. Also, the differences between the nominal and real income are found to be insignificant for the spatial lag and spatial error approach (Models 5 and 6).

The above analysis suggests that the application of regional price deflators has a significant impact on the absolute values of regional income dispersion. Here, the effect is clearly stronger in the case of the NUTS3 regions. Regardless of the territorial aggregation level, real income dispersion is lower than the nominal one. Yet, our results show that the regional price deflators hardly influence the results of the β-convergence analysis, nor do they affect the evolution of σ-convergence. This in turn suggests that the regional prices do not necessarily follow the patterns of income growth. In other words, regional income and prices do not necessarily grow at the same pace.

5 The impact of regional price deflators on non-parametric convergence analysis at the NUTS2 and NUTS3 level regions

The regression approach to the convergence analysis seems to suggest that the application of regional price deflators only marginally influences the income distribution dynamics. In this sense, the impact is very similar for both the NUTS2 and NUTS3 level regions. The question is whether these findings can be corroborated once we apply a non-parametric approach. Following Basile (2010) and Fischer and Stumpner (2008), we base our analysis in this section on the relative (to the national average) rather than absolute income, which allows us to abstract from overall changes in income levels.

Figure 5 shows the distribution of relative nominal and real income at the NUTS2 level in 2000 and 2012. The densities are calculated using a Gaussian kernel with bandwidths set to minimize the mean integrated squared error. It can be easily seen that the distribution has a bimodal shape. It indicates the presence of two groups in the population of regions – in our case, a larger group of low income areas and a smaller group of high income ones. Here, the height of the curve over any point on the horizontal axis shows the probability that a particular region will have a relative income corresponding to the value of this point. The application of regional price deflators seems to have a very small impact on the distribution in 2000. Yet, by 2012 the shape of real income becomes significantly steeper than in 2000, something that is not observed in the case of nominal income. This may indicate ongoing polarization of regional income at the NUTS2 level; in this sense, the use of regional price deflators seems to have a significant impact on the analysis results. Actually, formal tests confirm the distributions to differ statistically significantly (see Table 5).

Similar conclusions can be drawn in the case of the NUTS3 level regions. Here, as before, the distribution of real income appears to be significantly steeper for the low-income regions (see Figure 6). Yet, the main mode seems to have moved to the right as compared to the nominal income distribution. In addition, we can observe several peaks rather than a bimodal pattern. Unlike the case of the NUTS2 level regions, the distributions hardly change between 2000 and 2012. Still, formal tests show that the difference between distributions is statistically significant (see Table 6).[5]

Tukey boxplots can be considered as another tool to visualize the evolution of regional income distribution. Figure 7 shows the Tukey boxplots for the NUTS2 regions between 2000 and 2012 (where each box contains the middle 50% of the distribution and the vertical lines reach the upper and lower adjacent values). Also, dots outside the vertical lines stay for outliers – in our case we have only one over-performing region, that is the capital Mazowieckie region. It becomes very clear that

[5] Note that the differences are not statistically significant once the unpaired test is applied.

the application of regional price deflators significantly reduces the dispersion of income, something already discussed during the analysis of σ-convergence. The evolution of nominal income boxplots may suggest an increase in dispersion of income, or a tendency towards divergence. This is, however, not so obvious once we analyse the sequence of boxplots for real income. Here, both the size of the boxes and the length of the vertical lines seem to remain fairly constant over the whole period. This finding is particularly interesting, taking into account that the evolution of σ-convergence did not seem to be affected by the inclusion of real income.

Not surprisingly, Tukey boxplots for the NUTS3 regions reveal much higher levels of regional income disparities, with several over-performing regions (see Figure 8). Again, the disparities in real income are significantly lower than for the nominal counterpart. Contrary to the NUTS2 level regions it is hard though to see any substantial difference in the evolution of income inequalities; the income variable used appears to remain fairly constant over time.

Following Basile (2010), we also analyse cross-profile dynamics of regional per capita income. Figure 9 reflects the intra-distribution dynamics of the NUTS2 regions. The lowest curve shows the cross-section of relative income (in logs) in 2000 in increasing order. The middle and upper curves illustrate the same variable in 2006 and 2012, however, maintaining the order from 2000. This allows us to examine the intra-distribution mobility, that is, the greater spikiness that is observed for the middle and upper curves. On the left panel, sketched for nominal income, we can distinguish three main local peaks marked with dots at the upper line. They suggest a significant improvement in terms of relative income of Łódzkie and Dolnośląskie and a decline of Zachodniopomorskie between 2000 and 2012. Yet, on the right panel, sketched for real income, we can find only one significantly improving region (Dolnośląskie) and two declining ones (Kujawsko-Pomorskie and Zachodniopomorskie). Hence, the results point to certain differences in the analysis based on nominal and real income values.

The results of the same exercise performed for the NUTS3 regions are summarized in Figure 10. Since the number of regions is much higher than at the NUTS2 level, the number of peaks is much higher as well. Hence, we marked with dots only the highest peaks on both panels. In the case of the nominal income, the biggest improvement is found for Krakowski, Wrocławski, Ciechanowsko-Płocki and Legnicko-Głogowski subregions. At the same time, the subregions with the greatest decline of relative income are Przemyski and Szczecin. Once we examine the panel for real income, we find that Gliwicki (instead of Ciechanowsko-Płocki) and Tyski are now included among the most improved subregions. The most deteriorated subregions are the same as in the case of the nominal income. Hence, while there is not much difference between nominal and real values in terms of the most improved and most deteriorated regions, one can still observe that the real income curves seem to be on average smoother than the nominal ones.

Our last experiment consists in comparing the results of conditional kernel density estimates, using visualization tools proposed by Hyndman, Bashtannyk and Grunwald (1996). The upper part of Figure 11 shows the three-dimensional stacked conditional density plots of relative income at the NUTS2 level with a 5-year transition period. On the left panel, we can observe how the cross-section nominal income distribution at time t evolves into that at time $t + 5$. Here, the concentration of the graph along the 45^o diagonal shows that the elements in the cross-section distribution remain on average where they started. In other words, it indicates a relatively constant pattern in the regional income distribution. A similar picture can be found on the right panel sketched for the real income. Nevertheless, it seems that the density plots are slightly less concentrated along the diagonal. This may suggests a higher degree of real income mobility as compared to the nominal one.

The above can be verified using the “highest conditional density region” (HDR) plot revealed in the lower part of Figure 11. Here, following Basile (2010), each vertical bin shows the projection of the conditional density of per capita GDP at time $t + 5$ on per capita GDP at time t. In each bin the 25% (the darker-shaded part), 50%, 75% and 90% (the lighter-shaded part) HDRs are reported. If the 45-degree diagonal crosses the 25% or the 50% HDRs, it means that most of the elements in the distribution remain where they started. On the other hand, if it crosses only the 75% or the 90% HDRs, it indicates a relatively high level of intra-distribution mobility. Moreover, if some 25–50% HDRs are crossed by a horizontal line traced at any value of the $t + 5$ axis, we can say that there is strong club convergence. That means that there are regions catching up with each other but only within a particular group.

In the case of Polish NUTS2 regions, the HDR plots confirm a low level of intra-distribution mobility. In this sense there is hardly any difference between nominal and real income. Hence, we cannot confirm a higher degree of real income mobility, as suggested by the stacked conditional density plots. We can observe, however, signs of club convergence pattern for regions with per capita GDP above the national average. This pattern appears to be stronger at the real income plot as compared to the nominal income one.

Figure 12 displays conditional density plots for the NUTS3 regions. Similar to the NUTS2 regions, we can observe a relatively low degree of income mobility (most of the probability mass remains clustered along the 45^{o} diagonal). However, here the peaks on the left panel appear to be significantly higher than the ones on the right panel. Hence, unlike in the case of the NUTS2 regions, it is the real income estimation that seems to suggest more mobility than the nominal one.

The low degree of income mobility is confirmed by analysing the HDR plots. Here, the 45-degree diagonal crosses most of the 25% or the 50% HDRs. Additionally, we observe a club convergence pattern for regions with per capita GDP around 1.8 of the national average. Again, this pattern appears to be stronger at the real income plot than the nominal income one.

We may conclude that the application of regional price indices may influence to some extent the results of the analysis devoted to the dynamics of the regional income distribution. This is particularly important once we examine results for particular regions. For instance, HDR plots based on real income seem to reveal more clearly the existence of club convergence. Nevertheless, the evolution of both nominal and real income follows on average similar patterns.

6 Conclusions

This paper compares the impact of regional price deflators on the results of convergence analysis at different levels of territorial aggregation, taking as an example the evolution of income disparities between 16 NUTS2 and 66 NUTS3 Polish regions between 2000 and 2012. We find that the application of regional PPP deflators has a significant impact on statistical data in terms of relative regional per capita income levels. Furthermore, we show that the real regional income disparities are lower than the nominal income ones and that the difference is greater at the NUTS3 level. However, our results show that the regional price deflators hardly influence the results of the β-convergence analysis nor do they affect the evolution of σ-convergence. This finding, in turn, suggests that the regional prices do not necessarily follow the patterns of income growth. In other words, regional income and prices do not necessarily grow at the same pace.

We also find that the impact of regional price deflators on the results of the β-convergence analysis is rather limited. Nevertheless, regional price indices may influence to some extent the results of the analysis focused on income dynamics patterns once the non-parametric tools are applied. This is particularly important once we examine results for particular regions. The evolution of both nominal and real income follows on average similar patterns.

Statistical data available for other European countries do not allow us to verify to what extent our findings are universal. Nevertheless, the large price differentials observed between the metropolitan and peripheral regions of many EU member states (e.g. the UK) suggest that the potential impact of regional price deflators on the results of convergence analysis may be even more significant, especially at the lower level of territorial aggregation.

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Appendix

Figure 1
Spatial distribution of relative nominal and real per capita GDP at the NUTS2 level in 2000 and 2012

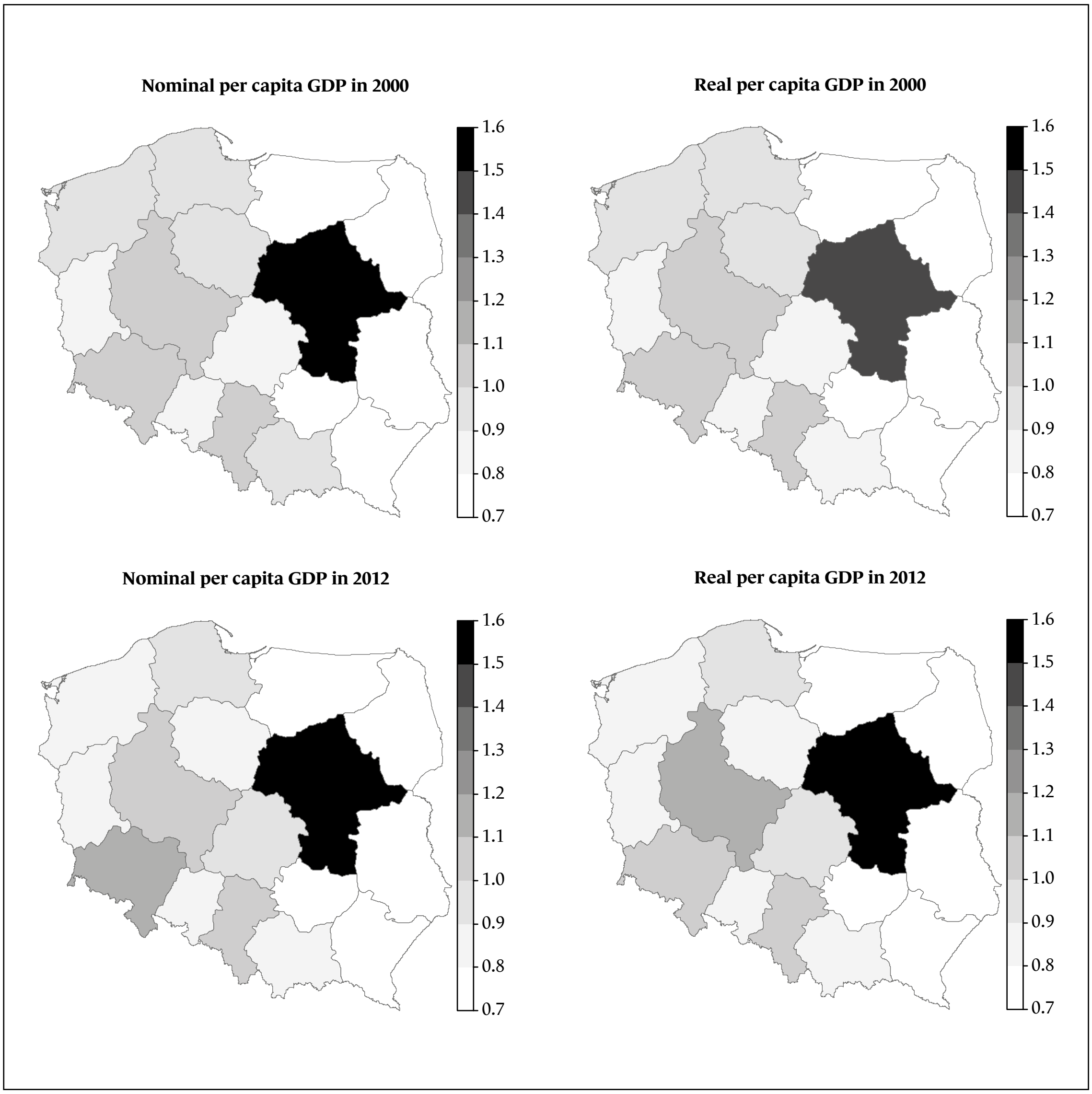


Figure 2
Spatial distribution of nominal and real per capita GDP at the NUTS3 level in 2000 and 2012

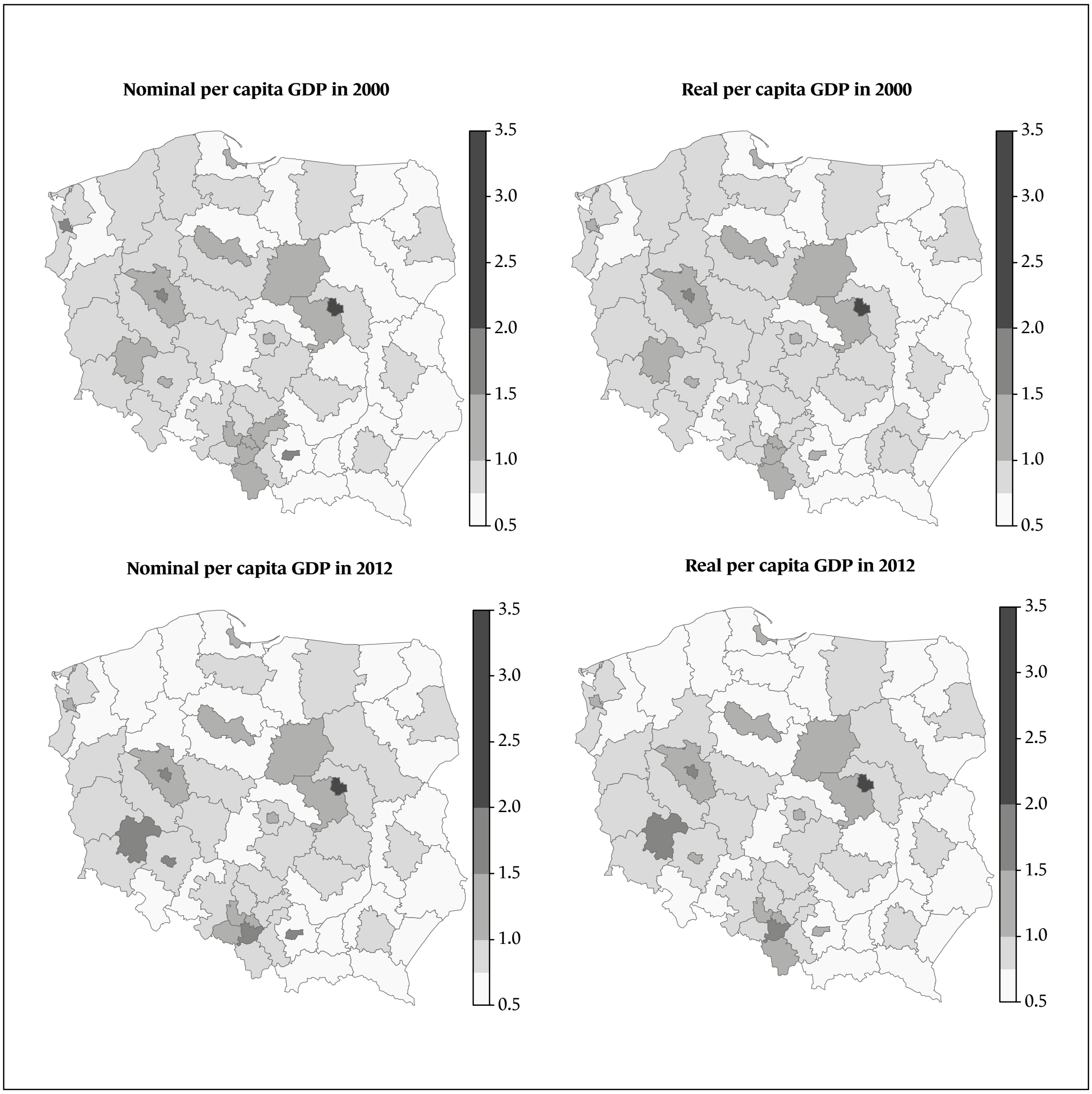


Figure 3
Unweighted and weighted sigma convergence among Polish NUTS2 regions between 2000 and 2012

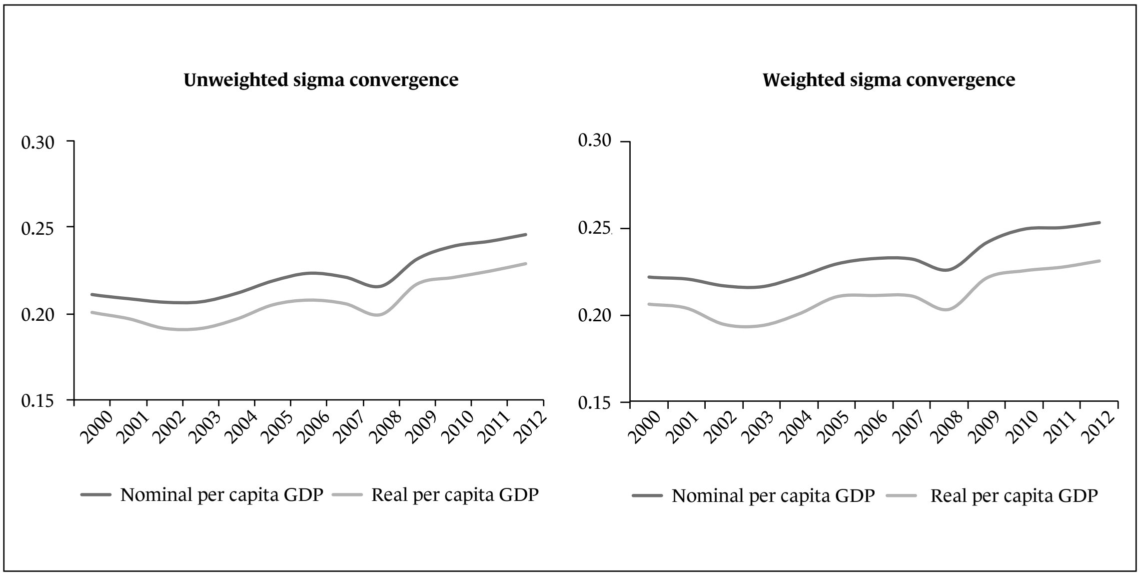


Figure 4
Unweighted and weighted sigma convergence among Polish NUTS3 regions between 2000 and 2012

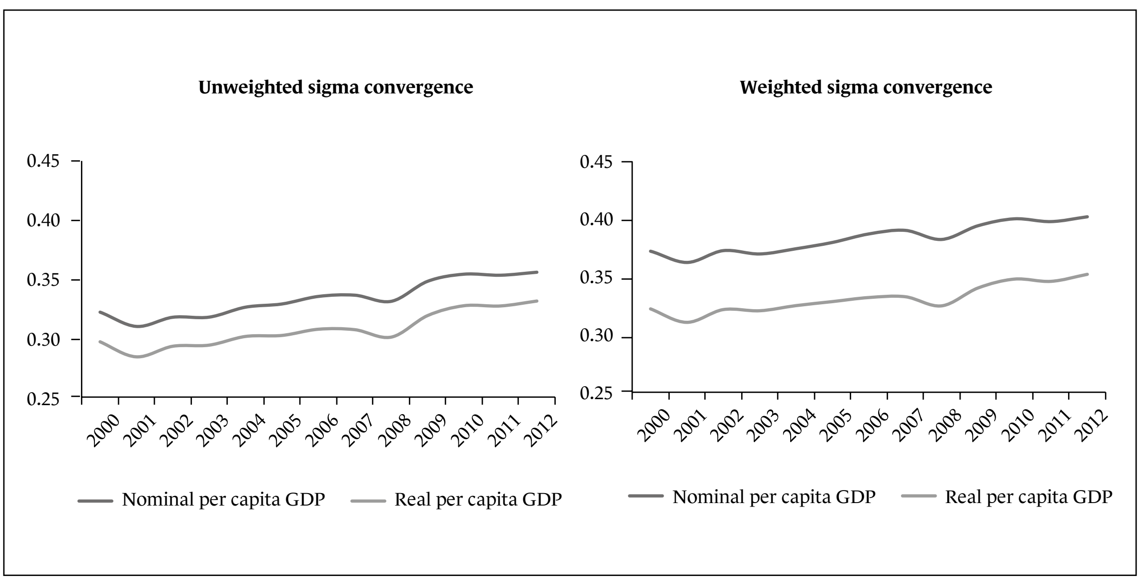


Figure 5

Distribution of relative nominal and real per capita income in 2000 and 2012 at the NUTS2 level

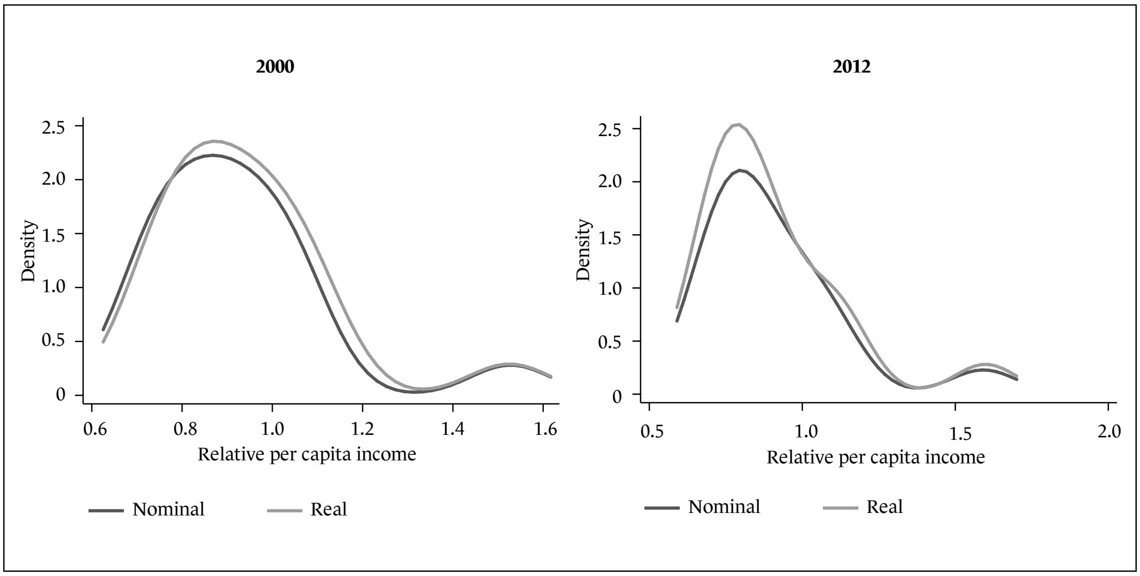


Figure 6

Distribution of relative nominal and real per capita income in 2000 and 2012 at the NUTS3 level

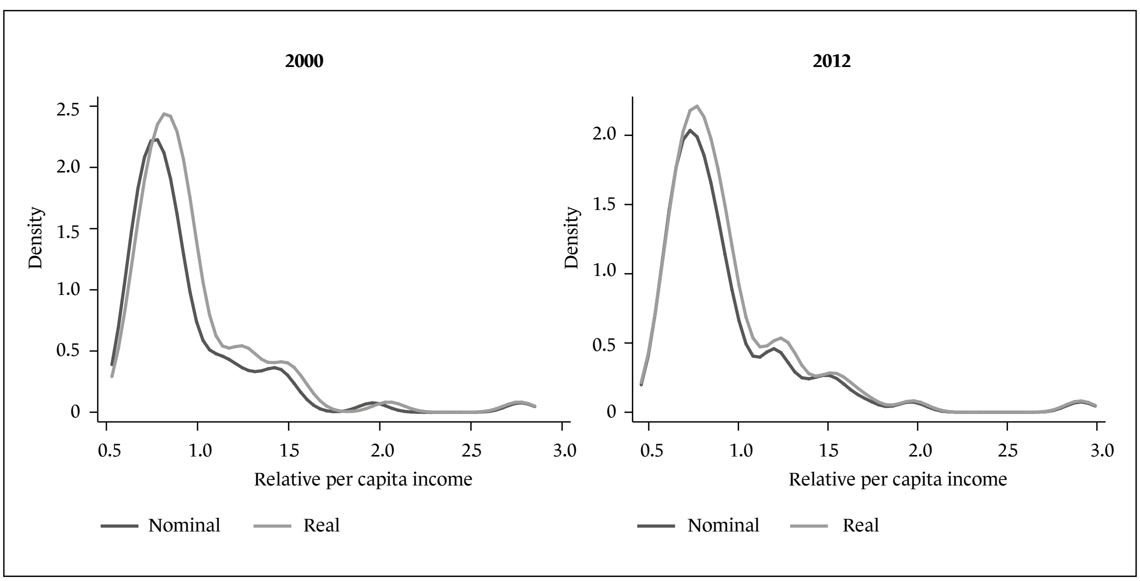
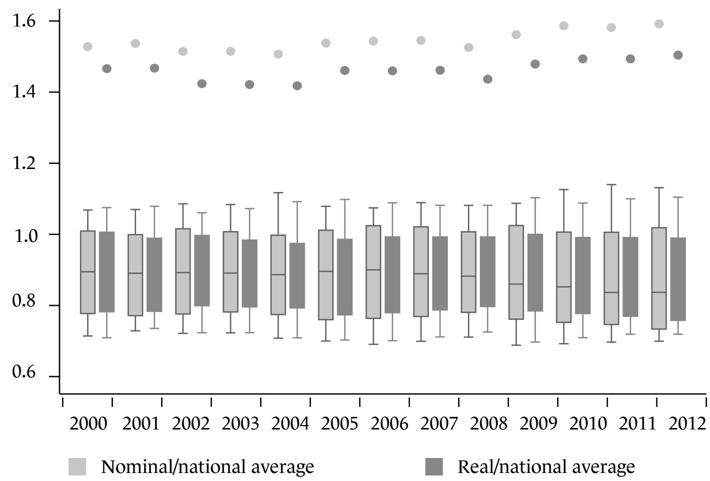


Figure 7

Tukey boxplots of relative regional income at the NUTS2 level

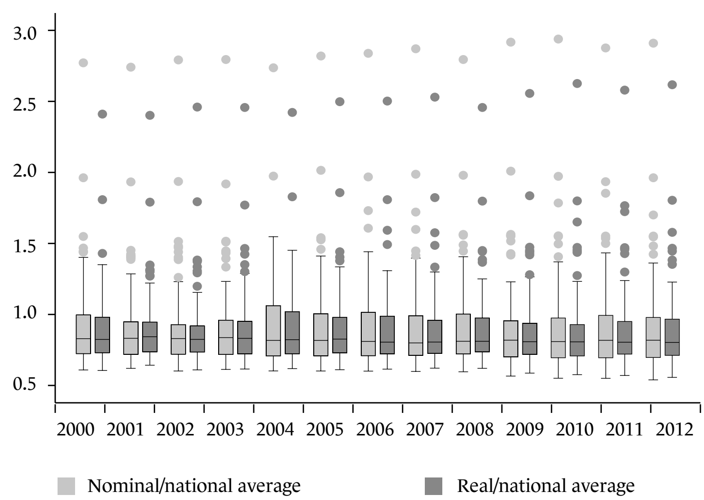


Notes:

Each box contains the middle 50% of the distribution. The thick line in the box locates the median. The dots indicate outliers – in the case of Poland it is Mazowieckie region.

Figure 8

Tukey boxplots of relative regional income at the NUTS3 level



Notes:

Each box contains the middle 50% of the distribution. The thick line in the box locates the median. The dots indicate outliers.

Figure 9
Cross-profile dynamics across NUTS2 regions

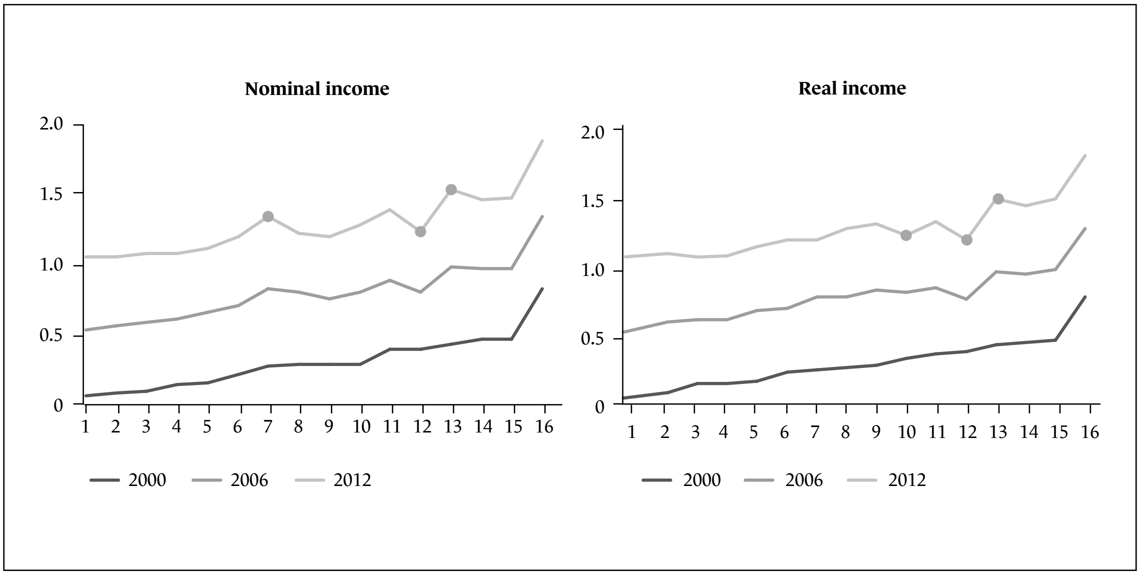


Figure 10
Cross-profile dynamics across NUTS3 regions

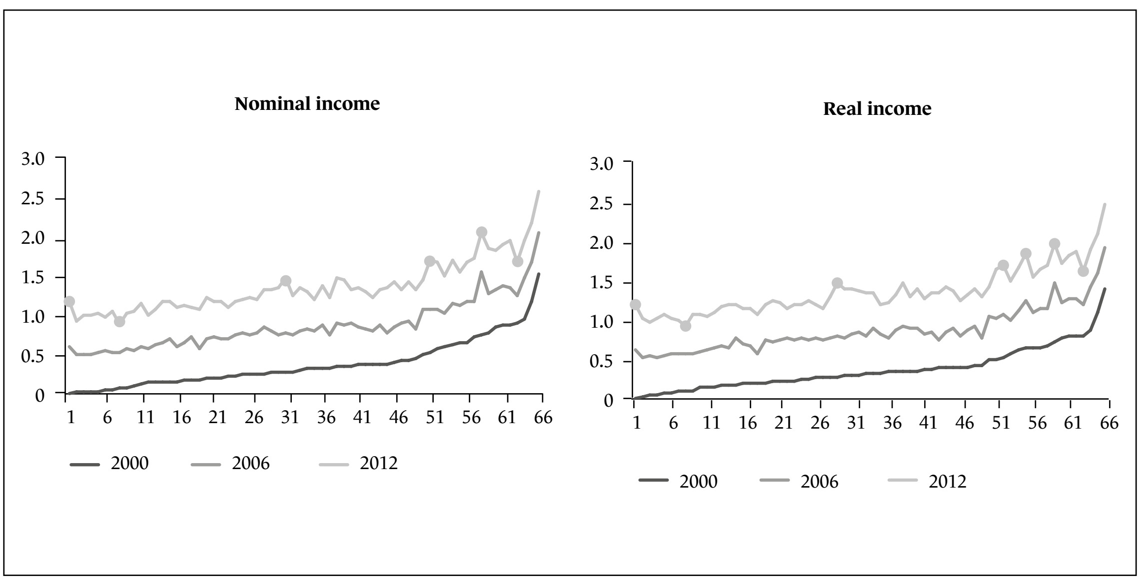


Figure 11
Relative income dynamics at the NUTS2 level

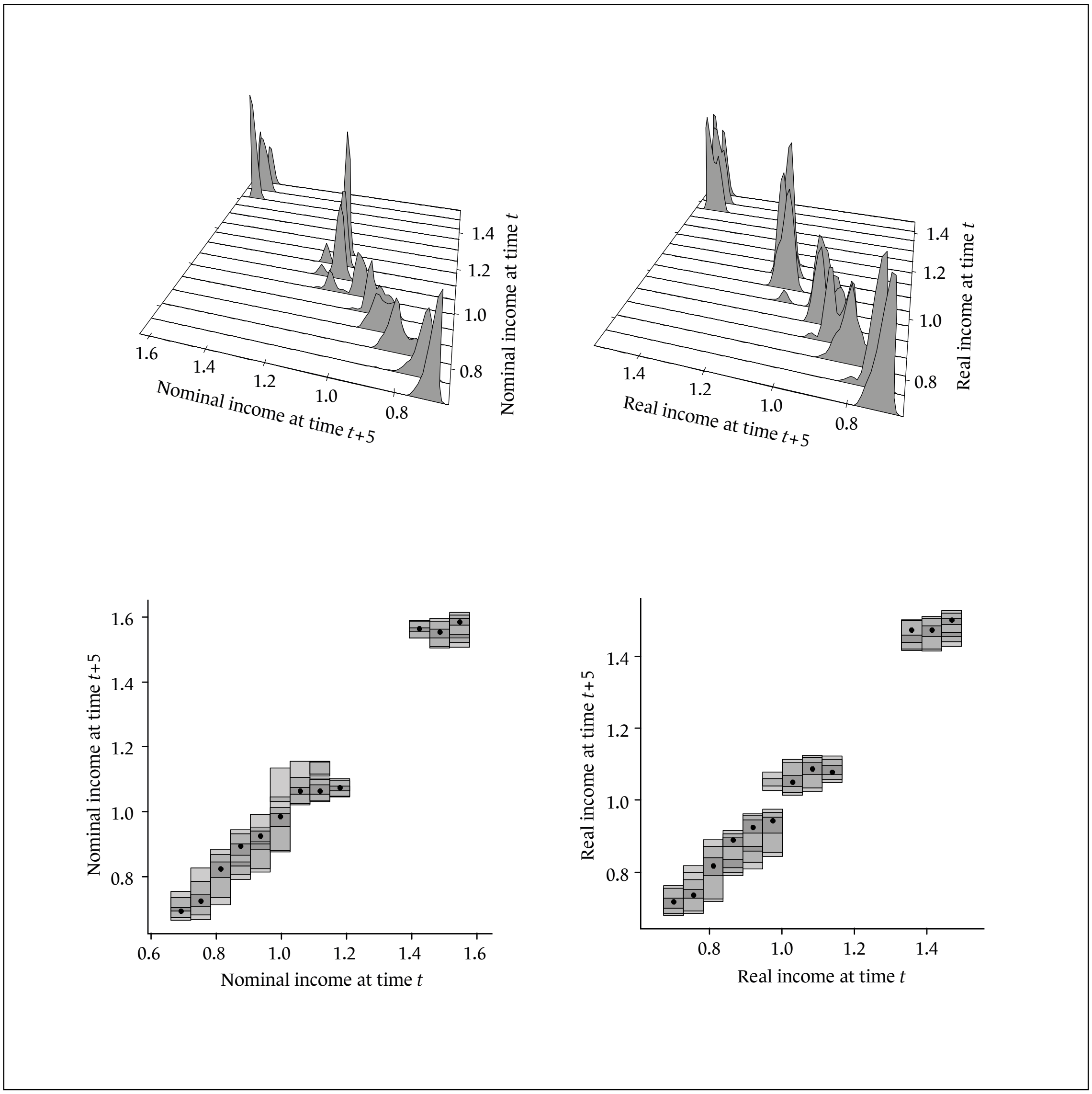


Figure 12
Relative income dynamics at the NUTS3 level

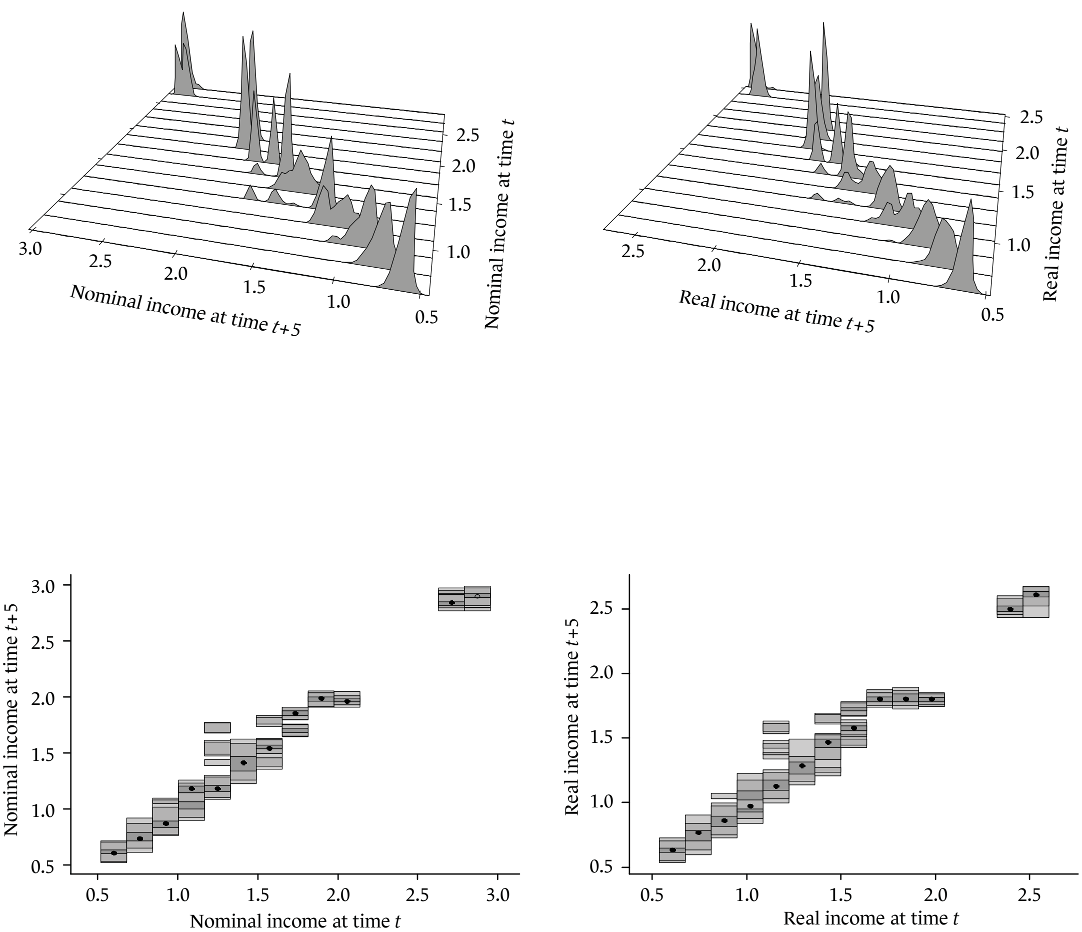


Table 1

Regional per capita GDP in 2012 at the NUTS2 level in Poland – the impact of the PPP deflators

Region	**Nominal per capita GDP**	**Nominal per capita GDP Poland = 100**	**Real per capita GDP**	**Real per capita GDP Poland = 100**
Dolnośląskie	47,440	1.131	45,693	1.090
Kujawsko-Pomorskie	34,095	0.813	35,324	0.842
Lubelskie	29,479	0.703	30,372	0.724
Lubuskie	34,862	0.831	34,153	0.814
Łódzkie	39,080	0.932	38,576	0.920
Małopolskie	36,961	0.881	37,133	0.886
Mazowieckie	66,755	1.592	63,076	1.504
Opolskie	33,888	0.808	34,008	0.811
Podkarpackie	29,333	0.700	30,374	0.724
Podlaskie	30,055	0.717	31,080	0.741
Pomorskie	41,045	0.979	39,170	0.934
Śląskie	44,372	1.058	43,811	1.045
Świętokrzyskie	31,459	0.750	32,497	0.775
Warmińsko-Mazurskie	30,065	0.717	30,155	0.719
Wielkopolskie	44,567	1.063	46,317	1.105
Zachodniopomorskie	35,334	0.843	34,337	0.819
Poland	41,934	1.000	41,934	1.000

Table 2

Regional per capita GDP in 2012 at the NUTS3 level in Poland – the impact of the PPP deflators on the top 5 and bottom 5 regions

Region	**Nominal per capita GDP**	**Nominal per capita GDP Poland = 100**	**Real per capita GDP**	**Real per capita GDP Poland = 100**
Subregion Warszawa	122,005	2.909	109,650	2.615
Subregion Legnicko-Głogowski	82,311	1.963	75,542	1.801
Subregion Poznań	71,313	1.701	66,161	1.578
Subregion Wrocław	65,103	1.553	60,519	1.443
Subregion Kraków	64,808	1.545	61,367	1.463
Subregion Krośnieński	25,279	0.603	26,439	0.630
Subregion Nowosądecki	25,274	0.603	26,777	0.639
Subregion Ełcki	24,812	0.592	25,119	0.599
Subregion Chełmsko-Zamojski	23,615	0.563	24,443	0.583
Subregion Przemyski	22,617	0.539	23,329	0.556
Poland	41,934	1.000	41,934	1.000

Table 3

The results of the β-convergence analysis – NUTS2 level between 2000 and 2012

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Nominal per capita GDP	0.008 (0.006)		-0.222*** (0.050)		0.008 (0.005)	
Real per capita GDP		0.004 (0.008)		-0.289*** (0.056)		0.004 (0.007)
Rho					0.347 (0.286)	0.086 (0.228)
Lambda					-0.355 (0.350)	-0.026 (0.224)
Constant	-0.038 (0.058)	0.005 (0.077)	2.256*** (0.578)	2.924*** (0.556)	-0.010 (0.053)	-0.053 (0.070)
Time dummies	yes	yes	yes	yes	yes	yes
Region dummies	no	no	yes	yes	no	no
Observations	192	192	192	192	192	192
Log likelihood	520.68	500.24	539.64	522.14	520.96	500.42

Notes:
OLS estimation (Models 1–4), LM estimation spatial lag and error model (Models 5–6). Spatial regressions based on contiguity weights matrix. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4

The results of the β-convergence analysis – NUTS3 level between 2000 and 2012

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Nominal per capita GDP	0.003 (0.004)		-0.276*** (0.042)		0.002 (0.004)	
Real per capita GDP		0.003 (0.004)		-0.302*** (0.040)		0.003 (0.004)
Rho					0.004 (0.032)	-0.019 (0.112)
Lambda					0.082 (0.059)	0.102 (0.117)
Constant	-0.033 (0.036)	-0.037 (0.040)	2.832*** (0.422)	3.078*** (0.406)	-0.029 (0.035)	0.002 (0.033)
Time dummies	yes	yes	yes	yes	yes	yes
Region dummies	no	no	yes	yes	no	no
Observations	792	792	792	792	792	792
Log likelihood	1,624.66	1,611.28	1,703.46	1,697.55	1,626.17	1,612.83

Notes:
OLS estimation (Models 1–4), LM estimation (Models 5–6). Spatial regressions based on contiguity weights matrix. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5

Formal testing of kernel distributions at the NUTS2 level (two-sample paired *t* test with equal variances)

Variable	**Observations**	**Mean**	**Standard error**	**Standard deviation**	**95% confidence interval**	
			2000			
Nominal GDP	16	0.927	0.212	0.850	0.474	1.380
Real GDP	16	0.994	0.220	0.879	0.526	1.463
Difference	16	-0.067	0.031	0.124	-0.133	-0.001
mean(diff) = mean(nominal GDP – real GDP)			*t* = -2.1729			
Ho: mean(diff) = 0		degrees of freedom = 15				
Ha: mean(diff) < 0	Ha: mean(diff) ! = 0			Ha: mean(diff) > 0		
Pr(*T* < *t*) = 0.023	Pr(*T* > *t*) = 0.046			Pr(*T* > *t*) = 0.977		
			2012			
Nominal GDP	16	0.821	0.185	0.738	0.428	1.214
Real GDP	16	0.950	0.214	0.854	0.494	1.405
Difference	16	-0.129	0.036	0.145	-0.206	-0.051
mean(diff) = mean(nominal GDP – real GDP)			*t* = -3.5426			
Ho: mean(diff) = 0	degrees of freedom = 15					
Ha: mean(diff) < 0	Ha: mean(diff) ! = 0			Ha: mean(diff) > 0		
Pr(*T* < *t*) = 0.002	Pr(*T* > *t*) = 0.003			Pr(*T* > *t*) = 0.999		

Table 6

Formal testing of kernel distributions at the NUTS3 level (two-sample paired *t* test with equal variances)

Variable	**Observations**	**Mean**	**Standard error**	**Standard deviation**	**95% confidence interval**	
			2000			
Nominal GDP	66	0.419	0.078	0.637	0.263	0.576
Real GDP	66	0.501	0.088	0.718	0.324	0.677
Difference	66	-0.081	0.026	0.210	-0.133	-0.030
mean(diff) = mean(nominal GDP – real GDP)			*t* = -3.1553			
Ho: mean(diff) = 0		degrees of freedom = 65				
Ha: mean(diff) < 0	Ha: mean(diff) ! = 0			Ha: mean(diff) > 0		
Pr(*T* < *t*) = 0.001	Pr(*T* > *t*) = 0.002			Pr(*T* > *t*) = 0.999		
			2012			
Nominal GDP	66	0.386	0.071	0.579	0.244	0.529
Real GDP	66	0.443	0.079	0.642	0.285	0.601
Difference	66	-0.057	0.012	0.096	-0.080	-0.033
mean(diff) = mean(nominal GDP – real GDP)			*t* = -4.8248			
Ho: mean(diff) = 0		degrees of freedom = 65				
Ha: mean(diff) < 0	Ha: mean(diff) ! = 0			Ha: mean(diff) > 0		
Pr(*T* < *t*) = 0.000	Pr(*T* > *t*) = 0.000			Pr(*T* > *t*) = 1.000		