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Is the division of Western and Eastern Poland still valid? The evolution of regional convergence in Poland[1]

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Abstract: The primary aim of the paper is the empirical verification of the hypothesis on the convergence of real GDP *per capita* of the regions (NUTS-2) in Poland and the catch-up effect of Eastern towards Western Poland. The empirical study is based on a relatively new analytical approach of Phillips and Sul convergence tests which consider significant differences in technological advancement between regions. The results show that the convergence hypothesis was rejected in the group of all regions of Poland and the group of Western Poland regions. Convergence was confirmed in the group of Eastern Poland regions. The strict catch-up effect of the Eastern towards the Western Poland regions was not observed. Nevertheless, thirteen of seventeen regions of Poland were characterised by convergence but within distinct convergence clubs. The identification of convergence clubs, however, was not determined by a sharp East-West Poland dividing line.

Keywords: club convergence, catch-up effect, log(t) convergence test, economic growth, time-varying factor model

JEL codes: C33, R11.

Introduction

Balancing the level of development between regions is one of the major objectives of the European Union. It is implemented through the cohesion policy to which the EU dedicates one third of its budget. Cohesion policy is crucial to the economic development of regions by providing funding for infrastructure investments which are necessary to support their growth and real convergence. At the same time there is a desire to reduce the EU's structural interventions and shift resources to support innovative activities in arguing that such actions are more effective. The effectiveness of cohesion policy is one of the most in-

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teresting and controversial research areas and the results of empirical studies are ambiguous. Some researchers attribute the lack of economic efficiency to the cohesion policy (Molle, 2007). Others argue that it has no or limited impact on regional convergence (De Freitas, Pereira, & Torres, 2003; Llussa & Lopes, 2014). On the other hand, the results of Puigcerver-Penelvar (2007) or Becker, Egger and von Elrich (2010) show a positive impact of cohesion policy on convergence. Despite the inconclusive research results the cohesion policy is implemented by the EU and can be an important source of convergence.

Currently the second full financial perspective (2007–2013, 2014–2020) of Poland's membership in the EU is ending. In this period Poland received about 150 billion euros (approximately 30% of Poland's 2019 GDP) under the cohesion policy, being the largest beneficiary of the EU's funds. When Poland joined the EU it was a country with large developmental disproportions conditioned by the historical division along East-West lines dating back to the times of the partitions of the First Republic of Poland. The problem of poorer Eastern Poland was observed already in the interwar period. The main reason was the partitions and the fact that the regions belonged to different partitioning powers. Prussia was a developed country and hence the western lands had better infrastructure and the level of education and cultural life was similar to that of Western Europe. The eastern regions and Galicia were under Russian and Austro-Hungarian rule which were less developed than Prussia. It was then that the division into Poland A and B was formed which geographically ran along the line separating East from West. The construction of the Central Industrial District and the fifteen-year plan to rebuild Poland announced in 1938 should reduce the regional differences. These plans were torpedoed by the outbreak of the Second World War. After the war Poland's borders changed but there were still great regional disparities. The fifty years of communism in Poland only deepened the differences. There was no vision for the eastern part of Poland as the regions were agricultural and industry was developed mainly in Western Poland. The subsequent post-communist transformation did not result in any aid systems aimed at the regions of Eastern Poland. The turning point in bridging the development gap between eastern and western Poland was the accession to the European Union and the launch in 2007 of the Development of Eastern Poland programme (from 2014—Eastern Poland) addressed to five voivodeships (regions): Warmińsko-Mazurskie, Podlaskie, Lubelskie, Świętokrzyskie and Podkarpackie. From these programmes the regions of Eastern Poland have obtained nearly five billion euros in additional support until 2021. The results of research on interregional differentiation in Poland (Gorzelak & Smętkowski, 2019; Smętkowski & Płoszaj, 2016) show that the historical dimension is a continuously important factor differentiating Poland's socio-economic space. The historical dimension in line with Braudel's concept of 'long duration' is the division of Poland into western (more developed) and eastern (less developed) parts. Hence based on the vertical division running along the line separating

the eastern regions from the remaining regions in Poland, which are conventionally classified in the article as regions of Western Poland.

Therefore it seems reasonable to examine whether in the analysed period and using the support from the cohesion policy the poorer regions have caught up with the richer ones. The primary aim of the paper is the empirical verification of the hypothesis on the convergence of real GDP *per capita* of the regions of Eastern towards Western Poland. Regional convergence within Eastern and Western Poland groups is also analysed, convergence clubs, non-convergence groups are distinguished and attempts are made to merge convergence clubs. The following reasons distinguish this research from previous studies of regional convergence in Poland. First this paper applies the analytical framework of convergence tests proposed by Phillips and Sul (2007a,b; 2009) which allows the consideration of the heterogeneity of technical progress in regions. This is because in practice there are significant technological differences between countries/regions. This method is relatively new and has not been widely used to test regional convergence in Poland. Second the study is based on the most recent set of available data (2000–2019) with the Warszawski Stołeczny region of the Mazowieckie voivodeship extracted (seventeen regions in total). The division of Mazowieckie Voivodeship into two statistical regions i.e. Warszawski Stołeczny and Mazowiecki Regionalny is due to a large development disparity. In Eurostat reports (February 2019), GDP *per capita* (PPS) relative to the EU average in Mazowiecki Regionalny was 59% and was 222nd out of 281 EU regions while in Warszawski Stołeczny PPS was 152% of the EU average and ranked 19th position among 281 EU regions. Therefore the analysis of the development path of the whole Mazowieckie region does not show these different development trajectories of the Warszawski Stołeczny and Mazowiecki Regionalny regions. Moreover, in the period 2021–2027 because this indicator is at a similar level as in the regions of Eastern Poland the Mazowiecki Regionalny region will also be covered by the programme of additional support under the Eastern Poland Programme. Third most previous analyses of regional convergence have been based on data up to 2010 and as relatively short time series. Thus this is the first study covering a relatively long period of Poland's EU membership. Besides this is the period in which the regions have already coped with the effects of the recession as a result of the post-communist transformation which significantly determined their development in 1990–2000.

The article is structured as follows. The next Section reviews the relevant literature. Section 2 describes the methodology and theoretical framework used as a basis for the empirical study. Section 3 presents the results of the empirical analyses. In the last section, a summary and major conclusions are delineated.

1. Literature review

1.1. Sources and concepts of convergence

According to the convergence hypothesis less developed countries/regions will develop faster than more developed countries/regions and thus get closer to each other in terms of the level of development measured by GDP *per capita*. When looking for the sources of convergence one should directly refer to the neoclassical models of economic growth. Less developed countries/regions have relatively less capital, offer a higher rate of return on capital which attracts external investment causing an increase in productive capital and consequently faster economic growth. In this situation one assumes that there is freedom of movement of technology and capital. Then, according to the Solow model, there is a tendency to equalise income levels provided that countries/regions strive for the same steady-state (Barro & Sala-i-Martin, 1992). The free movement of technology and capital helps to identify another source of convergence. New technology emerging mainly in highly developed countries/regions requires higher R&D expenditure and higher levels of human capital. However, the spread of technology makes less developed countries/regions become beneficiaries rather than initiators of development. Thus, they can gain access to new technology without incurring high costs and they can allocate their resources to expanding their production apparatus which allows them to develop faster. An important reason for convergence resulting from neoclassical models is also the assumption of decreasing marginal products of capital and constant returns to scale. In the case of poorer countries/regions the growth of capital results in greater output growth than in more developed regions. In comparison in endogenous models where at least constant marginal revenue is assumed convergence rarely occurs. Another reason for income convergence may be policy instruments leading to stimulation of economic growth in poorer countries/regions of which EU's cohesion policy is a good example (Bernardelli, Próchniak, & Witkowski, 2017).

Several convergence concepts can be found in economic literature. The best known and most empirically tested is the β and σ convergence introduced by Sala-i-Martin (1990). β convergence refers to the relationship between the growth rate of income *per capita* and its initial level and occurs in two variants: conditional and unconditional convergence (Misiak, Tokarski, & Włodarczyk, 2011; Pietrzykowski, 2019). Unconditional (absolute) convergence means that countries/regions converge to the same stock-state regardless of the initial fundamental characteristics. Conditional convergence means that poorer countries/regions will develop faster than richer ones but only when they converge to the same stock-state and all fundamental characteristics are the same. In contrast countries/regions with different levels of fundamental characteristics converge to different stock states. The typical method to verify the presence of

β convergence is to use Barro (1991) regressions. However, such a simple approach still widely used today has received quick criticism. Friedman (1992) and Quah (1993) argued that the use of Barro regression can lead to a bias of the convergence parameter. Despite the criticism this approach remains the most popular and has seen several extensions e.g. because of the use of panel data and more sophisticated estimators for convergence modelling (Meliciani & Peracchi, 2006). σ convergence occurs when the variation in GDP *per capita* between countries/regions decreases over time. These studies use different measures of dispersion (e.g. standard deviation, coefficients of variation or variance of GDP *per capita*) from the trend and verify that the dispersion measure used statistically significantly decreases over time.

Although β convergence is the best described in the literature and has received the largest number of publications similar concepts can also be found. An example is γ convergence proposed by Boyle and McCarthy (1997). Their concept is based on observing changes over time in the position of a country/region in terms of GDP in a particular group. If the position of a country/region remained constant over time one could conclude that convergence does not exist. They proposed the use of Kendall's rank concordance index as an indicator to verify their concept of convergence. Lucke (2008) proposed a new concept known as ρ (rho) convergence. His idea is based on an inverted chronology of time series to simultaneously consider divergence (based on an analogy with β convergence). Lucke proposes instead of studying convergence over time a focus on divergence in reverse time. In this approach the requirements that must be met to confirm convergence in his proposed sense are more restrictive.

Many methods have been used to test different convergence concepts. The first popular tool for testing β convergence was cross-sectional regressions. Initially a significant challenge was to identify the initial fundamental characteristics for verifying conditional convergence. Durlauf (2004) found that there are between 100–150 variables in empirical studies that can significantly affect the results of convergence estimates. Verification of the convergence hypothesis based on cross-sectional data involves loss of information regarding the variability of objects over time (beyond extreme years) and omission of individual characteristics. This approach also had the disadvantage of just a few observations which as shown by Islam (1995) and Canova and Mercet (1995) can affect the underestimation of the β parameter. An important development in this area has been the use of panel data to study convergence. Panel data allow the problem of a low number of observations to be overcome and to account for an object (individuals) and/or time-specific effects by appropriate estimation methods. The most popular methods for estimating the β convergence hypothesis on panel data include: Fixed Effects Model, Random Effects Model or using Arellano and Bond (1991), Blundell and Bond (1998) estimators as well as methods using panel unit root tests Evans and Karras (1996). An interest-

ing analytical framework for studying β convergence—a time-varying factor model is proposed by Phillips and Sul (2007a,b; 2009). This model and theoretical framework because of its applicability to the research presented here are discussed further in Section 3.

1.2. Empirical studies on regional convergence in Poland

Poland is a country with a relatively high regional differentiation of GDP *per capita*. Research studies show that the historical dimension determining the east-west divide is still an important factor in differentiating Poland's economic space (Smętkowski & Płoszaj, 2016; Gorzelak & Smętkowski, 2019). Besides the dispersion of regional GDP, the dynamics of the changes which are taking place is also important. Many studies conducted on regional data in Poland show that convergence of income *per capita* (measured most often by GDP *per capita*) did not occur (Wójcik, 2008, 2018; Markowska-Przybyła, 2010; Kusideł, 2013; Piętak, 2015). Despite the different approaches of the authors to the β convergence analysis it should be emphasised that most of the studies were characterised by relatively short time series which resulted in a low number of observations in the panel. Moreover, in many cases the period of analysis covered years in which regions were still struggling with the effects of the recession after the post-communist transition. Wójcik (2008), using a methodology that allows the analysis of the dynamics of the full income distribution—transition matrices and non-parametric kernel estimation and rejects the convergence hypothesis while pointing to the existence of convergence clubs. His research identifies two convergence clubs: the richest (Western Poland) and the poorest regions (Eastern Poland). Similar conclusions are formulated when examining convergence in the first decade after EU accession. Poland has achieved a significant improvement in income indicators at the national level. However, empirical analyses of the distribution of GDP *per capita* and its dynamics at the regional level in Poland show that this progress is not distributed proportionally across all regions. Neither beta nor sigma convergence is observed. Instead the relatively fastest growth of the initially richest regions introduces club convergence led to polarization while eastern regions lagged behind (Wójcik, 2017, 2021; Moroianu-Dumitrescu & Novac, 2020). Czudec and Kata (2016) argue that there has been significant progress in reducing development differences between eastern and western Polish regions due to the allocation of significant EU cohesion policy funds. However the analysis only considers the period 2004–2014, without comparing convergence patterns before EU accession. Horridge and Rokicki (2018) show that the regions of Eastern Poland gained the most from accession in 2004. They use regional dynamic computable general equilibrium (CGE) to simulate the growth of regional *per capita* income for the Visegrad Group countries in 2000–2013 at the NUTS 2 level. The authors conclude that all regions would have grown at a slower pace without

EU membership and that EU structural policies played a key role. According to these authors, without EU accession or with accession but without cohesion policy regional disparities in Poland would have grown even faster especially after the year 2008. Since as Horridge and Rokicki (2018) argue the regions of Eastern Poland gained the most after EU accession it is reasonable to investigate whether the development disparities between Western and Eastern Poland have decreased.

In this paper a relatively new analytical framework proposed by Phillips and Sul (2007a,b, 2009) is used to study β convergence which based on a time-varying factor model overcomes the difficulty of heterogeneity of technical progress across regions. Based on the analytical capabilities of the method described in Section 3 the following empirical hypotheses are made:

H1: There is a catch-up effect of the Eastern Poland regions towards the Western Poland regions.

H2: There is convergence within the group of the Eastern Poland regions.

H3: There is convergence within the group of the Western Poland regions.

Rejecting the hypothesis of real convergence in all regions or in an extracted group it is possible, at the same time by using the adopted research method to examine whether club convergence occurs among these regions. This leads to the following hypothesis:

H4: There are convergence clubs in Poland from a regional perspective.

If the H2 hypothesis could not be rejected it could suggest that the regions of Eastern Poland form their own convergence club. In such a case it is worth confirming the existence of this club using the procedure of identification of convergence clubs in the group of all regions of Poland. It is possible that one region of Eastern Poland shows convergence with the regions of Western Poland. To confirm the occurrence of such a convergence club the following hypothesis was put forward:

H5: Regions of Eastern Poland compared to all regions of Poland form their convergence club.

It seems that H2 and H3 are complementary to H4 but the bases of these hypotheses are different. Under H2 and H3 the basis for group formation is historical conditions that richer regions (Western Poland) and poorer regions (Eastern Poland) converge to the steady-state characteristic of the group. In H4 the basis for distinguishing convergence clubs is not historical conditions but the procedure proposed based on Phillips and Sul (2007a,b) rules for forming and identifying such clubs. Basically in H4 and H5 the aim is to identify convergence clubs and not-convergent regions and answer whether the identified convergence clubs form based on the historically determined East-West divide.

It is also worth noting that in the empirical literature on the convergence of regional GDP *per capita* in Poland there are no analyses based on the method proposed by Phillips and Sul (2007a,b). This is therefore a research gap that is worthy of consideration.

2. Methodology

2.1. Theoretical framework

According to the neoclassical steady-state model of economic growth, the growth rate of income *per capita* is equal to the rate of technical progress. Moreover, homogeneous technology is assumed meaning that regardless of initial conditions, all countries or regions have the same rate of technical progress over time. However, this assumption is too restrictive. To relax and at the same time account for heterogeneity between countries or regions Phillips and Sul (2007a) propose a new theoretical approach. Similar to the work of Howitt and Mayer-Foulkes (2005) Phillips and Sul (2007a,b) extend the neoclassical growth model to include technological heterogeneity which leads to expressing logarithmic *per capita* income:

$$lny_{it} = lny_i^{\star} + (lny_{i0} - lny_i^{\star})\, e^{-\beta it} + lnA_{it} \tag{1}$$

where: lny_{i0} and $lny_i^{\star}$ are the natural log of the initial and steady-state levels of *per capita* income, respectively, β_{it} is the time-varying speed of convergence and lnA_{it} is the natural log of technology accumulation for country/region i at time t. Technology is decomposed as:

$$lnA_{it} = lnA_{i0} + \gamma_{it}\, lnA_t \tag{2}$$

where: lnA_{i0} is an initial state of technology, lnA_t is the publicly available advanced technology at time t and γ_{it} is varies over time and across parameter measuring the distance of a country/region from the publicly available advanced technology (Borsi & Metiu, 2015). Assuming the available technology evolves over time according to a common trend μ_t, the model with heterogeneous technology admits a time-varying latent factor representation can be written as:

$$lny_{it} = \left(\frac{lny_i^{\star} + (lny_{i0} - lny_i^{\star})e^{-\beta_{it}} + lnA_{i0} + \gamma_{it} lnA_t}{\mu_t} \right) \mu_t = \delta_{it}\mu_t \tag{3}$$

μ_t is a steady-state trend which following either a non-stationary stochastic trend with drift or a trend-stationary process and the country/region-specific transition path of country/region i to the common trend μ_t is captured by the time-varying factor δ_{it}. This factor is a form of the economic distance of each country/region from the common trend which may arise from differences in technological progress. Thus the relative income gap between countries/regions can be specified as:

$$lny_{it} - lny_{jt} = (\delta_{it} - \delta_{jt})\mu_t \tag{4}$$

In the long run these income differences are explained only by technology differences between the countries/regions *i* and *j*. Based on equation (4) it is natural to formulate the growth convergence condition which Phillips and Sul (2007a) call a relative convergence condition as:

$$\lim_{t\to\infty}\delta_{it}=\delta \text{ or equivalently } \lim_{t\to\infty}\frac{lny_{it}}{lny_{jt}}=1$$

Thus, the convergence of all countries/regions to the common trend μt requires that δ_{it} and δ_{jt} converge to some common constant $\delta_i = \delta_j = \delta$.

Based on the general model Phillips and Sul (2007a,b; 2009) propose a wide spectrum of applications of their methodology. Their model forms a strong theoretical background for investigating convergence issues, including convergence club methodology and club clustering.

2.2. The relative transition path

Because of the specification of equation (3) it is practically impossible to estimate δ_{it} (number of unknowns in the model exceeds the number of observations). For this reason Phillips and Sul suggest the relative measure that allows approximating this parameter. They construct the relative transition paths:

$$h_{it}=\frac{lny_{it}}{N^{-1}\sum_{i=1}^{N}lny_{it}}=\frac{ln\delta_{it}}{N^{-1}\sum_{i=1}^{N}ln\delta_{it}} \tag{5}$$

where the common trend μ_t has been eliminated by scaling. H_{it} is called relative transition path that shows the transition process for country/region *i* about the cross-section average at time *t*. Thus, if the relative transition paths converge towards unity with time it means that there is growth convergence across countries. As noted by Cieślik and Wciślik (2020) the transition path measure can be further changed to show patterns of transition in a particular group concerning other groups, or even individual countries or regions.

2.3. The log(t) convergence test

The general model assumes the idiosyncratic component δ_{it} has the follow a semi-parametric process of the form:

$$\delta_{it}=\delta_i+\sigma_{it}\xi_{it},\qquad \sigma_{it}=\sigma_i L(t)^{-1}t^{-\alpha},\qquad \xi_{it}\sim iid(0,1) \tag{6}$$

where: $L(t)$ is a slowly varying function, e.g. $\log(t)$. Phillips and Sul observe that, for all $\alpha \geq 0$, δ_{it} is convergence to δ_i. Based on the above the authors formulate a test of the null hypothesis of convergence:

$$H_0 : \delta_i = \delta \quad \forall_i \quad \text{and} \quad \alpha \geq 0 \tag{7}$$

The alternative hypothesis is:

$$H_1 : \delta_i \neq \delta \quad \forall_i \quad \text{or} \quad \alpha < 0 \tag{8}$$

where: α is a parameter specifying the speed of convergence.

Alternative hypothesis H1 assumes no convergence between all countries/regions which however does not rule out the existence of club convergence.

To verify the hypothesis the first required step is the calculation of coefficients of variance H_i / H_t. If there is convergence that the factor δ_{it} converge to δ and the relative transition paths given by $h_{it} \to 1$. In that case the cross-sectional variance of h_{it} converges to zero asymptotically:

$$H_t = N^{-1} \sum_{i=1}^{N} \left(h_{it} - 1\right)^2 \to 0 \ \text{ as } \ t \to \infty \tag{9}$$

where h_{it} is given by equation (5) and H_t is the distance of country/region i from the common limit. In the next step it should be run the following log(t) regression model:

$$\log\left(\frac{H_1}{H_t}\right) - 2\log\left[\log(t)\right] = a + b\log(t) + \varepsilon_t \tag{10}$$

$$\text{for} \quad t = [rT], [rT] + 1, \ldots, T \quad \text{with} \quad r > 0$$

According to Du (2017), Monte Carlo experiments show that $r \in [0.2, 0.3]$ achieves a satisfactory performance. Specifically, it is suggested to set $r = 0.3$ for the small or moderate ($T \leq 50$) sample and set $r = 0.2$ for the large ($T \geq 100$) sample.

Phillips and Sul (2007b) showed that $b = 2\alpha$ provides a scaled estimator of the speed of the convergence parameter. The null hypothesis is conveniently tested through the weak inequality null $\alpha \geq 0$ which implies a one-sided t-test. The test is obtained with heteroscedasticity and autocorrelation consistent (HAC) formed from the regression residuals. At the 5% significance level, the null hypothesis is rejected when $t_b > -1.65$. The null hypothesis indicates only relative convergence where α [0;1]. To test for unconditional convergence the null hypothesis should be modified into H_0: $b \geq 2$, which corresponds to $\alpha \geq 1$.

2.4. Club convergence and clustering

Rejection of the null hypothesis of convergence between all countries/regions does not rule out the existence of club convergence. To investigate the possibility of convergence clubs Phillips and Sul (2007b) developed a data-driven

algorithm. With Schnurbus, Haupt, and Meier (2017), several improvements were made in this procedure. The general procedure for identifying convergence clubs comprises several steps:

1. Separating the trend from the time series with the use of statistical tools (e.g. HP filter) and ordering the series based on the last values. In the case of a series with high variability the ordering is based on the average value of the last 50% of observations.
2. Formation of the first group of k individuals ($2 \leq k < N$) based on the ranking (first step) using the maximum t_k statistic for estimated log(t) regression satisfying the condition that $t_k > -1.65$.
3. Successively increasing the number of individuals in a group with log(t) regression reassessment until $t_k > -1.65$.
4. Forming the next convergence clubs from the remaining individuals using log(t) regression. The procedure presented in points 1–3 is repeated until it is impossible to build a group of k individuals for which the $t_k > -1.65$.
5. In the final step Schnurbus, Haupt, and Meier (2017) advocated conducting club merging using the log(t) test for the initial clubs. Finally the classifications with the smallest number of convergence clubs is obtained.

3. Empirical results

3.1. Data

The research is based on panel data for seventeen regions of Poland in the years 2000–2019. The variable studied was GDP *per capita* expressed in PLN in prices for the year 2019 using regional price indices. The article uses statistical rather than ta administrative regional division—NUTS2 where the Mazowieckie voivodeship is divided into Mazowiecki Regionalny region and Warszawski Stołeczny region. Other regions are identical with an administrative division into voivodeships. Such a division allowed the identification of the Warszawski Stołeczny region where GDP *per capita* is at the highest level in Poland and 2019 was over 2.5 times higher than in the Mazowiecki Regionalny region and about 2.6 times higher than the average for the other regions. Table 1 shows the most important basic statistics for all regions of Poland and in the group of regions of Western and Eastern Poland.

The variation of GDP *per capita* is much higher in the group of regions of Western than Eastern Poland. In 2019 the ratio of max/min GDP *per capita* in the Eastern Poland group of regions was 1.05, in the Western Poland regions almost 2.8 and in all Poland regions 3.21 (Table 1). This suggests that the Eastern Poland regions are the most cohesive group. The group of regions of Western Poland is much more diverse where the most 'outlier' region is the Warszawski

Table 1. Real GDP *per capita*—descriptive statistics

	Regions					
	All Poland		Eastern Poland		Western Poland	
	2000	2019	2000	2019	2000	2019
Min	20240.54	40741	20240.54	40741	22576.25	47036
Max	62435.51	130962	22910.92	42976	62435.51	130962
Mean	27782.86	55500.31	21716.85	41811.62	30310.36	61203.92
SD	9585.22	21050.02	1121.91	1024.29	10463.56	22879.48
Kurtosis	11.99	11.48	–1.81	–2.76	10.05	9.66
Skewness	3.24	3.17	–0.33	0.01	3.06	2.99
Max/Min	3.09	3.21	1.13	1.05	2.77	2.78

Source: Own calculation based on data from www.stat.gov.pl using STATA 16.1.

Stołeczny region which is also clear in the analysis of relative transition paths in this group.

3.2. Relative transition paths

The trajectories of relative transition paths of GDP *per capita* calculated according to equation (5), are summarised in Figures 1–3. Since the relative transition paths of the analysed variable compare the logarithmized values of GDP p.c. of a given region to the average in the cross-section of the group the values of the calculated paths oscillate around unity. If the regions in the group converge it can be observed that the transition paths in time asymptotically approach unity from above or below. Such relationships can be observed in the regions of Eastern Poland (Figure 1).

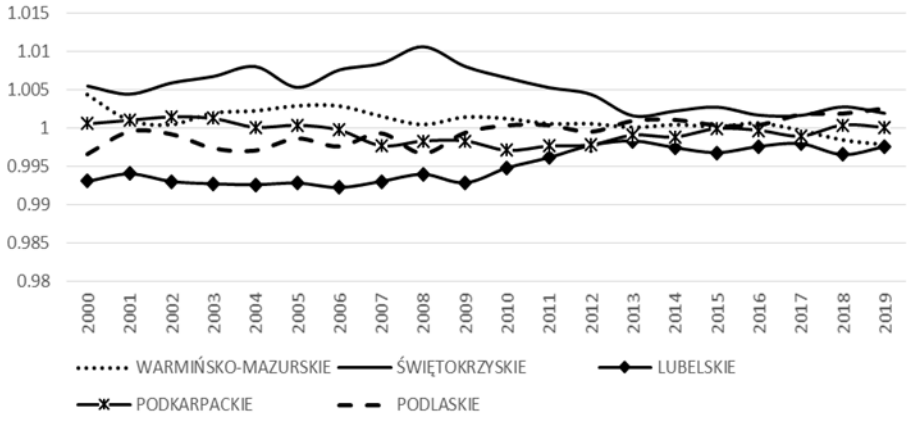

Figure. 1. Relative transition paths for the regions of Eastern Poland
Source: Own elaboration.

Greater coherence characterises the regions of Eastern Poland and when analysing Figure 1 the trends of transition paths converging towards unity can be observed. The Świętokrzyskie region characterised by higher than average logarithmic values of GDP *per capita*, converges from the top towards unity while the Lubelskie region converges from the bottom towards unity. The trajectories of the transition paths of other regions of Eastern Poland (Podkarpackie, Podlaskie, Warmińsko-Mazurskie) are closer to unity depending on the period converging from above or from below towards unity. The noticeable asymptotic convergence over time of the relative transition paths in this group towards unity may suggest that the regions are moving towards a common steady-state. The convergence of relative transition paths intensified after 2009. This may result from better absorption of EU funds supported by the additional programme for Eastern Poland launched in 2007 or from the faster recovery of these regions from the 2008 economic crisis.

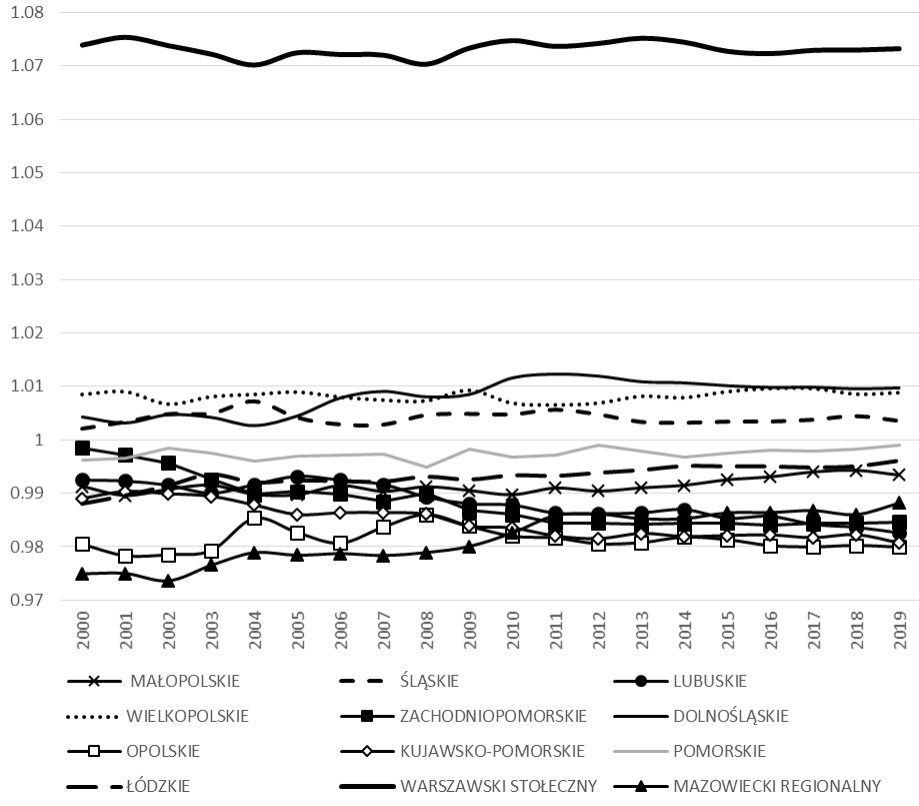

Figure 2. Relative transition paths for the regions of Western Poland
Source: Own elaboration.

When analysing the trajectories of relative transition paths in the regions of Western Poland (Figure 2) it can be confirmed that the regions of this group

are more diverse. The relative path for the Warszawski Stołeczny region is furthest from unity with no observable convergence. The higher (lower) relative to unity the transition path is, the higher (lower) income level in a given region was than the group cross-section average. Distances between transition paths show the relative *per capita* income gaps between regions. The situation is similar in the remaining regions with the difference that those paths are closer to unity. In this group only the relative paths of the following regions: Wielkopolskie, Dolnośląskie and Śląskie are located above unity. In the case of Dolnośląskie and Wielkopolskie it can be observed moving away from unity rather than converging. Relative transition paths for the remaining regions of the group are below unity. To sum up the relative transition paths of the regions of Western Poland are almost parallel and it is difficult to observe trends of convergence from above or below towards unity. This may suggest that the regions are developing at a steady pace and sticking to a similar level of development. This suggests also that the relative constancy of the income gap between regions and the lack of convergence.

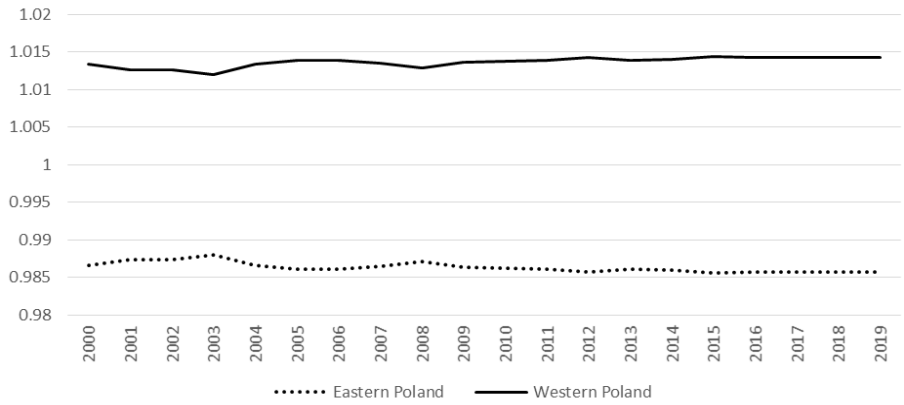

Figure 3. Average relative transition paths for groups of regions of Eastern and Western Poland
Source: Own elaboration.

An analysis of the trajectories of relative average transition paths for the groups of eastern and western Polish regions presented in Figure 3 shows that these paths are also located horizontally with regard to each other with no apparent effect of approaching unity. Moreover, the paths are far apart which suggests an enormous gap between the average GDP *per capita* between the groups. Observations of the average relative transition paths for Western and Eastern Poland suggest that there was no convergence between these groups. However, to confirm or reject the convergence hypothesis the graphical analysis of relative transition paths within and between groups is not sufficient. To

give an unambiguous answer the analysis should be supplemented with formal statistical tests.

To formally test the convergence the methodology proposed by Phillips and Sul (2007b) was applied. Its theoretical framework was described in Section 3. It is sometimes the case that graphical observations can be used to infer convergence but the tests cannot confirm it. The econometric log(t) regression test proposed by Phillips, Sul is very rigorous and requires strong trends in the data and is designed to reject weak convergence patterns. The *logtreg*, *psecta*, *scheckmerge*, and *immergeclub* commands developed by Du (2017) using STATA software were used in the empirical study presented here. The results of the log(*t*) regression test for the analysed groups are summarised in Table 2.

Table 2. Log(*t*) regression test—coefficient estimates and *t*-statistics

Regions groups	$\hat{b}$	SE	*t*-statistics	$\hat{\alpha}$	Convergence
Eastern Poland	1.447	0.163	8.852	0.723	Yes
Western Poland	–0.849	0.011	–75.741	–0.424	No
Western Poland (without Warszawski Stołeczny)	–1.097	0.005	–206.843	–0.549	No
All Poland	–0.872	0.011	–79.938	–0.436	No
Estern Poland towards Western Poland	–0.955	0.010	–93.952	–0.477	No

Notes: Coefficients $\hat{\alpha}$ were derived from $\hat{b}$ estimates, which are of the form $\hat{b} = 2\,\hat{\alpha}$. The last column presents the results of the test, based on Phillips and Sul (2007a) rule: the null hypothesis of convergence is rejected at 5% significance level if *t*-stat < –1.65. SE – standard errors.

Source: Own calculation using STATA 16.1.

Based on the results of the convergence tests summarised in Table 2 only in the group of regions of Eastern Poland the convergence hypothesis cannot be rejected and the speed of convergence can be described as medium ($\hat{\alpha} = 0.723$). In the group of Western Poland regions the null hypothesis of the existence of convergence was rejected. Also after removing the Warszawski Stołeczny region whose relative transition path was the highest from the regions of Western Poland the convergence hypothesis among the remaining regions of this group was rejected. Similarly the hypothesis of convergence among all regions of Poland was also rejected. An attempt was also made to examine whether the group of regions in Eastern Poland was catching up with the group of regions in Western Poland during the period under analysis however the hypothesis of convergence between those groups was also rejected. There is no catching-up of the Easter Poland regions towards the Western Poland group.

3.3. Convergence clubs

The rejection of the hypothesis on convergence in the group of regions of Western Poland and among all regions of Poland does not rule out the possibility that there is no club convergence among some regions. It may turn out that within a group the regions are not converging to a common steady state. However it is possible to distinguish subgroups of regions (clubs), where regions converge to different steady states characteristic for given clubs. For this purpose the procedure of selecting regions into subgroups and testing the hypothesis of convergence separating convergence clubs and the procedure of merging clubs was carried out. In the first place the procedure was carried out among regions of Western Poland and also among regions in the whole of Poland. The initiative to identify convergence clubs among all regions of Poland results from the desire to confirm whether the regions of Eastern Poland form their convergence club or maybe some regions form convergence clubs within the regions of Western Poland.

3.3.1. Western Poland

Following the procedure proposed by Phillips and Sul (2007b, 2009) and changed by Schnurbus and others (2017), two convergence clubs and a not-convergence group were identified among the regions of Western Poland (Table 3).

Table 3. Convergence club classifications in Western Poland regions

Club 1
MAZOWIECKI REGIONALNY POMORSKIE ŁÓDZKIE ŚLĄSKIE
Club 2
KUJAWSKO-POMORSKIE LUBUSKIE OPOLSKIE ZACHODNIOPOMORSKIE
Not-convergent—Group 3
MAŁOPOLSKIE DOLNOŚLĄSKIE WARSZAWSKI STOŁECZNY WIELKOPOLSKIE

Source: Own calculation using STATA 16.1.

The identified convergence clubs and the not-convergent group of regions seem logical. The not-convergent group is by far the richest region with thriving

metropolitan areas. Convergence club 1 regions are characterised by a higher level of GDP *per capita* than convergence club 2 regions, so that (in line with the convergence effect) the speed of convergence is slower than club 2 (see results in Table 4).

Table 4. Log(*t*) regression test in convergence clubs—coefficient estimates and *t*-statistics

Convergence clubs/ Not-convergent group	$\hat{b}$	*t*-statistics	$\hat{\alpha}$	Convergence
Club 1	0.255	4.218	0.128 (weak)	Yes
Club 2	1.095	19.436	0.548 (medium)	Yes
Group 3	–0.722	–39.721	–0.361	No
Group 3 (without Warszawski Stołeczny)	–0.700	–16.332	–0.350	No

Notes: as in Table 2.

Source: Own calculation using STATA 16.1.

The conducted convergence tests confirm that in the regions grouped into convergence clubs, the null hypothesis cannot be rejected. The speed of convergence between regions: Kujawsko-Pomorskie, Lubuskie, Opolskie and Zachodnio-Pomorskie (club 2) can be described as medium and was 4 times higher than calculated for the first club. This means that club 2 regions will approach their steady-state much faster than club 1 regions and their relative transition path trajectories will be more steeply sloped than club 1 regions (Table 4).

At the last stage of the procedure an attempt was made to merge the clubs and results shows in Table 5.

Table 5. Log(*t*) regression test for all pairs of adjacent clubs

Convergence clubs/ Not convergent group	$\hat{b}$	SE	*t*-statistics	$\hat{\alpha}$	Club merging
Club 1+2	–1.061	0.0285	–37.195	–0.531	No
Club 2 + Group 3	–0.920	0.0109	–84.309	–0.461	No
Club 2+ Group 3 (without Warszawski Stołeczny)	–1.366	0.0030	–419.88	–0.683	No

Notes: as in Table 2.

Source: Own calculation using STATA 16.1.

Merging clubs as proposed by Schnurbus and others (2017) comprise testing whether the identified convergence clubs are characterised by conver-

gence towards average GDP *per capita* values for the clubs that are attempted to merge. By merging clubs the number of convergence clubs is reduced and more regions can be shown to converge to a common steady-state. However, as shown by the convergence test results for all combinations of neighbouring clubs (Table 5) the convergence hypothesis cannot be confirmed in any configuration—no clubs merging.

3.3.2. All Poland

The same procedure of grouping and screening the regions applied to the whole of Poland. As already mentioned this will allow the confirmation or rejection of the hypothesis that all regions of Eastern Poland compared to the whole of Poland belong to the same convergence club. Using the *psecta* command in STATA (see Du, 2017) three convergence clubs and a not-convergent group were extracted from the group of all Polish regions (Tables 6–7).

Table 6. Convergence club classifications in Poland regions

Club 1	**Regions**
MAZOWIECKI REGIONALNY	W
POMORSKIE	W
ŁÓDZKIE	W
ŚLĄSKIE	W
Club 2	
KUJAWSKO-POMORSKIE	W
LUBELSKIE	E
LUBUSKIE	W
OPOLSKIE	W
PODLASKIE	E
ZACHODNIOPOMORSKIE	W
Club 3	
PODKARPACKIE	E
WARMIŃSKO-MAZURSKIE	E
ŚWIĘTOKRZYSKIE	E
Not-convergent – Group 4	
MAŁOPOLSKIE	W
DOLNOŚLĄSKIE	W
WARSZAWSKI STOŁECZNY	W
WIELKOPOLSKIE	W

Notes: W - Western Poland, E - Eastern Poland

Source: Own calculation using STATA 16.1.

Club 1 comprises regions belonging to Western Poland and it is the same subgroup as the first convergence club among the regions of Western Poland.

Table 7. Log(*t*) regression test in convergence clubs—coefficient estimates and *t*-statistics

Convergence clubs/ Not-convergent group	$\hat{b}$	*t*-statistics	$\hat{\alpha}$	Convergence
Club 1	0.255	4.218	0.128 (weak)	Yes
Club 2	0.133	2.505	0.067 (weak)	Yes
Club 3	1.313	5.739	0.657 (medium)	Yes
Group 4	–0.722	–39.721	–0.361	No

Notes: as in Table 2.

Source: Own calculation using STATA 16.1.

However, the composition of the second convergence club is interesting. This club comprises four regions of Western Poland and two regions of Eastern Poland (Lubelskie and Podlaskie). This does not mean that these regions of Eastern Poland are the richest but only that they follow the same steady-state as Kujawsko-Pomorskie, Lubuskie, Opolskie and Zachodniopomorskie. As shown in Figure 5 there is a large development disproportion between Lubelskie and Podlaskie and the other regions of this club hence their relative transition paths converge to unity from below. The third convergence club in Poland comprises the remaining regions of Eastern Poland (Podkarpackie, Warmińsko-Mazurskie and Świętokrzyskie). The non-convergent group of regions for the whole of Poland is the same as in the Western Poland group as it comprises the same regions. In general these are the richest regions of Poland with large cities strongly influencing the entire region as growth poles. The highest rate of convergence was calculated for club 3 comprising three regions of Eastern Poland ($\alpha = 0.657$). The slowest convergence rate was for the regions comprising club 2 ($\alpha = 0.067$) (Table 7). The occurrence of convergence in the separated clubs can also be observed by analysing the relative transition paths calculated against the average magnitudes from the cross-section of a convergence club (Figures 4–6).

An interesting observation is a fact that the Mazowiecki Regionalny region converges to the same steady-state as the Śląskie, Pomorskie, Łódzkie regions (Figure 4). However, it does not converge with the Warszawski Stołeczny region which may result from a large income gap between the regions although administratively they form one Mazowieckie voivodeship. It is justified to analyse the Mazowiecki Regionalny and Warszawski Stołeczny regions separately as their level of development is completely different and they are subject to different processes.

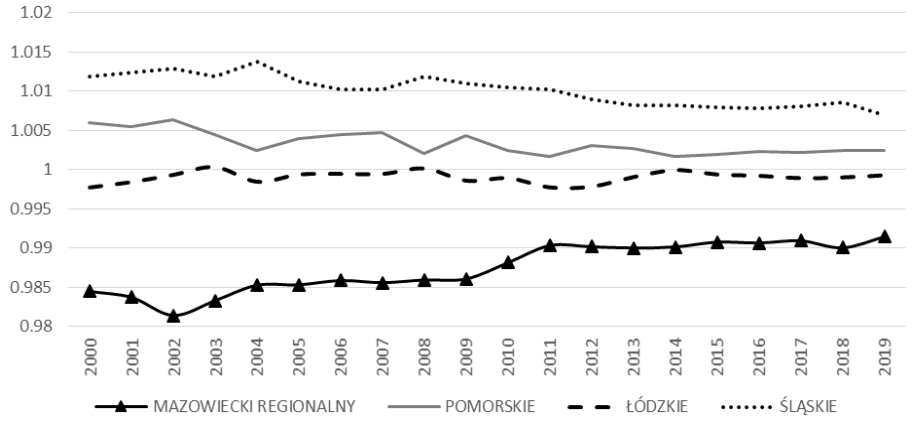

Figure 4. Relative transition paths for the convergence club 1
Source: Own elaboration.

In all the selected convergence clubs one can see a graphical convergence of relative transition paths to unity. Interestingly the relative transition paths are presented for the second club where relatively richer regions (four regions of Western Poland) converge asymptotically from above while two regions of Eastern Poland converge towards unity from below (Figure 5).

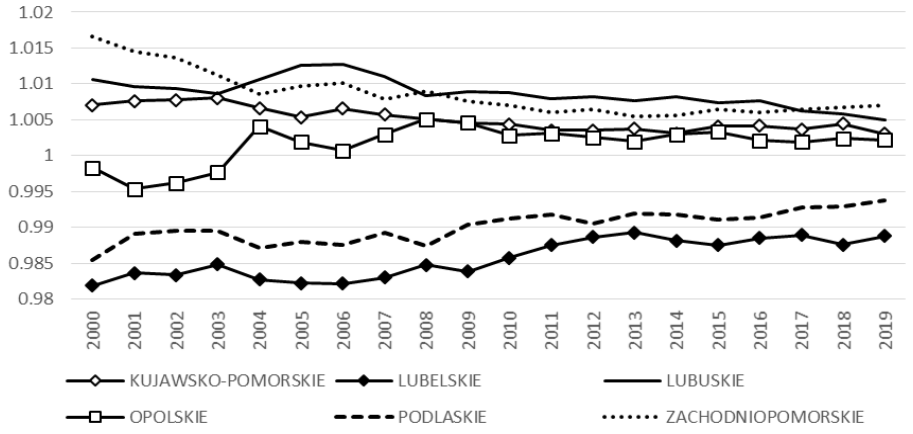

Figure 5. Relative transition paths for the convergence club 2
Source: Own elaboration.

The transition paths in the not-convergent group of regions are horizontal when calculated according to the cross-sectional average of the group. They run parallel to each other with no apparent convergence to unity. There is a visible gap between the Warszawski Stołeczny region and the remaining regions of the group. This means that the most developed regions in general have been

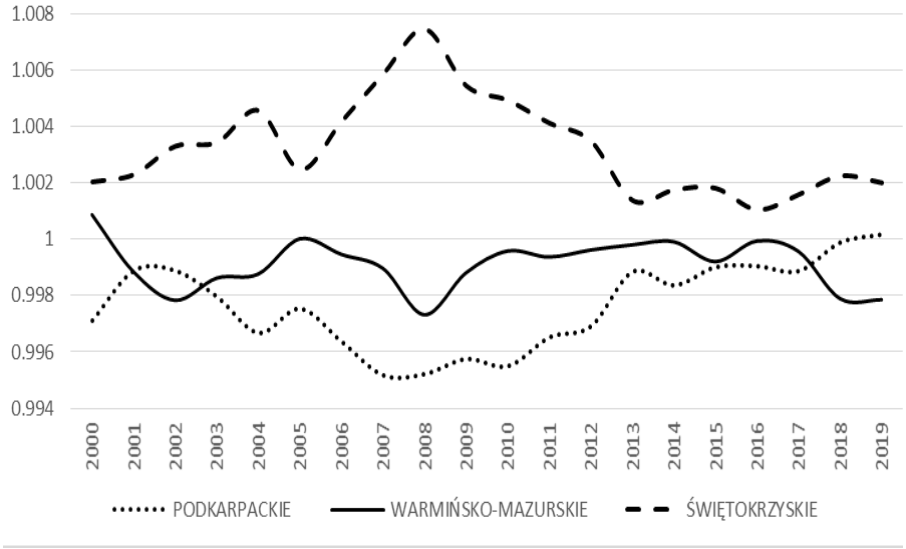

Figure 6. Relative transition paths for the convergence club 3
Source: Own elaboration.

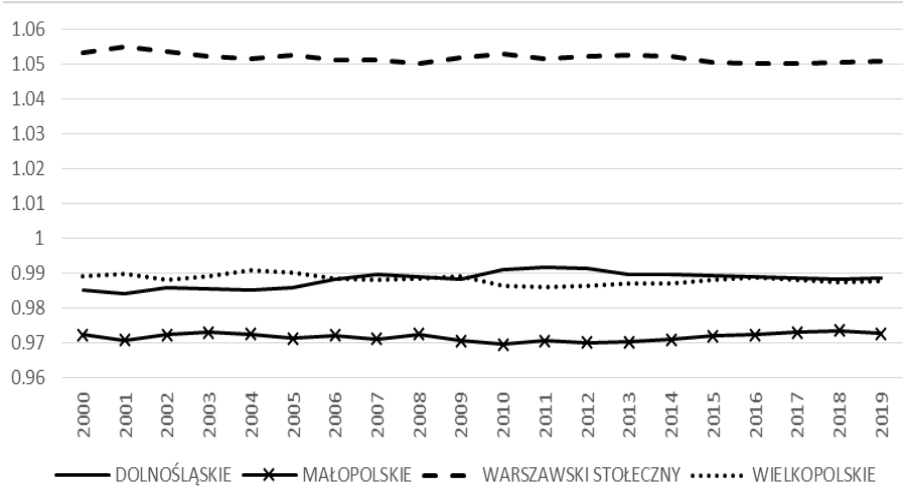

Figure 7. Relative transition paths for the not-convergent group
Source: Own elaboration.

developing at a similar pace over the last twenty years so the development gap did not change significantly (Figure 7).

To reduce the number of clubs an attempt was made to merge neighbouring clubs and the results are summarised in Table 8.

Table 8. Log(*t*) regression test for all pairs of adjacent clubs

Convergence clubs/ Not-convergent group	$\hat{b}$	SE	*t*-statistics	$\hat{\alpha}$	Club merging
Club 1+2	–0.747	0.0042	–176.964	–0.373	No
Club 2+3	–0.190	0.0313	–6.068	–0.095	No
Club 3+ Group 4	–0.906	0.0113	–80.317	–0.453	No

Notes: as in Table 2.

Source: Own calculation using STATA v. 16.1.

After inter-club convergence tests it was found that club merging was not possible in any configuration. The extracted clubs show convergence to their steady-states and it proved impossible to find common steady-states for two different clubs (Table 8).

Conclusions

The Polish economy has undergone profound economic and political changes started by the economic transformation in 1989. Introducing a market economy system boosted economic development. Nevertheless the historically entrenched division into Eastern and Western Poland continued to deepen in the 1990s. Poland's accession to the EU was to be an important turning point in this trend. The common European market, free movement of capital, people, goods and technologies and funds allocated for the cohesion policy was to determine Poland's catching up with the more developed economies of the old EU and to level the differences in development between Eastern and Western Poland. The study did not provide clear evidence for the existence of a strict catch-up effect between the regions of Western Poland and Eastern Poland (hypothesis H1 was rejected). It also failed to confirm the convergence in the group of regions of Western Poland (H3 was rejected). It turns out that the group of regions of Western Poland is very diverse and it was impossible for all regions of this group to converge to the same steady state. The group of regions of Eastern Poland was a more cohesive group which conditioned the regions of this group to converge to one steady-state (H2 was confirmed). According to the procedure proposed by Phillips and Sul, in the group of regions of Western Poland it was possible to distinguish two convergence clubs and a group of the richest regions that were not convergent. The procedure of selecting the convergence clubs was also applied to all regions of Poland which was to confirm or reject the hypothesis that the regions of Eastern Poland compared to all regions form a separate convergence club. Based on the performed grouping of the regions it turned out that three convergence clubs and a non-convergent group of the

richest regions could be identified. Interestingly only three regions of Eastern Poland (Podkarpackie, Warmińsko-Mazurskie and Świętokrzyskie) formed their convergence club. Lubelskie and Podlaskie regions showed more convergence to the common state established with Kujawsko-pomorskie, Lubuskie, Opolskie and Zachodnio-pomorskie regions than with the rest regions of Eastern Poland (H4 was confirmed, while H5 was rejected).

Although the convergence hypothesis was rejected for Poland as a whole and Western Poland and was confirmed for Eastern Poland it turns out that most of the regions (thirteen out of seventeen) converged but to three different steady-states within the convergence clubs. Moreover, within the convergence clubs, some regions of Eastern Poland were convergent with some regions of Western Poland. Assuming only a historically grounded division into regions of Eastern and Western Poland it can be concluded that the catch-up effect between these groups did not occur. This was mainly because of the high differentiation of the regions of Western Poland which within the analysed group did not converge to a single steady-state. However, when adopting the substantive criterion for the identification of convergence clubs proposed by Phillips and Sul it can be seen that the convergence clubs did not result from a sharp East-West dividing line. When analysing the relative transition paths of the identified convergence clubs one can see that the convergence effect intensified after 2009. This is especially visible in convergence clubs 2 and 3 where regions are relatively poorer than in club 1. This may be due to greater absorption of EU funds especially since some regions since 2007 benefited from additional support for Eastern Poland. Perhaps in these regions the supply effects of investments financed in the first years of EU membership were stronger. Moreover, richer regions were more strongly affected by the recession of 2008 which may have slowed down their development. To continue the implementation of cohesion policy programmes of additional support for less developed regions (e.g. Eastern Poland) should be continued. Furthermore when analysing the convergence clubs it is worth extending additional programmes to a larger number of regions but with development similar to that of Eastern Poland which would require an increase in funding for such additional support.

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