



Testing and measurement of economic convergence: A review of some recent developments

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ABSTRACT

Objective: This article reviews the empirical findings about the convergence hypothesis obtained in the period 1992-2017. In the first place it investigates the specifications of economic indicators used in testing the convergence effect. Further, the paper provides a breakdown of the convergence research development after the financial crisis.

Research Design & Methods: The research method is based on critical literature review. Hence, this article builds on other author's surveys, summarizes them and concludes the development.

Findings: No trend in analysed literature has been seen. The convergence debate is still not settled. With respect to the financial crisis, many authors describe it as having positive effect on convergence. However despite inserting dummy data or splitting the analysis for the pre- and post-crisis periods, no method to deal with the slowdown was noted.

Contribution & Value Added: Providing the empirical results in one place, this review is for sure a good starting point for people interested in the convergence process. Also some more experienced researchers may find, that the debate is still not settled and the topic is worth further investigation.

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INTRODUCTION

The convergence discussion can find its origins in the debate between the neoclassical and the endogenous growth theory. Whereas the neo-classicists see diminishing returns to capital, the endogenous growth followers seek increasing returns, i. e. in human capital. One try to see which theory is valid, was the introduction of the convergence hypothesis based on the neoclassical growth models. The positive evaluation of the convergence hypothesis

would prove the neoclassical models to be more realistic, than the ones from the endogenous growth theory. The theoretical backgrounds can be found in neoclassical models of economic growth. One of the oldest is the one constructed by Ramsey (1928), however the most popular one, from Solow, was introduced in 1956 (Solow, 1956). Based on them Barro and Sala-i-Martin (1992) and Romer, Mankiw and Weil (1992) derive the regressions.

The absolute beta convergence hypothesis means, that all countries are going to reach the same steady state (mainly because of the diminishing returns to capital). The poorer countries are going to catch up, or rather converge to the richer ones, which results in their faster growth. Further, also the sigma convergence concept was introduced, where the GDP p. c values of countries are tending to reach the same level. In contrary to the beta convergence, the richer countries may grow slower here, or even negatively, to approach the same steady state. Hence, the beta convergence is a necessary condition for the sigma convergence. Since many authors didn't find empirical prove for the absolute beta convergence all over the world, also the so-called conditional beta convergence concept was introduced. The conditional beta convergence takes into account differences of steady states between the countries or country groups. This concept refers to the differences in technical progress, investment, or government spending etc. between the countries. Thus, these additional variables are hold constant in the specific empirical analyses. Some of the authors also used to seek for the convergence in Total Factor Productivity levels, human capital or some other economical indices. They are the minority however.

The main goal of this article is to make an overview of the empirical literature that aims at specification of appropriate economic indicators utilized in the problem of testing the converge effect. In addition to the overview about the latest studies, the development in the research after the financial crisis will be examined.

The methodology is based on critical literature review, where recent articles were selected, analysed and summed up. The selection of articles was performed under some conditions. Only papers with empirical findings for countries or regions were selected. Articles without a clear methodology or robust results were declined. Furthermore, to see the recent research development, it was tried to find 1-2 appropriate articles for each year of the analysed period. With respect to the databases, well-known economic journals dealing with convergence and economic growth topics were preferred first.

The paper describes mainly three different figures, or rather types of convergence, where such was observed. The well-known beta and sigma convergence will be introduced. In addition, we will also describe the convergence of technological progress (TFP) and even some indices. All theories and empirical findings were mainly ordered by the leading methodology used, and further by the starting period of the samples analysis.

Four main parts of this article were formed. In the first, the leading research methodology was regression or a regression together with a standard deviation. In the second, the papers with focus on standard deviation only were included. The third part deals with the panel approach. Finally, the fourth section contains other combinations or rather methods used for testing the convergence hypothesis.

As we know, the 2008 financial crisis had a global impact on many countries; there should be also new findings in the research about the convergence theory. Because of that, in every article, which was published after the global financial crisis, an additional paragraph was added. We can find there, how the author dealt with the GDP slowdown in his analysis,

or if he didn't examine it at all. Furthermore, this article should be rather complementary, not substitutional, to the well-known convergence theory review by Islam (2003).

TESTING CONVERGENCE BY REGRESSION ANALYSIS

Our starting point is the seminal article *Convergence* from Barro and Sala-i-Martin (1992). The authors focus on the beta convergence for US regions, both in absolute and conditional sense. Using a regression analysis derived from common neoclassical growth models (Ramsey, Solow, Cass and Koopmans) they examine Gross State Products of various US-states or rather US-territories. Moreover, their data set-up contains 22 samples with periods of 10 or 20 years.

After the research the authors found evidence on the absolute convergence for the US in the long period, meaning that states with lower initial per capita income levels tended to grow faster, than the richer ones. The speed of convergence was about 2% per year, regardless of holding constant the region and measure of sectoral composition, or not.

The second part of the article compares the US-States results with other countries. Having analysed 98 countries from 1960 to 1985 the authors found evidence only on conditional convergence after they hold constant the initial school enrolment and the government consumption to GDP ratio. The authors also point out, that a realistic α -level (diminishing returns to capital) is crucial for the outcome.

Also in the year 1992 a paper called *A Contribution to the Empirics of Economic Growth* was published by three authors, N. Gregory Mankiw, David Romer and David Weil (1992). They examined the Solow model consistency with empirical data. While the Solow model turned out to be consistent and effective, the authors also analysed the data for convergence.

Using three samples of data from the Real National Accounts by Summers and Heston (1988) the authors run a regression based on the Solow model. In the first sample 98 countries were used, where oil production was not a dominant industry. The second sample consists of 75 countries, which do not include small ones, where the income is likely to be dominated by specific factors. The last sample includes 22 OECD countries, where the populations are higher than one million. For all calculations the analysed periods were 1960-1985.

The unconditional beta convergence was observed only in the OECD sample with an R^2 value of 46%, the convergence itself had a value of 1.67%. The remained samples didn't show convergence and R^2 was lower than 0.03. Secondly the authors analysed the conditional convergence including the rate of investment and population growth. For the first sample the convergence speed of 0.6% with R^2 of 38% were noted, for the second 1.04% with R^2 of 35% and for the OECD sample 1.73% and 62% respectively. The third table shows an analysis with a measure of human capital – the average percentage of working people in secondary school. This lead to higher convergence rates. First sample with 1.37% and R^2 of 46%, second with 1.82% and 65% and the final one with 2.03% and 65% respectively. Finally, the authors run a regression imposing that some coefficients don't sum up to zero. Having this restriction does not change the last results very much. The convergence rate and R^2 equalled for the first sample 1.42% and 46%, for the second 1.86% and 44% and for the third 2.06% and 66% respectively.

Dowrick and DeLong (2003) argue in their paper about the globalization and its effects on convergence, or rather about the convergence debate. Furthermore, there are some

empirical finding about the GDP growth. The authors use Penn World Tables 5.6a with 109 countries, they split the samples into the years 1960, 1980 and 1998. The countries are also divided into three groups according to the 1960 real PPP GDP level, poor (<USD 1,500), rich (>USD 5,000) and the countries between. An increasing dispersion between the groups was noted throughout the years. The poor countries grew at 2.1%, the richest at 2.7% and the middle-income at 3.2% per year between 1960 and 1980.

The paper also deals with a different type of beta convergence. The authors sorted the countries by dummies, if they are open for international trade, or not. Reading the charts with the average annual growth rate 1960-1980 and the 1960 GDP level, we can see a divergence among the closed economies and a convergence trend amongst the open ones. Nearly the same trend can be seen on a chart analysing the period between 1980-1998.

At the end, the authors state that the reason for the inability of poor countries to catch up the rich ones is the poverty trap. Furthermore, opening to the world economy makes the growth higher, it doesn't necessary promote the convergence however.

Before the huge eastern European Union enlargement many articles about Central and Eastern Europe's economies were published, also with respect to the convergence theory. The paper from Martin, Valazquez and Funck (2001) is one of them.

The authors try to analyse the convergence of four less developed EU countries back then, namely Spain, Portugal, Ireland and Greece. Based on the outcome, they give advices regarding the strategy for CEE countries.

The paper measures per capita GDP rates at purchase power standards from years 1960 to 2000. Greece, Portugal and Spain converged to the average GDP rate of EU, whereas Ireland even outstripped it, reaching around 120% of GDP of the EU in the year 2000. Further the paper describes the ratios and reasons for countries' convergence and analyses Ireland's success. Amongst other things Ireland managed to pull much higher foreign investment amounts than the remained countries.

Furthermore, the article also looked at the GDP rates for 10 CEE countries from 1991 to 2000 and compared it with the EU average. In average CEE countries reached after 20 years of growth around 38% of the EU's GDP compared to around 36% at the beginning in 1991. To sum up the results, sigma convergence in some countries was noted, in other i. e. Bulgaria, was seen.

In 1995 the paper from Ingo (1995) about the beta convergence and divergence within the European Union was published. He uses the same regression equation as Barro and Sala-i-Martin (1992), however bearing in mind that it catches only the average change in periods and is therefore limited in continuous time.

As data basis the Regio from Eurostat is used. It consists not only of 12 member states, but also of 166 regions, whereas the periods are between 1980-1991. The GDP levels are calculated with the purchase power parity.

Examining the correlation between the GDP p. c. 1975 level and the average annual growth rate of the member states (1975-1991) the absolute beta convergence was confirmed and reached a level of 1.61%. Furthermore, the author run another regression, one with holding constant the industry employment and the second without the outliers countries Luxembourg and Greece. The outcome for the convergence was 1.86% and even 2.73% respectively. Splitting the samples into smaller time periods however even divergence during 1980-1991 of -0.5% was found.

For the regression of 166 regions much lower absolute convergence level was noted, namely 0.34%, and the conditional with country dummies 1%.

The research on the sigma convergence supports the previous results based on member states. For the 166 regions no clear evidence in sigma convergence was noted.

Also Kaitila (2005) wrote a paper about a conditional convergence. This time the old 15 EU countries and the 8 new CEE members were analysed. The author made two samples. First, the ppp adjusted GDP of EU15 in the period from 1960 to 2002 was checked. Secondly, the eight CEE countries in a shorten period, from 1993 to 2002, were examined.

Conditional beta convergence was calculated by a pooled mean-group estimation. The described attitudes of this estimator were the allowance of heterogeneity in short run and the homogeneity in longer periods. To be closer to the production function spirit, the GDP levels were divided by the labour force, not as usual by the population. To make the research conditional, variables like investment were controlled.

The conditional beta convergence proved to exist both in the EU15 countries and in the 8 CEE towards the EU15. In addition, the author confirmed statistically, that the public consumption and high inflation had a negative effect on growth. The openness (measured by exports-to-GDP ratio) was not statistically significant.

Another paper, which is dealing with the absolute beta convergence, was written by Mathur (2005). The author is analysing four different groups of countries, namely 8 East Asian, 5 South Asian, 15 CIS and 16 European Union's. In addition, the examined time was split in four periods, 1961-2001, 1970-2001, 1980-2001 and 1990-2001.

For estimating the absolute beta convergence and its speed, a linear and non-linear regressions (least squares) was used.

Looking at all periods, only EU and East Asian countries seemed to have absolute beta convergence. Furthermore, the speed of the convergence was increasing throughout the years. While convergence in the EU during first two periods was strong, in 1980-2001 and 1990-2001 there was no statistical evidence found. Also no convergence for South Asian and CIS sample was noted. Looking between the country's groups however, statistical evidence for South Asia, East Asia and European Union after 1980 was seen.

The speed of convergence for the four periods is in the range from 0.99%-2.56% per year for the EU countries and between 0.57% and 1.16% for East Asia with the EU countries.

Jahan (2013) checks in his publication whether the sigma and absolute beta convergence exists or not. The author uses data from World Bank's World Development Indicators for 31 years. The period analysed is 1980-2011. All available countries in the database were used for testing the convergence hypothesis. The enormous size of the sample makes the study different from the ones previously discussed. Further, the sample for all countries was split into two parts: One with a GDP per capita and the second with a GDP per person employed calculation.

Beta convergence was checked with a simple regression, while for the sigma convergence standard deviation was used.

No sigma convergence was noted in the whole country sample, both in GDP per capita, as well as per person employed terms. A Beta convergence trend was only seen in GDP per person employed terms. In addition, the author divided his sample into more country-groups. The developed countries, developing, 23 Europe and Asia, 42 North and Sub-Sa-

haran Africa and finally 24 Latin America and Caribbean countries. For the developed countries both sigma and beta convergence were noted. For the developing ones, only beta convergence for GDP per person employed was seen. After examining the remaining groups, beta and sigma convergence occurred only in the 23 European and Asian countries. The remaining ones didn't show any trend.

No remarks regarding the financial crisis were found. Furthermore, it should be noted, that no signs of statistical significance calculations were found in this paper.

At the end of 2003 a paper concerning the EU convergence was published. At the beginning Martin and Sanz (2003) revive the convergence theory and its debate, later the methodology. Based on the regression model from Barro and Sala-i-Martin (1992) they look for the absolute and conditional beta convergence across the EU member states and its regions.

The absolute beta convergence for 15 EU members during 1986-1998 reached 3.9%, whereas the conditional one 3.1%. On the other hand, the absolute convergence for 210 EU Regions at NUTS II level was around 2.6% and the conditional even 12.2%, the conditional contains a regional dummy however.

Furthermore, the authors also use various indicators to check the economic cohesion. To review the outcome, the rank index showed that the difference between the richest and poorest region has diminished.

The Gini Index also confirms the smaller inequality dropping from 0.175 in 1986 to 0.151 in 1998.

Another index used, Theil, also supports the reduction of spatial income inequality in the EU back then during the 1986-1998 period. It is however important to note, that when looking on particular countries, some expected higher inequality rate i. e. Greece.

An article from Rapacki and Próchniak (2009) was published shortly after the beginning of the global financial crisis. The authors analyse 27 transitional countries (CEE & CIS) in the period from 1990-2005 for absolute beta convergence, as well as sigma convergence. The main data source is IMF (2006).

Both concepts of convergence are estimated by regression equations, whereas the beta convergence equation is derived from the Solow model, and sigma is calculated with the standard deviation of the GDP log. The sample was split into 3 periods, namely 1990-2005, 1993-2005 and 2000-2005. In addition, also 5 splits of the countries were performed. The first group consists of all 27 transition countries, the second 12 CIS countries, third 15 CSEE, 10 CEE and the final group of 8 CEE countries. To make an overview about the results Table 1 and Table 2 was formed with beta and sigma convergence respectively.

As one may see, the final conclusion is not clear. Beta convergence seems to exist in most of the samples, however with a poor statistical significance assuming R^2 lower than 15% (greyed out cells). The smaller the sample, i. e. for 8 CEE countries, the better evidence for absolute beta convergence.

Although R^2 is much higher, sigma convergence has similar development to beta. We can see it more often in a smaller sample and in shorter periods, than vice versa.

No remarks and other development regarding the global financial crisis was seen.

Two years later Próchniak (2011) wrote an article about the determinants of economic growth. Despite the determinants, he also checked for the absolute and conditional convergence.

10 CEE countries were subject to the research throughout 1993-2009. Five samples were formulated; each sub-period is 3 years long. As leading methodology, correlation and regression analysis were used. The data comes from three bases, World Bank, IMF, EBRD and Heritage Foundation.

Table 1. Beta Convergence Rates for CEE and CIS countries by Rapacki and Próchniak (with R² values)

| Period | 27 States | 12 CIS | 15 CSEE | 10 CEE | 8 CEE |
|------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| 1990-2005 | 0.0017 (0.0016) | no (0.1257) | 0.0385 (0.5749) | 0.0090 (0.0366) | 0.0371 (0.4164) |
| 1993-2005 | 0.0084 (0.0383) | 0.0048 (0.0130) | 0.0454 (0.5629) | 0.0201 (0.1389) | 0.0509 (0.7404) |
| 2000-2005 | 0.0139 (0.1215) | no (0.0458) | 0.0042 (0.0115) | 0.0371 (0.3965) | 0.0762 (0.6200) |

Source: Adopted from Rapacki and Próchniak (2009, p. 317-318).

Table 2. Sigma Convergence Rates for CEE and CIS countries by Rapacki and Próchniak (with R² values)

| Period | 27 States | 12 CIS | 15 CSEE | 10 CEE | 8 CEE |
|------------------|-----------------|----------------|-----------------|-----------------|-----------------|
| 1990-2005 | no (0.2482) | no (0.5381) | yes (0.7243) | no (0.1457) | yes (0.4082) |
| 1993-2005 | yes (0.1181) | no (0.4112) | yes (0.5043) | yes (0.1156) | yes (0.9571) |
| 2000-2005 | yes (0.9440) | no (0.9933) | no (0.0262) | yes (0.9935) | yes (0.9892) |

Source: Adopted from Rapacki and Próchniak (2009, p. 317-318).

After analysing 10 different models, the convergence hypothesis was confirmed in every single of them, despite model no. 10 with the demand formula, which had too low statistical significance. Furthermore, among the most important economic growth determinants we could find the investment rate, human capital, financial sector development and some other variables.

Since the global financial crisis was in the researched period, the author had to deal with it somehow. He took it as an exogenous factor. To “exclude it” as a determinant of economic growth, a dummy variable was constructed. This variable equaled 1 in the years 2008-2009, and 0 in all other periods, where financial crisis didn’t occur.

Solanko (2003) wrote a paper about the convergence in Russian regions using Goskomstat data. Based on neoclassical growth models a regression was formulated. To see if absolute or conditional convergence exist, correlation between the 1992 income level and the average growth rate in the period 1993-2001 was observed. To examine the sigma convergence, standard deviation was used.

After checking the correlation for the sample it turned out, that absolute beta convergence exists and its speed is equal to 3%, but because of the different price/income levels in Russia the result has to be take into account carefully. Further analysis suggests, that Russian regions have different steady states, because of the high heterogeneity of the country.

On the other hand, to measure the conditional beta convergence, the author took some regional dummies into account (i. e. geography) and has ran different regressions. All of them

retrieved a negative coefficient of the 1992 income level, confirming the existence of conditional beta convergence. The linear LTS regression with the highest R^2 value of 0.58 had a coefficient even of -0.057 pointing out towards a strong conditional beta convergence.

Since 1992 to 2001 sigma divergence in 87 Russian regions was noted, to be exact the disparity in 2001 was around 3 times higher, then in 1992. The author also ran another calculation, namely excluding four richest regions. The divergence there was as expected smaller, however still 2 times higher in 2001 than in 1992. Analysing deeply the disparity within years, one may see that during the Ruble-Crisis in 1998 it nearly halved. Short after the crisis, divergence started to rise again.

Siljak (2015) wrote an article about the convergence across 28 EU countries. She checked for both types of beta convergence, and for sigma convergence as well. The time period is 1995-2013 – it was also split between 4 sub-periods, namely 1995-2003, 2004-2013, 2004-2008 and finally the post crisis period 2009-2013.

For the sigma convergence the author used not only the well-known standard deviation, but also the min and max values of GDP relative to the average. To calculate the beta coefficient a regression was run. For conditional beta convergence variables like inflation or economic openness were set independent.

The coefficient of variation was 42.17 in the year 2013, while 50.22 in the starting period in 1995 – sigma convergence occurred. Another interesting development is the minimum to the average GDP ratio. It was equal to 0.3460 in 1995, 0.4168 in 2007 and 0.4761 in 2013. In contrary the maximum to the average GDP ratio was 2.5059, 2.8107 and 2.7117 in 1995, 2007 and 2013 respectively. The absolute beta convergence in all EU states was equal to 2.08% from 1995-2013, the conditional one to 2.34%. In the sub periods the rates varied a little bit, however still occurred. In addition, the conditional beta convergence with extra socio-political variables was calculated and the outcome was 1.91% for the same period.

While the variance coefficient was nearly stable before the financial crisis, it decreased from 46.19 in 2007 to 41.75 in 2009. In 2010 it reached 43.09 and started to fall again reaching 42.17 in 2013. The same development can be seen in the min to avg. GDP or max to avg. GDP ratio. This means, that in the short run the financial crisis reduced the income variance, and had a positive effect on the sigma convergence. The beta convergence with respect to the financial crisis was analysed in the period 2004-2008 and reached a value of 1.15%. Six eastern Europe countries formed according to the author a club of convergence, having a positive growth rate, while many western European economies were affected by the negative growth rate.

Głodowska (2015) investigates 28 EU members and 276 regions (NUTS2) to check for the convergence process. To perform the analysis, the author was using Eurostat data from 2000-2013. For beta convergence, Głodowska used the methodology derived from Barro (1992) and did a regression analysis. The sigma convergence was examined based on the difference between the initial GDP and its average, meaning that standard deviation formula was applied.

Evidence for absolute beta convergence was found in the EU countries (2000-2013) and the EU regions (2000-2011). The speed was around 3.7% and 2.5% respectively, whereas the statistical significance based on R^2 was higher (0.7574) in the country sample and lower (0.4482) in the regional one. Sigma convergence was also observed in both

groups. For EU countries the deviation declined from approx. 0.24 in 2000 to 0.15 in 2013; for the EU regions similar from 0.23 in 2000 to 0.16 in 2011.

After the year 2008, the GDP level declined in both samples. In the general overview for the EU States the decline was higher in the richer countries. While checking the variance, the process stopped from 2008 onwards resulting in a negative effect of the global financial crisis on sigma convergence. The slowdown of the sigma convergence from 2008 onwards was noted in EU countries and EU regions.

Dvorokova (2014) presented in her study an impact of the global financial crisis on the real convergence across the EU28 countries. Analysed are the years 2001-2013. The data is taken from Eurostat and UNCSTAD.

For the sigma convergence standard deviation was used, and for the beta we can find a modified Baumol (1986) equation. To estimate the beta parameter, the author performed the OLS method.

Absolute beta convergence was found among EU28 countries in the period 2001-2012. Looking at the sigma convergence development we can see, that during 2001 and 2007 the income disparities increased. During the financial crisis, in the year 2008, the standard deviation remained nearly on the 2007 level. A year later, the deviation dramatically felled and remained in 2012 nearly on the same small level as in 2009. Despite their decrease during the financial crisis time, the income inequalities were higher in 2012 than in 2001.

With respect to the global financial crisis, the author is in the opinion, that the reduction of income inequalities is due to a larger decline of GDP in rich countries, and a lower reduction in the catching-up ones.

TESTING CONVERGENCE BY STANDARD DEVIATION

This paper deals with the productivity and sigma convergence. Inklaar and Timmer (2009) researched 29 industries and compared the PPP adjusted Input/Output amounts using a bilateral Törnqvist model. Further, the authors defined an index in Multifactor productivity. For sigma convergence, standard deviation was used. Productivity and Income levels were driven from the GGDC and EU Klems databases.

To check the productivity sigma convergence 1997 benchmark productivity levels were extrapolated to 1970 and 2005 with MFP growth rates. 14 countries were included in this sample. From 1970 till 2005 sigma convergence was noted only in market services. Both, manufacturing industry and other goods services (agriculture, mining, utilities and construction) were subject to sigma divergence.

In addition, the authors split the industries into 24 detailed ones. In the years 1980-2005 only 13 were subject of sigma convergence, whereas 11 have even higher deviation than in 1980. The important conclusion from this analysis is, that industry perspective plays a huge role in the convergence theory. There was no information with respect to the financial crisis.

Slaughter (1997) argued in his paper called Per capita Income Convergence and the Role of International Trade about the role of international trade in economies. In his opinion the country's trading itself cannot be a proof for per capita income convergence and further research needs to be done.

At the end the author is using open countries from Penn World Tables to measure the sigma convergence via the standard deviation. On the chart one may see, that sigma convergence did exist from 1970 to approx. 1992, hence by the end the deviation was lower than at the beginning. Looking on the details however, there was a strong decrease of the income disparity from 1970 to 1980, and then the deviation soared to reach the level of 1970 already in the year 1988. After this big change, the deviation started to decrease rapidly, to reach finally in 1992 a much lower level than in 1970.

Furthermore, Slaughter also analysed the sigma convergence in Denmark, Ireland and the United Kingdom during the years 1965-1992. The income differences there also decreased, with similar trends to the open economies.

Dauderstädt (2014) first revives the literature about convergence theory and gives basic information about the development of Europe in the 20th century. After that, he analyses the convergence in the EU since 1999 based on economic growth, income distribution and social living standards. Mostly standard deviation, graphical illustrations and yearly analysis of the indices/data is used.

Three groups of EU countries were formulated. 12 richest Northwest countries (NW), three poorer southern countries (STH), and 13 eastern countries (EST). Furthermore, the period is split in 1999-2007 and 2007-2012 because of the financial crisis.

In fact, the 13 EST countries managed to increase their PPP GDP level from 1999 till 2007 by 73.3% and from 2007 till 2012 by 9.3%. The NW countries managed to increase their GDP levels by 41.0% and 0.5%, while the STH by 52.6% and -7.6% from 1999 till 2007 and from 2007 till 2012 respectively. It shows a convergence process despite the STH countries. The sigma convergence calculated by standard deviation was around 8.2 in 1999, on a higher level in 2007 with 11.2 and a bit lower in 2012 with 10.5, meaning a slight reduction after the financial crisis, however still bigger than in 1999. A convergence trend was also noted with respect to the hourly productivity level. It grew in average by 20% between 1999 and 2007 across the EU27, while even twice as much in some of the EST countries (i. e. Romania). No convergence in social protection was noted among EU27, the GINI coefficient however improved over time.

In connection with the financial crisis the author simply split the analysed periods till and after it occurred. Some special findings need a remark. The unemployment rate reached the lowest difference between the countries in 2008, but after that it started to increase – divergence was noted. In contrary the productivity development was much stronger in the poorer countries after the crisis, then before. During the crisis a slowdown in GDP levels was noted, but the income convergence started to rise again afterwards in the EST countries with respect to the NW. The STH countries did in some cases even worse, than before 2007.

TESTING CONVERGENCE BY PANEL ANALYSIS

Villarroya (2007) wrote an article about the convergence in Latin American countries. The author puts his focus on Latin America and human capital. Examined are 18 countries during the years 1950-2000. The data used comes from Penn World Tables, CEPAL statistics and Oxlad.

To check whether absolute or conditional convergence takes place, a panel approach with a pool estimate and fixed effects model was used. For the human capital, Principal Components methodology was used. Further, the author calculated the human capital

variable not only based on primary and secondary schooling rates, the literacy rate, the number of years spend on education but also on some additional variables i. e. mortality, inhabitants per doctor etc.

With exception to a small group of richest countries, no unconditional beta convergence was observed in that sample. The sigma convergence in the 7 richest countries sub-sample took place from 1955 to 2000, however for the 12 poorest countries sub-sample not – the divergence was even higher. After considering the main steady state variables, no significant convergence was seen. The author found signs of conditional convergence however, when he introduced the human capital variable. Furthermore, a positive correlation between the convergence process and human capital with investment in physical capital was noted.

Islam (1995) uses in his paper *Growth Empirics: A Panel Data Approach* as already mentioned in the title – panel data. The methodology is based on the paper from Mankiw, Romer and Weil (1992) described previously. However contrary to the previously described regression methods, the panel approach allows to use differences in the aggregate production functions across various countries. After conducting the Monte Carlo study the author decided to use the Least Squares with Dummy Variables and the Minimum Distance estimators. Furthermore, the author uses the same data samples as MRW used, however without Indonesia and Burkina Faso. The first sample consists then of 96 countries (non-oil), 74 (without small ones) and 22 (OECD). Islam also holds constant the population and depreciation growth rate assuming $(g+\delta)$ equal to 0.05 for all countries and periods.

First, Islam performed a regression to check for differences with MRW approach. Analysed years are 1960-1985. The results for the conditional beta convergence speed were for the first sample 0.54%, for the second 0.98% and 1.59% for the third one with OECD countries only. Islam's results from the panel approach are nearly the same as in the regression from MRW. Furthermore, an analysis in restricted form has been performed, where the investment and population growth were set equal, but opposite in sign. The following results for the convergence rate have been obtained: For the first sample 0.55%, for the second 0.92% and for the third 1.53%.

Secondly, the author divided the sample into 5 year periods making a pooled regression. The unrestricted results for the convergence speed were 0.48%, 0.74% and 1.61% for the first, second and third country-samples respectively. After the restriction the results of 0.59%, 0.95% and 1.46% didn't differ too much.

Thirdly the Minimum Distance estimation was done. The convergence speed was calculated as 4.34% for the 96 countries sample, 4.17% for the 74 countries, and 6.7% for the 22 OECD sample. We can see, that the rates after allowing for correlated country effects are much higher.

Fourthly Islam ran the LSDV estimation with fixed individual country effects. The convergence speed for the unrestricted calculation was 5.07% for the first sample, 4.62% for the second and 9.66% for the OECD countries. After the restriction the values were 4.67%, 4.58% 9.26% respectively for the three samples.

Finally, a calculation of with integration of human capital was performed. To do it, Islam used a variable called Human, introduced by Barro and Lee (1993), which consists of average schooling years at all levels. To integrate it, a change in the sample had to be done.

So the first one was reduced to 79 countries and the second to 67. The convergence speed can be found in Table 3 below.

Table 3. Convergence Rates for selected group of countries by Islam (with standard errors)

| Category | Single cross section | Pooled regression | Panel estimation |
|----------------------|----------------------|-------------------|-------------------|
| 79 Non-Oil countries | 1.11% (0.0038) | 0.69% (0.0025) | 3.75% (0.0093) |
| 67 Countries | 1.18% (0.0045) | 0.79% (0.0028) | 4.44% (0.0102) |
| 22 OECD countries | 1.87% (0.0077) | 1.62% (0.0055) | 9.13% (0.0160) |

Source: own elaboration based on Islam (1995, p. 1151).

Same as before considering the human capital rate, the panel estimation proved to show much higher convergence rates than the regressions showed. Contrary to MRW analysis, the rates are smaller, not higher. We should also note the standard errors, not every result is statistically significant.

Another different approach to measure the convergence, or rather it's nonstandard type, was provided by Liberto, Pigliaru and Mura (2007), who wrote about the convergence of Total Factor Productivity.

The authors test the presence of TFP convergence with a fixed effect panel estimator derived from the article previously described, Islam (2003). To check whether the TFP convergence takes places, the GDP per worker for the standard convergence equation was calculated. Further, three main estimators were used to see if regional TFP heterogeneity is present: Least Square with Dummy Variable, biased-corrected LSDV and the Generalized Method of Moments. The sample includes 19 Italian regions in the years 1963-1993.

The TFP heterogeneity of Italy's regions was confirmed. Also the evidence for technology convergence between 1963-1978 and 1978-1993 was found. There was no convergence in the second period however. The authors assume it is due to the halt of technology diffusion, but also mention that further research would need to be done. The last interesting finding is that human capital is strongly positively correlated with the technology level. According to the authors, this fact confirms the hypothesis from Nelson and Phelps, where human capital is the highest determinant of technological catch-up.

Three authors Chapsa, Tsanana and Katrakilidis (2015) researched the conditional beta convergence theory on a sample of 14 EU countries between 1995 and 2013. In addition, the authors also investigated growth/convergence determinants. The sample was split in two groups, the cohesion countries (Portugal, Ireland, Greece, Spain) and the remaining EU10. The data was taken from the World Bank, International Transparency Database, Heritage Foundation and from Penn World Tables.

The panel analysis was performed by using the GMM method. For capturing the validity, the Sargan and Arellano and Bond tests were computed.

Conditional beta convergence turned out to exist and have a 1% significance level. Also an interesting outcome considering the growth determinants appeared: The biggest driving powers for growth (with high statistically significance) were physical capital investments and trade openness. In contrary the government, consumption and inflation are negatively correlated with the economic growth.

The authors mentioned that constructing a dummy variable allows to control for the financial crisis, whereas the GMM method proves to be effective in this case.

TESTING CONVERGENCE: ALTERNATIVE APPROACH

In the middle of 2004 a paper from Holmes (2004) about absolute income convergence among Latin American Countries was published. The author uses Penn World Tables and filters for sixteen Latin American Countries which are characterized by competitive markets, however with more and more insights for trade liberalization. The sample was split for three periods. A full period from 1960-2000, the period with the LAIA operation in 1981-2000 and the last one before the LAIA agreement in 1960-1989.

Holmes uses a principal component technique. The tests for convergence was performed by a benchmark deviation from base country income. Then it was checked if its largest principal component (LPC) was stationary or not. The approach is different, then the previous regression models and panel methods described. It checks, whether per capita output has a tendency for deviation from the equilibrium in the long run. Furthermore, the author also run a traditional, standard OLS regression to check the absolute beta convergence.

The first OLS test didn't confirm the absolute convergence. The result of the LPC method however, shows the strongest convergence trend among the CACM countries (1960-2000), and a weak in LAIA (1981-2000). Considering all Latin American Countries, or geographical groupings, didn't confirm any convergence type.

Jayanthakumaran and Lee (2013) analysed the convergence in growth rate and beta convergence among Asian countries using a time-series approach. Two country groups were checked. Five members of the Association of South East Asian Nations (ASEAN) throughout 1967-2005 and five members of South Asian Association of Regional Cooperation (SAARC) in the years 1973-2005.

Two methods were used. First, stochastic convergence was examined. Here the authors define this process as shocks to income of a given country in relation to the average income of a countries' group. As methodology for this type of convergence, following Lumsdaine and Papell (1997), stationary unit-root tests were used. To check the null hypothesis, the authors did two structural breaks. Secondly, beta convergence is estimated differently, then in the cross-sectional data approach. In this study, the authors didn't check for the speed of convergence, but how big the initial income of a country is with respect to the average income of countries groups and then the countries growth rate.

For 5 ASEAN countries stochastic convergence was noted. In contrast, 5 SAARC nations didn't show any stochastic convergence trend. Beta convergence was noted for Thailand in the whole period. Malaysia, Indonesia and Philippines converged firstly, however after the Asian Crisis, the countries started to diverge. In contrary, Singapore began its convergence process after the financial crisis.

Despite the fact, that the article was published in 2013, the analysed period was before the financial crisis. The authors dealt with other crises, i. e. the Asian Crisis. For the crises periods, the results are interpreted and another period after the crisis was analysed. To sum up the procedure, breaks in the analysed periods were used to deal with the income slowdown problem.

Begu, Spataru and Constantin (2014) analyse the effects of the global financial crisis on European Union countries. For data Eurostat, World Bank and UNCTAD were used. The

sample consist of 27 EU member states from 1992-2007, 1995-2012 and 2000-2010 for other indicators than GDP.

To investigate the EUs member countries GDP levels and convergence, the authors used Markov Chain method. First, based on the historical data and using the Sturges Formula a transition and probability matrix was calculated. After that, the authors could run predictions for 2008 and 2009. They split the countries between 8 groups according to the GDP/capita levels and compared the estimates with the real data.

The first outcome showed dramatic differences between the prediction and the real 2008 data, meaning that a financial crisis is very difficult to predict. In 2009 however, the prediction was close to the real GDP data. There was a huge decline in GDP levels, where the amount of countries in the lowest income group doubled. The years 2011 and 2012 were also driven by high prediction differences. Further, four indices were analysed. The Corruption Perception Index (CPI), Economic Freedom Index (EFI), Gross external Debt in % of GDP (GED) and Foreign Direct Investments (FDI). While the CPI increased from 2008 to 2009 in the 2 poorer groups of countries, it remained stable in the richer ones, no trend for 2011 and 2012 was noted. The EFI showed a decrease in the richer group of countries from 2011 to 2012, while from 2008 till 2009 it remained nearly stable. Gross Debt increased in every group nearly in the same proportions, no difference between the groups were seen. For FDI no conclusion can be made. No convergence trend was seen.

Summing up, the authors approach to deal with the financial crisis was to formulate an estimate based on Markov Chain method, however it is not very accurate.

Also an interesting paper about the convergence was written by Kumo (2011). The paper is different from the previously described, because it examines 14 Southern African countries (SADC members without Zimbabwe) for beta, sigma convergence and also for the convergence to a common stochastic trend.

The methodology is based on Sala-i-Martin (1995), which means, that the author is using a regression for the beta convergence. For the model, the OLS technique was applied. For the sigma convergence, a deviation of the sigma variance between the starting and the end period was used. The data was taken from the IMF and the World Bank. The timeframe is 1992-2009. Also an Augmented Dickey-Fuller unit root test to examine the time series was performed.

The beta coefficient turned out to be negative (-0.08) implying beta convergence, however the data was statistically irrelevant (Standard Error 0.14), concluding that convergence didn't take place. Also no sigma convergence was noted, even divergence occurred. In the next section, conditional beta convergence was checked using panel data with 198 observations based on 11 countries. Four variables i. e. saving rate, pop growth, trade and gross fixed capital formation were controlled. Nevertheless, for conditional beta convergence no evidence was found. Also in the third, final approach, using the root test on 12 countries, no convergence was noted (despite Botswana and South Africa).

By the end, the author didn't deal with the financial crisis specially. He only noted the growth decreases in 2007/2008 in nearly all economies analysed. Although the author didn't mention anything, the interesting finding is, that standard GDP at PPP deviation in 1992 was 1.2229, in 2007 before the crisis 1.3370 and in 2009 the deviation was even less, namely 1.3016. This would mean, that the financial crisis contributed to sigma convergence, making the income differences between 14 South African countries smaller in 2 years.

Brzeski and Colombatto (1999) published the article *Can Eastern Europe Catch Up?* about some former eastern bloc economies and their plausibility for catching up Western Europe's countries. The paper is different than the previous described, because instead of presenting the economic growth in the past, it is trying to show the future development for 2030.

Considered are 16 Western Europe countries and 6 from Eastern Europe. For the later, the authors extrapolated future data for population, capital stock, depreciation, investment trade and technical progress. Based on the retrieved data and some others considerations he was able to create three scenarios for the catching up process. In the best one (i. e. with the lowest initial k/y ratio) all Eastern Europe countries, despite Romania, would half their gap to Western Europe by 2030. In the worst scenario however, none of them could catch up by half Western Europe.

Summing up the estimate, it is most likely to convergence for the better-developed countries; this means Czech Republic, Hungary, Slovakia, Bulgaria then Poland and finally Romania.

Although the paper does not check the convergence hypothesis and the authors are also very careful about the results, it is an interesting approach for checking the future scenarios.

Turganbayev (2017) did a study on regional total factor productivity convergence in Kazakhstan. 16 regions between the period 1997-2013 were analysed. He used Kazakhstan's statistical databases for most of the data needed.

The methodology is based on the Cobb-Douglas production function and growth accounting. The author assumes, that capital input is proportional to capital stock level. For calculating the capital stock, a perpetual inventory method is used, whereas the initial capital stock level is estimated by the 1993 book cost of fixed assets. To find the labor input, data on working population was employed. Applying a panel unit root test, the convergence process on TFP levels could be done. For the TFP dynamic across the regions, the author used the standard deviation.

Looking at the standard deviation of TFP overall, the 1993 level was equal to 0.33 and to 0.24 in 2013. Hence the TFP converged. Further, the author performed three tests. All confirmed TFP convergence in every Kazakh-Region and in non-oil regions. Two of the tests showed divergence across the oil-rich regions.

Thinking about the financial crisis aspect, while checking the chart with the standard deviation of TFP levels, one may see a huge decrease in 2007 in oil rich regions, a small in all regions, and a slight increase in non-oil regions. This would mean that due to the crisis richer regions converged higher, than the poorer.

CONCLUSIONS

While many articles were analysed and the research methods were somehow more innovative throughout years, we can say that the convergence debate is still not settled. To have a better overview about the findings, Table 4 with the various methods and results was constructed below.

The empirical findings in this article differ between each other. This is mainly due to different samples that are used, not only with respect to countries, but also to the periods. While no one argues, that the absolute beta convergence concept all over the world

is not taking place, we see differences in the observations between some countries' groups. To sum it up, the more homogenous a country group is, the more likely we can find the conditional, absolute beta and even the sigma convergence hypothesis to be true. We can just think about OECD, EU, US or regions of countries where the convergence can be observed. It is also more likely to find the conditional beta convergence, than the absolute or the sigma. Furthermore, the conditional convergence speed turns many times to be faster, than the absolute.

In the leading methodology we can find regressions based on the Solow model, performed by different methods, mostly OLS. We should add however, that before the 21st century most of the reviewed authors used cross sectional data. Nowadays a panel approach is more common. Moreover, more and more unit root tests are observed now, than before. The sigma convergence, as the name already says, is mainly checked by the standard deviation.

Another aspect of this article was to find out, how the financial crisis impacted the convergence research development. Frankly speaking, the research methods didn't change very much. Many authors just split the analysed periods in pre- and post-crisis ones, and some of them integrated a "crisis dummy" into the regression. About the effect of the financial crisis on the convergence process, one may note that the crisis was quite often in favour of the beta and sigma convergence. Some of the authors argue that it is due to the fact, that the richer countries were stronger hit by the economic slowdown, than the poorer.

The research was confronted with some limitations. First of all, the selection of the appropriate papers was not as easy as it seems. The convergence topic is widely discussed, in this paper however we were about to find a good tool for selection. While putting some criteria for filtering, the selection process could still be improved in some way. Another imitating aspect is the comparison problem. Not even one analysed paper is completely the same as another. While it may happen, that the data sample is similar, the methodology may be different – and vice versa. This is not giving the opportunity to fulfil a simple judgement if the convergence process exists, or not. Every single paper dealing with the convergence topic needs therefore to be checked individually.

There are also directions, where this research may be continued. After some period of time, the analysis can be performed again to see if a common indicator for testing the convergence is used. The convergence debate is still not settled, but the situation may change after a breakthrough in the economic growth theory – this would be the second appropriate direction for further research. Last, but not least, it would be interesting to investigate purely the financial crisis effect on the convergence process.

Table 4. Breakdown of the authors with results and methods used

| Authors | Sample | Convergence Type and Result | Method used |
|------------------------------------|-----------------------------------|---|--------------|
| Barro & Sala-i-Martin (1992) | US-States 1880-1988, 98 countries | Beta Abs: US Beta Cond: US and countries | Regression |
| Begu, Spataru, & Constantin (2014) | EU27 | Indices: No | Markov Chain |

| Authors | Sample | Convergence Type and Result | Method used |
|--|---|---|---|
| Brzeski. & Colombatto (1999) | 6 CEE countries | Catch up in 2030: All, despite Romania | Estimate |
| Chapsa, Tsanana, & Katrakilidis (2015) | EU14 | Beta Cond.: yes | Regression |
| Dauderstädt (2014) | EU27 | Sigma: no/yes Indices: Yes GDP levels: Yes | Standard deviation/ Indices comparison |
| Liberto, Pigliaru & Mura (2007) | 19 Italian Regions | TFP: yes between periods/no in the second period | Panel estimator |
| Dowrick & DeLong (2003) | 109 countries, Penn World Tables | Beta Abs.: No | Regression |
| Dvorokova (2014) | EU27 | Beta Abs.: Yes Sigma: No | Regression, Standard deviation |
| Glodowska (2015) | EU27, 276 Nuts2 | Beta Abs.: Yes 3.7% and 2.5% Sigma: Yes | Regression, Standard deviation |
| Holmes (2004) | 16 Latin American Countries | Beta Abs.: No LPC method: Yes (2 samples), no (1 whole sample) | Regression, LPC approach |
| Ingo (1995) | 12 EU Members 1975-1991 166 EU Regions 1975-1991 | Beta Abs.: 1.61% Member States, 0.34% for Regions Beta con.: 2.73% Member States, 1% for Regions Sigma: Since 1985 for Member States, not for regions | Regression |
| Inklaar & Timmer (2009) | 24 OECD countries | Sigma productivity: No dominant trend | Standard deviation |
| Islam (1995) | 3 samples, nonoil, inter and 22 OECD | Beta Cond: Yes | Panel Approach |
| Jahan (2013) | All World Countries and groups | Beta abs.: yes/no Sigma: yes/no | Regression, Standard deviation |
| Jayanthakumaran (2013) | 5 ASEAN, 5 SAARC countries | Stochastic: Yes ASEAN Beta abs.: yes/no | Unit root test |
| Kaitila (2005) | EU15, 8 CEE | Beta Cond.: yes | Regression (PGE) |
| Kumo (2011) | 14 South African states | Beta abs.: no Beta cond.: no Sigma: no | Regression, Standard deviation, Unit root test |
| Mankiw, Romer & Weil (1992) | 3 Samples: Nonoil, Inter and 22 OECD | Beta Abs: None Beta Cond: Yes | Regression |
| Martin & Sanz (2001) | 15 EU members | Beta Abs.: Yes Beta Cond: Yes | Regression |

| Authors | Sample | Convergence Type and Result | Method used |
|----------------------------------|---|---|------------------------------------|
| Martin, Valazquez & Funck (2001) | 4 EU members: Portugal, Ireland, Greece, Spain | Sigma: Yes, Indicators: yes, not Greece | Regression |
| Mathur (2005) | 8 East Asia, 5 South Asia, 15 Cis and 16 EU Countries | Beta Abs.: only EU (0.99%-2.56%) and East Asia (0.57%-1.16%). No convergence in South Asia and CIS. | Regression |
| Prochniak (2011) | 10 CEE | Beta abs.: yes | Regression |
| Rapacki & Prochniak (2009) | 27 Transition countries | Beta abs.: no/yes Sigma: no/yes | Regression |
| Sanz Villaroya (2007) | 18 Latin american countries | Beta abs.: No Beta cond.: No/yes with Hum. Capital Sigma: No (only in 7 rich countries yes) | Panel Approach |
| Siljak (2015) | EU28 | Beta Abs.: yes Beta Cond.: yes/no 2009-2013 Sigma: yes | Regression, Standard deviation |
| Slaughter (1997) | Open world economies | Sigma: yes | Standard deviation |
| Solanko (2003) | Russian Regions | Sigma: no, divergence Beta Abs.: 3% Beta Cond.: 5.7% | Correlation/Regression |
| Turganbayev (2017) | 16 Kazakhstan regions | Sigma TFP: yes/no TFP convergence: yes (divergence for oil-rich regions) | Unit root test, Standard deviation |

Source: own elaborations based on the analysed papers.

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