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CHAPTER 5

THE ROLE OF HUMAN CAPITAL IN THE PROCESS OF CONVERGENCE. EMPIRICAL ANALYSIS

Introduction

In the second half of 1980's a return to research on economic growth was observed. The main factor influencing this change was statement that long run economic development is much strongly affected by economic growth factors than by countercyclical policy (monetary and fiscal) and business cycles. Simulatenously empirical analyses suggested growing role of new growth factors, apart from labor and capital, such as human capital and capital diffusion. This resulted in the revision of economic growth models. In the classical Solow model long run growth rate was assumed to be depended on exogenous technical growth rate, which was not explained by the model. The way of solving this problem was shift towards endogenous growth models.

The first papers by P. Romer (Romer, 1986), R. Lucas (Lucas, 1988), S. Rebelo (Rebelo, 1991) were based on K. Arrow (Arrow, 1962), E. Sheshinski (Sheshinski, 1967) or H. Uzawa (Uzawa, 1965) research and did not presented technical progress. In their models unlimited growth stemmed form incomes generated by capital investment (widely interpredted, including human capital), which were not necessarily diminishing in the situatuion of economic development (contrary to the assumption of constant scale effects in the neoclassical growth model).It was assumed that externalities from human capital accumulation and knowledge diffusion result in disappearance of diminishing marginal returns. The differences between initial endogenous models and neoclassical theory of growth, represented mainly by Solow model, were result of dispute whether economies are subject to convergence (classical model) or divergence (endogenous models). Primarily convergence hypothesis was considered as implication of neoclassical growth theory, so its empirical confirmation was interpreted as back up for classical theory of growth. On the other side, lack of confirmation was used to support endogenous models. On can say that convergence was indicator of significance for growth theory[1].

Discussion about growth models was aimed rather at possible applications than theoretical cohesion and mathematical issues. Modern theory of economic growth is strongly aimed at empirical research and cohesion between theory and statistical data. One of the most commonly tested hypotheses is convergence hypothesis.

The most intensive empirical research on economic convergence took place in the 1990's. This fact is strictly linked with above mentioned discussion about theory of growth. The point of refernce for modern thinking about convergence, interpreted as convergence of group of econonies to common steady state (which is characterized by comparable wealth and growth rate) is publication of W. Baumol from 1986 (Baumol, 1986). One has to remember that W. Baumol was inspired by M. Abramovitz (Abramovitz, 1986). M. Abramovitz on the

[1] P. Romer states in the „The Origins of Endogenous Growth" from 1994 that disputes in 1980's about convergence were, apart from need for model cosidering imperfect copmetition, main factors for developing new growth theory.

basis of long run observations, discovered that in the period 1870-1979 there were significant changes in the labor productivity level for chosen OECD economies with tendency to unification. Very similar conclusions were achieved by W. Baumol for identical period and comparable set of developed economies (OECD countries). Both M. Abramovitz and W. Baumol were questioned by B. De Long (De Long, 1988). Author stated that convergence hypothesis is strictly linked with arbitrary choice of economies and expanding set makes results unclear. W. Baumol together with E. Wolff responded to his criticism (Baumol, Wolff, 1988). In their paper they proved that convergence can be observed only in case of rich countries, in result rich countries set up "convergence club", while poor countries stay poor. It is commonly considered that above mentioned cycle of publications from 1980's can be treated as the beginnig of modern discussion about economic convergence[2].

The effects of mutual influence of economic growth theory and convergence research result in adopting endogenous factors, such as technology diffusionon (Barro, Sala-i-Martin, 1997) or human capital (Mankiw, Romer, Weil, 1992) by classical model. On the other side convergence was applied to endogenous models (Lucas-Uzawa model (Lucas, 2000), Jones model (Jones, 1995), Eicher-Turnovsky model (Eicher, Turnovsky, 1999)).

Theory of endogenous growth aimed attention on human capital as importatnt growth factor. The first paper inspired directly by dispute between classical and endogenous growth theory was written by R. Barro (Barro, 1991). Human capital, interpreted as growth factor, was widely accepted especially in explaining differences of growth rate between various economies. Putting human capital into growth model requires prior elimination problems with its quantification and interpreting various categories as significant from this point of view (Piech, 2005). The most controversial is usually defining measures of human capital. The most successful, commonly accepted, attempt to employ human capital both to convergence and growth analysis is augmented Solow growth model (Mankiw, Romer, Weil, 1992).

In this paper human capital is interpreted according to proposal of G. Mankiw, D. Romer i D. Weil. Authors notified some controversial issues linked with human capital and its measuring. According to G. Mankiw, D. Romer i D. Weil human capital is usually boiled down to educational spending, while ignoring other investment such as investment in healthcare. Even if so narrow interpretation is accepted, it is very hard to measure it, because some investment in education result in income lost by learning people. According to authors there is no fully acceptable solution for this problem, because lost salary depend on qualifications. Low skilled employee will loose low salary, while High skille eployee probably in due to further learning will loose higher salary[3]. Moreover investment in education can be financed both by government and households, which complicates measuring them. Eventually not all educational spending result in improved productivity of human capital: studying philosophy, theology or literature results in mind development, however it can also be treated as form of consumption. According to this G. Mankiw, D. Romer and D. Weil decided to treat human capital as percentage of active population that is in secondary school. In the paper human capital is interpreter as share of wages of employees with high school and university education level in the global wages. Despite of above mentioned controversies linked with measuring, it was proved that employing human capital in convergence analysis both in theory and empirics allowed to achieve more adequate results.

[2] Most imporant revievs are : X. Sala-i-Martin (Sala-i-Martin, 2002), A. De La Fuente (De La Fuente, 1997) and most common N. Islam (Islam, 2003). In polish literature W. Nowak (Nowak, 2006), K. Malaga (Malaga, 2004).

[3] Another problem mentioned by G. Mankiw, D. Romer i D. Weil is difference between production and GDP. If investment in eduction results in the lost salary, it should be included in the GDP, while it is not.

Data sources, time and subject scope of analysis

Statistical data comes from „EU KLEMS Database March 2008" developed by M. Timmer i B. van Ark from University of z Groningen and M. O'Mahony from Birmingham University. Database was created withn EU KLEMS „Productivity in the European Union: A Comparative Industry Approach"[4]. The aim of this project was to develop database required for research on economic growth, labor productivity, creation of new jobs, investment and technological changes both at the aggregate and sectoral level for EU members starting from 1970. The aim of project was to assess results of EU countries economic policies, especially in the context of competitiveness and growth of economic strength goals set on summits in Lisbon and Barcelona. Form the point of view of paper's authors above mentioned database enhances possible fields of research on convergence, especially allows to analyze new EU members .

Using database authors made attempt to verify classical convergence hypothesis for 20 economies of EU[5]: Austria, Belgium, Czech Republic, Denmark, Finland, France, Greece, Spain, Netherlands, Ireland, Luxembourg, Germany, Poland, Portugal, Slovakia, Slovenia, Sweden, Hungary, UK and Italy (EU-20).

Analysis was conducted considering labor productivity for market economy. Data representing productivity was Gross Output per one employee. Data on production was originally expressed in national currency and in current prices. Firstly, data was converted to fixed prices (1995=100) using volume indices. In order to achieve international comparability EU KLEMS conversion factor for the whole market economy was used[6]. Conversion factor was caclulated on the basis of relative purchasing power parity of national currencies in comparison to purchasing power parity of currency in the reference country (Germany). It was assumed that year 1997 is base year for conversion factor.

Data for market economy was selected directly from database. According to EU KLEMS market economy is sum of all sections complying with NACE Rev. 1.1, 2002[7] without sections: L – Public administration and defence; compulsory social security; M – Education and N – Health and social work.

EU KLEMS contains time series starting from 1970 for old EU members (EU-15), while for new members (EU-10) since 1995. All data cover period till 2005. Due to significant geopolitical changes in the 1990's (i.e. transition of most of EU-10 countries from planned to market economy, reunification of Germany, collapse of Czechoslovakia, collapse of USSR, technological and internet revolution, and unobserved integration within EU), in the analysis was assumed that period of analysis covers years 1995-2005. In this period potentially more convergence factors, linked especially with acumulation of human capital, could occur and influence convergence process.

Method for testing classical convergence hypotheses

Neoclassical growth model implies convergence, which means positive correlation

[4] Datatabase and other information about Groningen Growth and Development Centre are available at www.ggdc.net.

[5] Data about investment in human capital is unavailable for listed countries: Cyprus Estonia, Lithuania, Latvia and Malta.

[6] For more details about construction of conversion factor see EU KLEMS Growth and Propuctivity Accounts Version 1.0, PART I Methodology March 2007" M. Timmer, T. van Moergastel, E. Stuivenwold, G. Ypma, M. O'Mahony and M. Kangasniemi in chapter 8.

[7] In the later period NACE was subject to changes, but draft classification from 2002 is still available on European Commission website.

between initial distance from steady state and further growth rate towards steady state. Let y^* be labor productivity in the steady state, while $y(t)$ will be labor productivity at time t. The speed of convergence can be obtained from:

$$\dot{y}/y = \beta^*[\ln(y^*) - \ln(y(t))] \quad (1)$$

where β^* is speed of convergence towards staeady state y^*. Solution of differential equation (1) is given by:

$$\ln(y(t)) = (1 - e^{-\beta t})\ln(y^*) + e^{-\beta t}\ln(y(0)) \quad (2)$$

where $y(0)$ is labor productivity of chosen country at some initial time.

Time t, at which $\ln(y(t))$ is in the half way to $\ln(y(0))$ implies that $\ln y^*$ meets condition $e^{-\beta^* t} = 1/2$. This implies that time required to reduce difference between actual state and steady state can be obtained from the following: $T = \ln(2)/\beta^*$.

After dividing both sides of equation (2) by $\ln(y(0)_i)$ and by the time period t, one can obtain equation which represents growth labor productivity rate:

$$(1/t)[\ln(y(t)) - \ln(y(0))] = [(1 - e^{-\beta t})/t]\ln(y^*) - [(1 - e^{-\beta t})/t]\ln(y(0)) \quad (3)$$

On the basis of above equation two convergence hypotheses were verified :

- absolute β-convergence of labor productivity;
- conditional β-convergence of labor productivity for MRW model[8].

In the first case steady state y^* is identical for all analyzed economy. In this situation we have absolute convergence and average yearly labor productivity growth rate depends only on labor productivity level at the initial time. This relationship can be estimated from the following equation:

$$(1/t)[\ln(y(t)/\ln(y(0))] = b_0 + b_1\ln(y(0)) + \varepsilon_{0,t} \quad (4)$$

Equation (4) describing absolute convergence of analyzed economies is called *absolute convergence equation*, where:

$y(t)$ - labor productivity in chosen country in 2005;

$y(0)$ - labor productivity in chosen country in 1995;

b_j - estimated coefficients (where j is parameter order number)

$\varepsilon_{0,t}$ - random disturbance, with normal distribution, zero expected value and constant variance.

In the second case steady state y^* is different for each economy, specific for every country. Adjustment process is in this case called conditional convergence, and yearly growth rate of labor productivity depends both on labor productivity at the initial moment and properties of steady state for chosen country. Conditional convergence equation depends on applied production function. In the MRW model neoclassical production function was augmented and includes human capital (H) with the following form:

$$Y(t) = K(t)^{\alpha} H(t)^{\lambda} (A(t)L(t))^{1-\alpha-\lambda} \quad (5)$$

Function assumes constant scale effects and diminishing returns to all production inputs. Growth in the analyzed economy is described by equations for physical capital and human captial:

$$k(t) = s_K y(t) - (n + g + \delta)k \quad (6)$$

[8] MRW model was proposed by G. Mankiw, D. Romer and D. Weil in 1992 and is treated as augmented Solow model. Augmentation means employing human capital in the neoclassical model.

$$h(t) = s_H y(t) - (n + g + \delta)h \tag{7}$$

where:

- s_K is fraction of income invested in physical capital;
- s_H is fraction of income invested in human capital;
- $y = Y / AL$, $k = K / AL$, $h = H / AL$ are units per effective unit of labor.

Economy converges to a steady state in which physical capital per effective unit of labor is given by: $k^* = [s_K^{(1-\lambda)} * s_H^{\lambda} / (n + g + \delta)]^{1/(1-\alpha-\lambda)}$, while human capital per effective unit of labor is given by: $h^* = [s_K^{\alpha} * s_H^{(1-\alpha)} / (n + g + \delta)]^{1/(1-\alpha-\lambda)}$. Labor productivity for the steady state is represented by: $y^* = [s_K^{(1-\lambda)} * s_H^{\lambda} / (n + g + \delta)]^{\alpha/(1-\alpha-\lambda)} * [s_K^{\alpha} * s_H^{(1-\alpha)} / (n + g + \delta)]^{\lambda/(1-\alpha-\lambda)}$, so equation (3) can be transformed to:

$$(1/t)[\ln(y(t)/\ln(y(0))] = [(1 - e^{-\beta t})/t]\frac{\alpha}{1-\alpha-\lambda}\ln(s_K) + [(1 - e^{-\beta t})/t]\frac{\lambda}{1-\alpha-\lambda}\ln(s_H)$$
$$-[(1 - e^{-\beta t})/t]\frac{\alpha+\lambda}{1-\alpha-\lambda}\ln(n + g + \delta) - [(1 - e^{-\beta t})/t]\ln(y(0)) \tag{8}$$

Relationship given by (8) can be estimated using:

$$(1/t)[\ln(y(t)/\ln(y(0))] = b_0 + b_1 \ln(y(0)) + b_2 \ln(s_K) + b_3 \ln(s_H) + b_4 \ln(n + g + \delta) + \varepsilon_{0,t} \tag{9}$$

Equation (9) describing conditional convergence of analyzed economies is called *conditional convergence equation for augmented model*, where in comparison to equation (4) there are some additional parameters:

s_K - average investment rate in the period 1995-2005;

s_H - average rate of investment in human capital in the period from 0 to t;

n - average employment growth rate in the period from 0 to t;

$g + \delta$ - rate of real capital depreciation, assumed for all countries at 5% level[9].

In the context of equation (9) two cases can by analyzed. In the first one can assume that $b_2 + b_3 + b_4 \neq 0$, while another case assumes that sum of b_2, b_3 and b_4 equals to 0[10].

One has to notice that in both equations parameter b_1 by log of initial productivity level can be written as:

$$b_1 = -(1 - e^{-\beta t})/t \tag{10}$$

The above mentioned equations allows to estimate β coefficient which reflects speed of convergence to steady state both for absolute and conditional convergence equations:

$$\beta = -\ln(1 + b_1 t)/t \tag{11}$$

Where β coefficient is estimated on the basis of data for interval between 0 and t.

In the next part of paper σ-convergence hypothesis was verified. σ-convergence hypothesis is apart from β-convergence most common and widely tested convergence hypothesis. One has to notice that contrary to β-convergence idea is usually linked with question whether less productive economies are subject to higher productivity growth rates than more productive economies, σ-hypothesis is linked with cross section dispersion. Idea of σ-convergence aims to answer whether differences in labor productivity among analyzed set of

[9] 5% depreciation rate is common assumption in the literature. G. Mankiw, D. Romer i D. Weil in their paper „A Contribution to the Empirics of Economic Growth" state that even significant changes of this assumption have no strong influence on further estimations.

[10] Convergence equation with parameter restrictions complies with model and is derived from equation (8).

countries diminish over time. Most popular measure of dispersion is standard deviation (SD), however it refers to absolute values. Another, also very commonly used, measure of variation is coefficient of variation (CV), which refers to relative values. The subject of σ-convergence hypothesis verification is labor productivity in analyzed countries. This implies that σ-convergence is measured by standard deviation of labor productivity at time t weighed by average labor productivity level, given by formula:

$$CV_t = \frac{SD_t}{\bar{y}(t)} \tag{12}$$

where $SD_t = \sqrt{\sum_{j=1}^{N}[y(t)_j - \bar{y}(t)\ ]^2}$ is standard deviation at time t; $y(t)_j$ - labor productivity level for j country at time t;

$\bar{y}(t)$ - average labor productivity at year t;

N - number of countries in panel.

Verification of β-convergence hypothesis supported with σ-convergence analysis allows to avoid critics known as „Galton Fallacy", which is also called reversion to the mean[11]. Such situation may occur when b_1 estimator will be significantly negative either in case of absolute convergence or conditional convergence equation and σ-convergence is not confirmed. Due to this simultaneous verification of β-convergence and σ-convergence hypotheses allows to identify real trends in labor productivity among analyzed countries.

Empirical analysis of classical convergence hypotheses for EU-20 in the period 1995-2005

Below presented results refer respectably to β-absolute, β-conditional and σ-convergence hypotheses. Estimations and graphical presentation of absolute β-convergence for EU- 20 in the period 1995 – 2005 are presented in table 1 and figure 1.

Table 1. Estimations of absolute β-convergence for EU-20 countries in the period 1995–2005

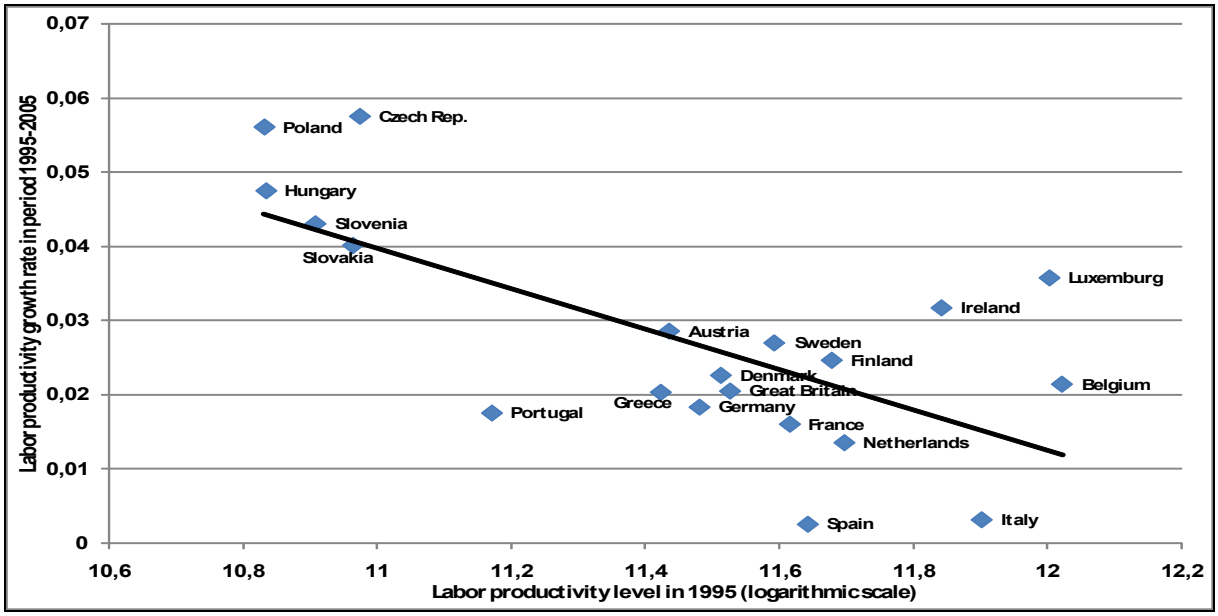
CONVERGENCE EQUATION*	b_0	b_1	b_2	b_3	b_4	R^2	$p(F)$	β / T
β-ABSOLUTE	**0,339 (0,079)**	**-0,027 (0,007)**				**0,461**	**0,001**	**3,23% 21 years**

*standard deviations in parenthesis.

Source: own calculation.

[11] For more details see D. Quah „Galton's Fallacy and Tests of the Convergence Hypothesis".

Figure 1. Absolute beta convergence for EU-20 in the period 1995-2005



Source: own calculation.

On the basis of analysis one can state that:

- slope of regression line is significantly negative, which is confirmed by data from table 1. According to table 1 economies were converging towards steady state at a rate 3,23% yearly. This implies that half way period towards steady state is 21 years.
- β coefficient is significant at 1% level;
- R^2 is 46,1%, which implies that almost 50% of changes of differences between labor productivity growth rates can be explained by initial productivity level;
- significance level of F statistics is 0,001, which suggests rejecting null-hypothesis about lack of joint influence of explanatory variables on dependent variable with over 99% probability.

Especially interesting e1emant of figure 1 is labor productivity growth scenario among new EU members which complies with convergence hypothesis. Czech Republic, Polish, Hungarian, Slovenian and Slovakian economies were initially less productive, but in the analyzed period were subject to most rapid changes in labor productivity. Economies of Luxembourg and Ireland were remote from growth scenario, they had both high productivity level in the initial year and rapid positive growth in the analyzed period . On the other side *in minus* were Portugal and Spain. In this case relatively low productivity in the initial period did not resulted in further fast productivity growth.

Due to statistical properties from table 1, absolute β-convergence hypothesis do not fully explain differences between changes the labor productivity, so it seems reasonable to include in the analysis of conditional β-convergence hypothesis derived from MRW model.

Results of estimations are presented in table 2 and table 3. Table 2 presents comparison between estimations of conditional and absolute convergence in MRW model for EU-20 in the period 1995-2005.

Table 2. Estimation of convergence equations for EU-20 in the period 1995-2005

CONVERGENCE EQUATION*	b_0	b_1	b_2	b_3	b_4	R^2	$p(F)$	β / T
β-ASBSOLUTE	**0,339 (0,079)**	**-0,027 (0,007)**				**0,461**	**0,001**	**3,23% 21 years**
β-CONDITIONAL	**0,215 (0,102)**	**-0,025 (0,009)**	**-0,007 (0,017)**	**0,013 (0,012)**	**0,016 (0,010)**	**0,584**	**0,008**	**2,96% 23 years**

*standard deviations in parenthesis.

Source: own calculation.

On the basis of data from table 2 one can state, that including variables describing differences between steady states has positive influence on statistical properties of convergence equation. This suggest conditional convergence.

On the basis of statistical properties of convergence equation one can state that:

- β coefficient in both equations has expected sign and is statistically significant for absolute convergence at 1% significance level and at 5% for conditional convergence;
- The highest R^2 was obtained for conditional convergence equation. Changes of labor productivity growth is explained in almost 60%;
- F significance level is for all equations below 1%, which suggests rejecting null-hypothesis about lack of joint influence of explanatory variables on dependent variable with over 99% probability.

Table 3 presents estimated conditional convergence equations in the MRW model with restriction on parameters for EU-20 in the period 1995-2005 for the market economy[12]. Data from table 3 meets formal requirements for convergence equations derived from augmented neoclassical growth model and on the basis of this approach production function can be assessed.

Table 3. Convergence equation estimation results for EU-20 in the period 1995-2005 with restriction on parameters

CONVERGENCE EQUATION	b_0	b_1	b_2	b_3	R^2	$p(F)$	β / T	α	λ
β-CONDITIONAL	**0,216 (0,102)**	**-0,020 (0,008)**	**0,010 (0,008)**	**-0,020 (0,008)**	**0,557**	**0,004**	**2,26% 31 years**	**0,27**	**0,23**

*standard deviations in parenthesis.

Source: own calculation.

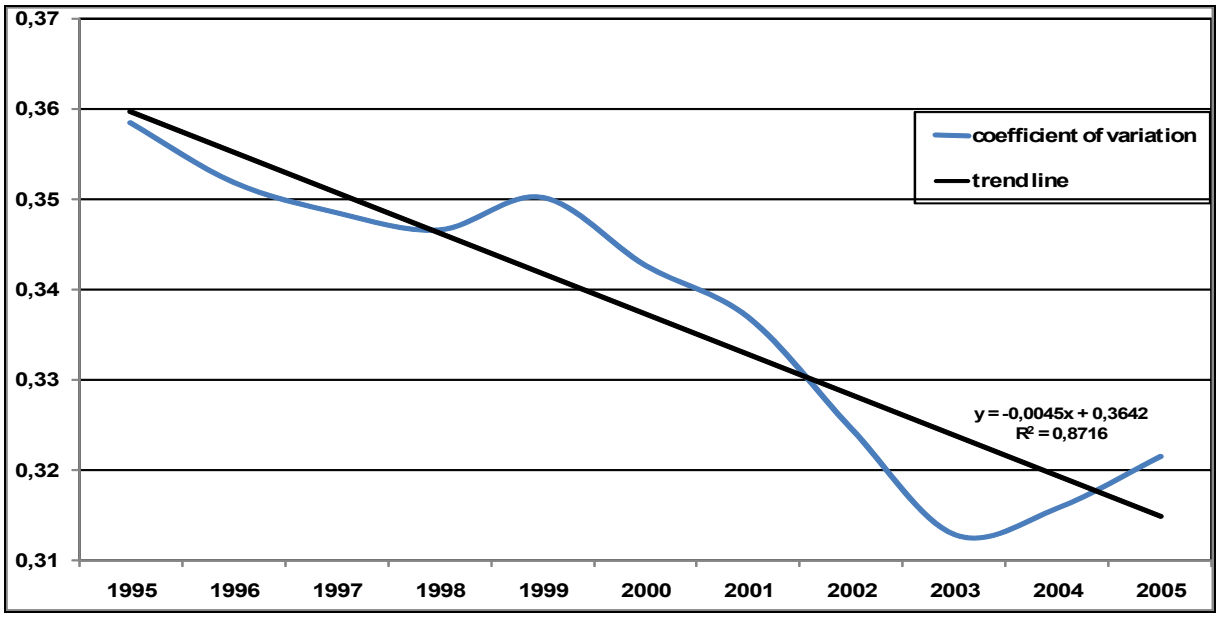
Restriction on parameters influenced statistical properties of equation and β parametre which represents speed of convergence. On the basis of estimated equations one can assume that conditional convergence from MRW model has the best statistical properties. Over the analyzed period 1995-2005 conditional convergence has 2,26% yearly rate, which implies that for economies in which productivity was lower by 1% than the average for EU-20 in 1995 cumulated rate of productivity growth over the period 1995-2005 was higher than aver-

[12] Convergence equation with restriction is given by :
$(1/t)[\ln(y(t)/\ln(y(0))] = b_0 + b_1 \ln(y(0)_i) + b_2 \ln((s_K)/(n+g+\delta)) + b_3 \ln((s_H)/(n+g+\delta)) + \varepsilon_{0,t}$

age by 2,26%. Time required for reducing differences between actual productivity and productivity in steady state by half is 31 years. Production function estimated for EU-20 in the period 1995-2005 is given by: $Y = K^{0,27} H^{0,23} (AL)^{0,5}$. This implies that increase of physical capital by 1% results in production growth at 0,27% rate. Increase of human capital by 1% results in production growth at 0,23% rate, while 1% increase in effective labor input results in production growth at 0,5% rate.

Third element of analysis is verification of σ-convergence. Figure 2 presents values of coefficient of variation for EU-20 in the period 1995-2005. Differences between labor productivity among chosen countries were diminishing which is represented by negative slope of trend line. This trend suggests σ-convergence for EU-20 group. Trend line is relatively flat which suggests diminishing differences between labor productivity in chosen countries. The yearly differences in labor productivity for EU-20 countries were diminishing at around 0,5% rate per year.

Figure 2. Sigma convergence coefficints for EU-25 in the period 1995-2005



Source: own calculation.

The initial difference which equaled to 36% shrunk over 10 years to around 32%. One can assume that this value is small especially taking into account that set of analyzed economies is dominated by highly developed countries (EU-15) with only 5 new EU members that are significantly less productive.

Summary

Conducted analysis of convergence for EU–20 countries in the period 1995–2005 proves significant role of human capital for economic growth. Including human capital in the convergence equations improved statistical properties of the estimated equations and as a result around 60% of differences in labor productivity growth rates between chosen EU countries were explained.

On the basis of achieved results one can state general conclusion according to which both human and physical are equally important for economic growth. According to produc-

tion function equation physical capital contributes 27%, while human capital 23% of growth. Another 50 % of growth can be explained by effective labor, interpreter as joint influence of increase of labor and technical progress.

Despite the fact that in the analyzed period diffrences between labor productivity were diminishing, sustained differences vary about 30 % around mean value. Considering fact that that each economy is converging to its specific steady state (conditional convergence) this deviation is relatively small, especially when one notice that there are differnces in economic development around analyzed countries.

REFERENCES:

1. Barro R. (1997), Determinants of Economic Growth: A Cross-Country Empirical Study, The MIT Press, Cambridge, Massachusetts, London, England.
2. Barro R. (1997), Makroekonomia, Wydawnictwo PWE, Warszawa.
3. Barro R., Sala-i-Martin X. (2003), Economic Growth, Second Edition, The MIT Press, Cambridge, Massachusetts, London, England.
4. Malaga K. (2004), Konwergencja gospodarcza w krajach OECD w świetle zagregowanych modeli wzrostu, Wydawnictwo AE Poznań, Poznań.
5. Michałek J.J., Siwiński W., Socha M. (2007), Polska w Unii Europejskiej: Dynamika konwergencji ekonomicznej, Wydawnictwo Naukowe PWN, Warszawa.
6. Abramovitz M. (1986), Catching Up, Forging Ahead, and Falling Behind, Journal of Economic History 46, June, ss. 385-406.
7. Barro R. (1991), Economic Growth in a Cross Section of Countries, Quarterly Journal of Economics 106, May, ss. 407-443.
8. Barro R., Sala-i-Martin X. (1997), Technological Diffusion, Convergence and Growth, Journal of Economic Growth 2, March, ss. 1-27.
9. Barro R., Sala-i-Martin X. (1992), Convergence, Journal of Political Economy 100, ss. 223-251.
10. Baumol W. (1986), Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show, American Economic Review 76, December, ss. 1072-1085.
11. Baumol W., Wolff E. (1998), Productivity Growth, Convergence, and Welfare: Reply, American Economic Review 78, December, ss. 1155-1159.
12. Caselli F., Esquivel G., Lefort F. (1996), Reopening Convergence Debate: A New Look AT Cross-Country Growth Empirics, Journal of Economic Growth 3, September, ss. 363-389.
13. De Long B. (1998), Productivity Growth, Convergence, and Welfare: Comment, American Economic Review 78, December, ss. 1138-1154.
14. Eicher T., Turnovsky S. (1999), Convergence in a two-sector nonscale growth model, Journal of Economic Growth 4, December, ss. 413-428.
15. Friedman M. (1992), Do Old Fallacies Ever Die?, Journal of Economic Literature XXX, December, ss. 2129-2132.
16. Islam N. (2003), What Have We Learnt From the Convergence Debate?, Journal of Economic Surveys vol. 17, nr 3, ss. 309–362.
17. Jones C. (1995), R&D-Based Growth Models, Journal of Political Economy vol. 103, nr 4, August, ss. 759-784.
18. Lucas R. (2000), Some Macroeconomics for the 21st Century, Journal of Economic Perspectives vol. 14, nr 1, ss. 159-168.
19. Lucas R. (1988), On the Mechanics of Economic Development, Journal of Monetary Economics 22, July, ss. 3-42.

20. Mankiw G., Romer D., Weil D. (1992), A Contribution to the Empirics of Economic Growth, Quarterly Journal of Economics, May, ss. 407-437.
21. Nowak W. (2006), Koncepcje konwergencji w teorii wzrostu gospodarczego, w: Woźniak M.G., Nierówności społeczne a wzrost gospodarczy Zeszyt nr 8, Uniwersytet Rzeszowski, Katedra Teorii Ekonomii, Rzeszów, ss. 253-266.
22. Próchniak M., Rapacki R. (2007), Konwergencja beta i sigma w krajach postsocjalistycznych w latach 1990-2005, Bank i Kredyt nr 8-9, ss. 42-60.
23. Quah D. (1993), Galton's Fallacy and Tests of the Convergence Hypothesis, Scandinavian Journal of Economics vol. 95, nr 4, ss. 427-443.
24. Rebelo S. (1991), Long-Run Policy Analysis and Long-Run Growth, Journal of Political Economy 99, June, ss. 500-521.
25. Romer P. (1994), The Origins of Endogenous Growth, Journal of Economic Perspectives 8, Winter, ss. 3-22.
26. Romer P. (1986), Increasing Return and Long-Run Growth, Journal of Political Economy 94, October, ss. 1002-1037.
27. Sala-i-Martin X. (2002), 15 Years of Growth Economics: What Have We Learnt?, Central Bank of Chile Working Papers No 172.
28. Sala-i-Martin X. (996), Classical Approach to Convergence Analysis, Economic Journal 106, July, s. 1019-1036.
29. Sala-i-Martin X. (1996), Regional Cohesion: Evidence and theories of regional growth and convergence, European Economic Review 40, June, ss. 1325-1352.
30. Sheshinski E. (1967), Optimal Accumulation with Learning by Doing, w: K. Shell, Essay on the Theory of Optimal Economic Growth, The MIT Press, Cambridge MA, ss. 31-52.
31. Shioji E. (1997), It's Still 2%: Evidence on Convergence from 116 Years of the US States Panel Data, Economics Working Paper 235, Univesitat Pompeu Fabra.
32. Solow R. (1969), Investment and Technical Change, w: Arrow K. (red.), Mathematical Methods in the Social Sciences, Stanford University Press, Palo Alto, California.
33. Solow R. (1957), Technical Change and the Aggregate Production Function, Review of Economics and Statistics 39, August, ss. 312-320.
34. Solow R. (1956), A Contribution to the Theory of Economic Growth, Quarterly Journal of Economics 70, February, ss. 65-94
35. Timmer M., O'Mahony M., van Ark B. (2007), EU KLEMS Growth and Productivity Accounts: Overview November 2007 Release.
36. Uzawa H. (1965), Optimal Technical Change in an Aggregative Model of Economic Growth, International Economic Review 6, January, ss. 18-31.
37. Piech K. (2005), Mierzenie rozwoju edukacji i kapitału ludzkiego w krajach transformacji systemowej z punktu widzenia gospodarki opartej na wiedzy, w : Konkurencyjność rynku pracy i jego podmiotów, praca zbiorowa , red. D. Kopycińska, Szczecin, ss. 17 – 32.
38. EU KLEMS Database http://www.euklems.net (up to date 23.03.2009)