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CONVERGENCE IN THE NEO-CLASSICAL MODEL OF ECONOMIC GROWTH

Theoretical foundation of the convergence concept in neo-classical growth model has been analysed. According to that concept, the income per capita growth tends to grow in reverse correlation of income initial level. In fact, however, there is obviously an outspoken lack of convergence in standards of living between developed and less developed countries. The new (endogenous) growth theories offer possible explanations for the observed lack of convergence between rich and poor countries.
An empirical study is presented, reviewing 42 countries in the world (including 30 developed and 12 less developed countries) over the period 1900-2005 as well as by divided sub-periods. Special attention is paid to the convergence among EU member states by GDP by per capita in a historical retrospective..

JEL: C2; E13; F43; O12

Theoretical concept of convergence

According to the traditional neo-classical, Solow growth model, one would expect less developed countries (laggers) to grow faster than developed ones (frontiers), as a result of the difference in the capital-labour proportions, and the difference that this entails in marginal productivities of capital. In the context of open economies, and under sufficiently high mobility on international capital markets, a capital flow would be created from 'rich' countries (with a low marginal productivity) to 'poor' countries (with a high marginal productivity), and the original difference in capital intensity would thereby tend to disappear. At the same time existing differences in technology (and therefore in the form of the production function) would tend to disappear as well through the (assumed) intensity of voluntary and involuntary knowledge transfers.

This theoretical implication of neo-classical growth models clashes however with the observations. The new ('endogenous') growth theories, on the contrary, do offer possible explanations for the observed lack of convergence between rich and poor countries: rich countries, with an initial comparative advantage in terms of knowledge and know-how (resulting from a higher stock of human capital, resulting, in turn, from a relatively higher level of educational efforts), would be able to sustain a systematically higher rate of growth when increasing returns to scale effects are present and/or important positive externalities related to human capital and use of technology can be exploited (the so-called knowledge and technology spill-over effects).

According to the neoclassical model if the level of the physical capital K is low, i.e. under the steady state condition K*, the growth rate will be high.[1] The

[1] It is interesting to note that Solow did not think of his model as providing a model for explaining cross-country growth performance; rather he believed it was a way of thinking about the growth dynamics of a single economy.

explanation of the differences in the growth rates among the considered countries could be found in their initial level of development and potential to develop in a long-term perspective. If a given country has a scare capital K, and its ratio with the labour L, i.e. K/L is low it is expected that this country could realize higher rate of profit in comparison with another country with a higher rate of capital accumulation and respectively a higher growth rate. As far as capital is mobile in a world scale it will try to replace in countries where the perspectives for returns are the best and the described tendency will get higher and higher. Thus it is expected that the gap between income level of the rich and the poor countries will decrease and gradually will disappear.[2]

If a number of conditions are met, the neo-classical model of economic growth implies economic convergence between a number of countries or groups of countries, at least in terms of rates of growth.[3] The model's basic assumptions and conclusions are as follows:[4]

- labour supply grows at a constant rate n*:* $L^S(t) = L_0 e^{nt}$;
- the labour market continuously clears: $L^S(t) = L^D(t) = L(t)$;
- technological progress is 'labour augmenting'; this means that the effective input of labour E (Employed) can be written as $E(t) = L(t) e^{\varphi t}$*;* φ is the rate of labour-augmenting, so-called Harrod-neutral, technological progress;
- savings are a constant fraction of income: $S(t) = sy(t)$;
- the production function is neo-classical and is characterised by constant returns to scale: $y(t) = F(K(t), E(t))$, with $F(\mu K, \mu E) = \mu F(K, E)$ $(\mu > 0)$.

The hypothesis of constant returns to scale means that the production function can be written as follows, without loss of generality:

(1) $q \equiv y / E = f(K/E) = f(k)$,

where q is income per efficiency-unit of capital; $k = K/E$ is the capital-labour ratio.

This function is concave, with diminishing marginal product with respect to the labour-efficiency adjusted capital-labour ratio k. The dynamics of k provide the starting point of the analysis.[5] From (1) it follows that:

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[2] It is supposed that the change in the population number and the proportion of savings in GDP, or the factors determing the savings are identical for all countries consireded. If they are not identical, different steady states will be separated, but the GDP growth per capita in the different countries will continue to converge, because the new technologies are implemented in new capital goods and the importance of capital acumulation will increase.

[3] In the modern analyses two terms are used: convergence and chatching-up. The more correct meaning of the latter implies the 'poor' countries speed of approaching the 'rich' countries income level. Considering the theoretical concept of the process we use the 'convergence'.

[4] See *Solow, R. M.* A Contribution to the Theory of Economic Growth. - Quarterly Journal of Economics, February 1956, Vol. 70, N 1, p. 65-94.

[5] The formal expression of these relationship is made using the following publications: *Barro, R. J. and X. Sala-i-Martin*. Convergence. - Journal of Political Economy, Apri 1992,Vol. 100, N 2, I, p. 223-251; *Sala-i-Martin, X*. Regional Cohesion: Evidence and Theories of Regional Growth and

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{E}}{E}.$$

After substitution of $\dot{K}$ by I (= sy) this becomes:

(2) $$\dot{k} = \frac{sy}{K}\frac{K}{E} - (n+\varphi)k = s f(k) - (n+\varphi) k .$$

The equation (2) is called the fundamental differential equation of the neo-classical growth model. In the equilibrium state it holds that:

(3) $$s f(k^*) = (n+\varphi)k^* .$$

From (2) we get:

(4) $$\frac{\partial g_k}{\partial k} = \frac{s\left[f'(k) - \frac{f(k)}{k} \right]}{k} < 0 ,$$

where g_k is growth rate of the capital-labour ratio. The derivative of this growth rate with respect to k is always negative since, under the hypothesis that the so-called Inada conditions are met,[6] the slope of the tangent line to the production curve f'(k) will always be smaller than the slope f(k)/k of the ray out of the origin. The immediate consequence of this is that the growth rate of the capital-labour ratio (and therefore of income per capita) is larger in countries with a smaller initial value of k, which in turn means that – when the production technology is the same – the capital-labour ratio in less developed countries will grow faster than in advanced economies. This implication of the neo-classical growth model is known as the hypothesis of 'absolute convergence', as it leads to the conclusion that ultimately all countries will follow the same growth path.

An alternative way of looking at this is by substituting the equilibrium condition (3) into (2):

(5) $$g_k = (n+\varphi)\left[\frac{f(k)/k}{f(k^*)/k^*} - 1 \right] = (n+\varphi)\left[\frac{v^*}{v} - 1 \right].$$

The two equations (4) and (5) mean that the absolute value of the speed with which the capital-labour ratio and the capital-output ratio grow will be greater when the economy is farther away from its long-run equilibrium position.

Convergence. - European Economic Review, June 1996, Vol. 40, N 6, p. 1325-1352; *Quah, D.T.* Empirics for Economic Growth and Convergence. - European Economic Review, June 1996, Vol. 40, N 6, p. 1353-1375.

[6] They are as follows: $\lim_{K\to 0} F_K = \lim_{E\to 0} F_E = \infty$ and $\lim_{K\to\infty} F_K = \lim_{E\to\infty} F_E = 0$.

Measurement issues: β- and σ-convergence

In order to test the hypotheses mentioned above empirically, it is necessary to use a specific form for the production function. It is usual in this context to opt for a simple Cobb-Douglas specification:

(6) $q = f(k) = Bk^{\alpha}$, with 0 < α < 1.

We can now give the convergence implications of the neo-classical model a more concrete form. From (2) it indeed follows that

(7) $$\frac{\dot{k}}{k} = \frac{\mathrm{d}\log k}{\mathrm{d}t} = sB\,k^{\alpha-1} - (n+\varphi) = sB\,e^{-(1-\alpha)\log k} - (n+\varphi)$$

$$\dot{k} = \frac{sy}{K}\frac{K}{E} - (n+\varphi)\,k = s\,f(k) - \left(n+\varphi\right)k$$

After a first-order Taylor series expansion of (7) around the logarithm of the long-run equilibrium (log k^*), we get:

(8) $$\frac{\mathrm{d}\log k}{\mathrm{d}t} = \frac{\mathrm{d}\log(k/k^*)}{\mathrm{d}t} \cong -\,(1-\alpha)(n+\varphi)\log(k/k^*)$$

with

$$\log k^* = \frac{1}{1-\alpha}\log\frac{sB}{n+\varphi}$$

And therefore, because of (3),

(9) $$\frac{\mathrm{d}\log q}{\mathrm{d}t} = \frac{\mathrm{d}\log(q/q^*)}{\mathrm{d}t} \cong -\,(1-\alpha)(n+\varphi)\log(q/q^*)\,.$$

The parameter $\beta \equiv (1-\alpha)(n+\varphi)$ indicates how fast income per capita (measured in efficiency-units) will approach the equilibrium value. The equation (9) lies at the origin of the term 'β-convergence', as an alternative designation for 'convergence in growth rates'. When β would be equal to 0.03 (suppose, e.g., that n = 0.01, φ = 0.03 and α = 0.25), then each year 3% of the relative difference between q and its equilibrium value will be bridged.

The solution of the differential equation in (9), after adding a disturbance term, can be written in the following empirically testable autoregressive form:

(10) $$\log q_{it} = a + b\log q_{i,t-1} + u_{it}\,,$$

where

$$a = (1-e^{-\beta})\log q^* \qquad \text{and}$$

$$0 \;<\; b = e^{-\beta} < 1\;,$$

i is a country-index. Absolute convergence would imply that *a* and *b* are equal for all countries and, of course, statistically significant.

The variable *q* in (10) means income per efficiency-unit of labour (*y*/*E*). When expressed in terms of income per capita in its more usual definition ($\hat{q} \equiv y / L$) we have

$$\log \hat{q}_{it} = (a + b\varphi) + b \log \hat{q}_{i,t-1} + \varphi(1-b)\, t + u_{it} \quad (11)$$

It is proved however, β-convergence does not hold in general. It only can be confirmed for countries within a more or less homogeneous group (i.e. the EU or the OECD, or the states of the USA), but not within more heterogeneous groups, and certainly not on a planetary scale.

The latter point of course undermines the theoretical concept of absolute convergence, because there where convergence should play in the first instance, i.e. between rich and poor countries, it fails to do so. A formal solution to the theoretical problem that leaves the neo-classical growth model intact is to redefine convergence in conditional terms. One then supposes that countries are characterized by different model coefficients, and therefore have different long-run equilibrium values k^* and different growth paths.

The consequence is that a rich country will grow faster than a poor one if its capital-labour ratio is, comparatively, further removed from its equilibrium value. The latter is determined, in the logic of (7), by the savings rate (that obviously is higher in rich than in poor countries), by technological parameters such as α and φ and demographic parameters (see Figure 1). Put differently, there is conditional β-convergence in the neo-classical model in the sense that a lower initial value for per capita income corresponds to a higher rate of growth, as soon one controls for the exogenous variables that determine the long-run equilibrium value.[7]

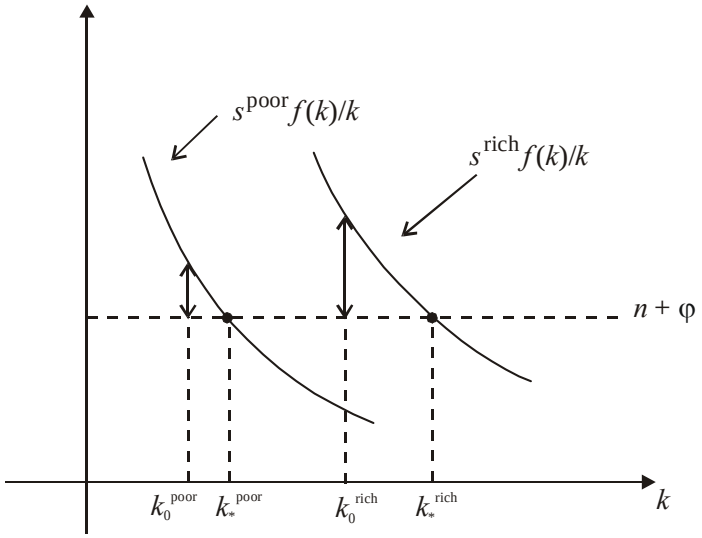
Rather than, in (11), to make *a*, and possibly also *b*, country-specific in some kind of panel-regression, researchers usually opt for a regression specification as in (12), but augmented with terms expressing the influence of the exogenous variables (*X*) on the long-run equilibrium values:

$$\log q_{it} = a + b \log q_{i,t-1} + \sum_{j=1}^{k} \gamma_j X_{ijt} + u_{it} \quad (12)$$

[7] The theory defines three convergence hypotheses: (a) *absolute (unconditional)*, when the income per capita in the individual countries converges in a long-term perspective no matter what their initial level is; (b) *conditional,* when income per capita in countries, which are similar by structural characteristics (for example, technology progress, growth rate of population, government policy, etc.) converges in a long-term, as the countries with lower initial level of income realized higher economic growth and catch-up that of the more developed countries; (c) *club convergence,* when countries in a given group, which have a closed initial level of income and similar structural characteristics catch-up each other in a long-term. At present days the discussion on convergence is stimulated by leading researchers of the economic growth.

Figure 1

β-convergence in the neo-classical model of economic growth



Convergence as defined (β-convergence) so far relates to convergence in growth rates of per capita income. Whether such (absolute or conditional) convergence exists in specific cases is always an open question, but one that most of the time can be empirically answered. An altogether different question however is whether this type of convergence implies also that income inequality between countries diminishes as time goes by. The answer is 'not automatically', even in the case of absolute β-convergence. In other words, convergence of growth paths does not necessarily lead to a lower variance in the group, to so-called σ-convergence. This could be shown as a measure for inequality of per capita income and we take the sample variance of the logarithm of q_{it}:

$$(13) \quad D_t = \frac{1}{N} \sum_{i=1}^{N} \left(\log(q_{it}) - \mu_t\right)^2 ,$$

where μ_t is the sample mean over the units considered (countries, regions, etc.). If N is sufficiently large then we can consider D_t to be a good estimate for the variance of the population. Under the assumption that the disturbances u_{it} are independently distributed in time and between 'countries' with a constant variance σ_u^2, we get the following first-order difference equation for D_t describing the dynamics of income inequality in the group under study:

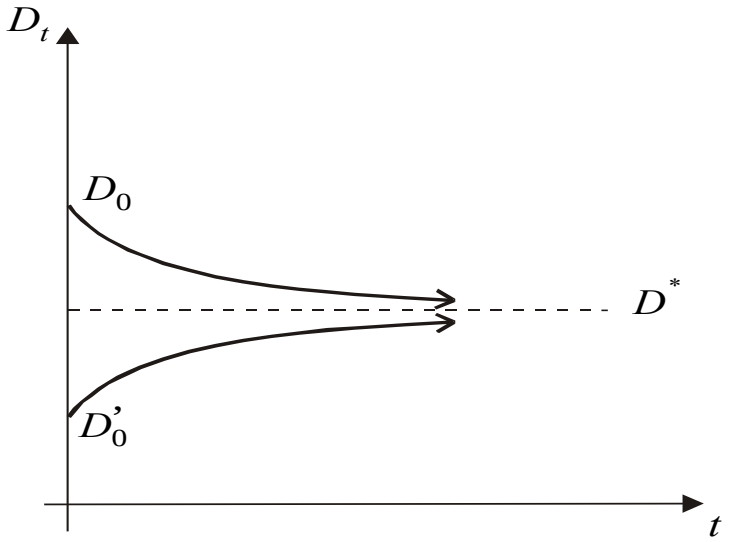
$$(14) \quad D_t = b^2 D_{t-1} + \sigma_u^2 .$$

The long-run equilibrium value for D follows immediately:

$$(15) \quad D^* = \frac{\sigma_u^2}{1-b^2}.$$

Figure 2

σ-convergence starting from two different initial positions



From (15) and Figure 2 it follows that, even with absolute β-convergence, the variance of the income levels remains positive (as a result of the positive variance of the disturbances). It can even increase in time when the initial variance is lower than the equilibrium value D^*. The existence of β-convergence (i.e., $b < 1$) does not necessarily lead to a decrease in inequality between countries (σ-convergence).[8]

Examining the two concepts - β-convergence and σ-convergence – there is a conceptual difference between them. The former studies the mobility of income within the same distribution, while the latter studies how the distribution of income evolves over time. On the other hand, β-convergence is a necessary but not a sufficient condition for σ-convergence.[9]

For the purpose of empirical works the speed of convergence could be estimated using the following non-linear equation.[10]

[8] For further details see *Barro, R. and X. Sala-i-Martin*. Economic Growth. Singapore: McGraw-Hill International Edition, 1995, p. 383.

[9] See *Sala-i-Martin, X.* Regional Cohesion: Evidence and Theories of Regional Growth…, p. 1325-1352.

[10] See *Barro, R. J. and X. Sala-i-Martin*. Convergence…, p. 230.

(16) $1/T \ln (y_{i, t0+T}/y_{i, t0}) = \alpha - (1 - e^{-\beta T})/T. \ln (y_{i, t0}) + u_{it0, t0+T}$,

where $\ln y_{i, t0+T}$ and $\ln y_{i, t0}$ mean log of the growth rates of the income per capita in the initial and respectively final year; I. is country index; T – duration of the observed period in years; α – constant; $u_{it0, t0+T}$ - average error u_{it} in the time interval between t_0 и t_0+ T. Thus the equation could be estimated using the Least Squares method:

(17) $1/T \log (y_{i, t0+T}/y_{i, t0}) = \alpha - (1 - b_T) \log (y_{i, t0}) + u_{it0, t0+T.}$

The speed of β-convergence could be estimated, using the equation:

(18) $(1 - b_T) = (1 - e^{-\beta T})/T.$

It is proved that *conditional β-convergence* could observe if the partial correlation between the income per capita growth and its initial level is negative. In case the regression coefficient of the variable of the initial level is negative, we can speak about absolute *β-convergence.* Absolute β-convergence is limited to relatively homogeneous groups of countries, conditional β-convergence is an empirically well established fact, and σ-convergence is not warranted, even in the case of absolute β-convergence.

Empirical works prove that the speeds at which the regions of different countries converge over different time periods are surprisingly similar – about 2% per year. This estimate is very robust and always significant. The comments on this fact are going into two directions (see Appendix). Firstly, by its economic meaning this speed is very slow. This means that in order to shorten the distance of a given country by 50% between its initial income level and steady state nearly 35 years are necessary, and 75% of this difference would be compensated in 70 years.[11] Secondly, the constant estimate of nearly 2% is the main evidence of the opponents to criticise the theory of convergence based on β-convergence and σ-convergence. As Quah states, "The idea here is that such consistency might only reflect something mechanical and independent of the economic structure of growth".[12] Reasons for this constancy are searching in some statistical artefacts, like measurement errors, small samples, etc.[13]

Looking for explanations for this economists like Baumol[14] and others include in the regression analysis other variables (except for physical capital and labour), for example education level and this change the results – countries

[11] See *Sala-i-Martin, X.* Regional Cohesion: Evidence and Theories of Regional Growth…, p. 1325-1352.

[12] See *Quah, D. T.* Empirics for Economic Growth and Convergence. - European Economic Review, June 1996, Vol. 40, N 6, p. 1353-1375.

[13] See *Sala-i-Martin, X.* Regional Cohesion: Evidence and Theories of Regional Growth…, p. 1325-1352.

[14] *Baumol, W. J.* Productivity Growth, Convergence and Welfare: What the Long-Run Data Show. - The American Economic Review, December 1986, Vol. 76, N 5, p. 1072-1085.

with similar level of education converge consistently. Such a kind of models provokes researchers' interest to invent new growth models (see Appendix). Other authors stake on human capital accumulation,[15] the role of the institutions[16] and so on.

In actual practice, definite limits above which savings rates cannot climb and under which demographic growth cannot drop. Therefore, higher savings rates and lower demographic growth cannot be advanced as causes for *enduring* differences in growth performance. Credible explanations should rather be sought in differences in rates and directions of technological progress.

It is for that matter the opinion of Solow himself that the use of convergence criteria is only meaningful if one may assume that the countries involved have a significant number of features in common: the savings rate, demographical parameters, common entry to a stock of technological knowledge, etc.[17] This requirement is unlikely to be met for countries with a very different history and culture.

The only opposite concept of convergence belongs to Lucas. Considering a very long historical period (1800-2001) he claims that convergence is increasing, in particular since 1970 and it will be one of the basic economic phenomena throughout 21st century (see Appendix).

In conclusion, the neo-classical model of economic growth, although fairly compatible with observations, does not deal with technological progress as a variable to be explained. Given this weakness, it is not really able to offer an insight into the question why some countries grow faster than others. The so-called theories of endogenous growth try to do just that.

An empirical study of convergence

The studies on convergence (and catching-up) are mainly descriptive including historical analyses. From econometric point of view they take the dependent variable for GDP per capita as a proxy for the degree of catching-up (see Appendix). Most empirical studies are related to the growth in the industrially developed country-members of OECD mainly due to the available and reliable long-term data series. In other studies well-known data series of GDP per capita of A. Maddison, Heston&Summers or the World Bank are used.

To test the convergence hypothesis we use A. Maddison time series for GDP per capita for the period 1900-2005, divided into two basic sub-periods: 1900-1950 and 1950-2005. In the second sub-period is separated another sub-period -

[15] *Mankiw, G. N., P. M. Romer and D. N. Wail.* A Contribution to the Empirics of Economic Growth. - Quarterly Journal of Economics, May 1992, Vol. CVII, Issue 2, p. 407-437.

[16] See *Knack, S.* Institutions and the Convergence Hypothesis: The Cross-national Evidence. - Public Choice, 1996, Vol. 87, N 3-4, p. 207-228.

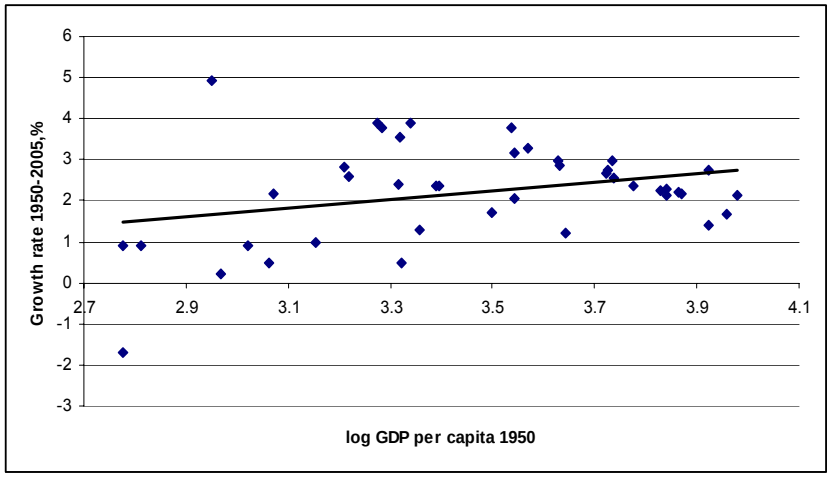
[17] See *Solow, R. M.* Growth Theory. An Exposition, Second edition. Oxford: Oxford University Press, 2000.

1980-2005.[18] The country sample consists of 42 states all over the world, 30 of which are developed and 12 – developing.[19]

If the convergence hypothesis is correct we would expect this regression line to be downward slopping, which means we would expect low levels of GDP per capita in the initial year to be associated with a higher growth rate over the considered period. In Figure 3 convergence between the total 42 country set over the period 1950-2005 is shown. The scatter diagram shows in fact an absence of convergence, which is confirmed by the positive correlation coefficient 0.31, which means the higher level of GDP per capita in the initial year the higher rate of growth (Table 1).

Figure 3

Convergence between 42 countries over the period 1950-2005
(R = 0.31)



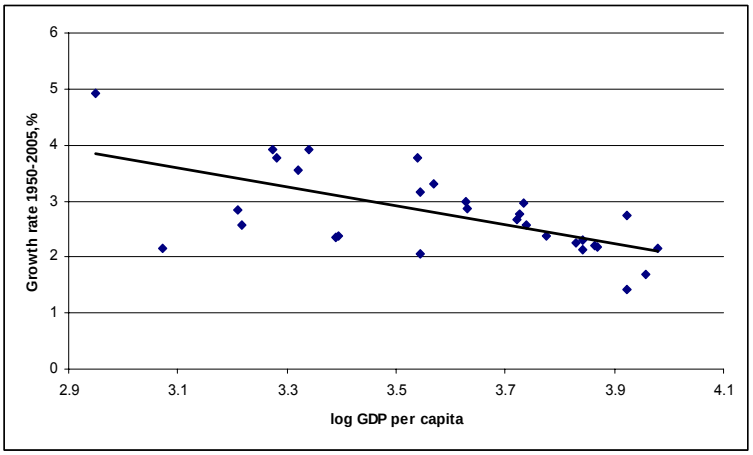
It seems that this prediction is indeed met for the case of the 30 developed countries (Figure 4). In this case the correlation coefficient is negative (-0.63), which means a negative dependency between the initial level of economic development and growth rates.

[18] Time series of GDP per capita are based on Purchasing Power Parities, in 1990 prices, Geary-Khamis method. Source: Groningen Growth and Development Centre, www.ggdc.nl

[19] The sample of developed countries includes the most developed countries, among which 15 countries of 'old' EU and 7 new member countries (Bulgaria, the Czech Republic, Cyprus, Hungary, Malta, Poland and Romania), 4 other European countries (Island, Switzerland, Norway and Turkey) and 4 countries outside Europe (the USA, Canada, New Zealand) as well as 12 less developed countries in Africa – Algeria, DR Congo, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Morocco, Nigeria, South Africa, Sudan and Tanzania. A. Maddison deliver estimates for GDP per capita for Czechoslovakia as a sum of data for the Czech Republic and Slovakia, in order to keep the consistency of the data series for this country existing until the beginning of the 1990s.

Figure 4

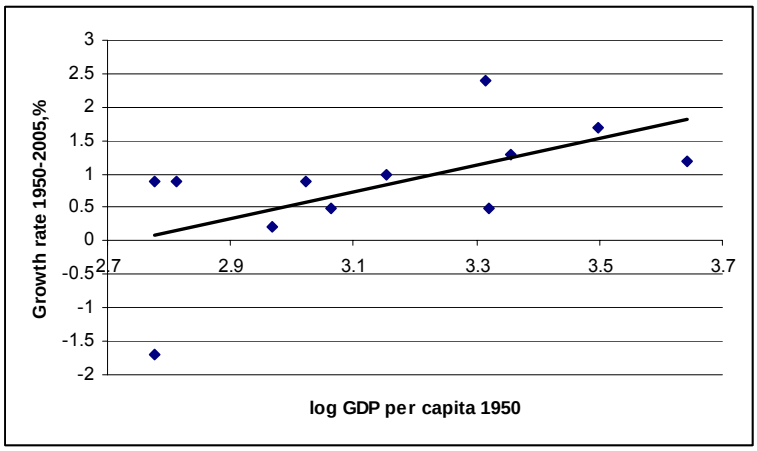
Convergence between 30 developed countries, 1950-2005
(R = - 0.62)



Another country sub-set consists of 12 selected countries from Africa with a very low level of income per capita (Figure 5). They show lack of convergence with a positive correlation coefficient 0.58. Egypt marks the highest rate of growth (2.4%) and its dot is highest displayed at the scatter plot. Sudan is the slowest developed country with growth rate – 1.7%.

Figure 5

Convergence between 12 less developed African countries,
1950-2005 (R=0.58)



Convergence could be studied using different time periods. A definite interest is the latest, namely 1980-2005, which reflects the modern developments as a result of the dynamic technological progress and going on globalization. For the developed countries this is the period of recession at the beginning of the 1980s and the 1990s; for the USA this is a particularly successful period of the 1990s especially at the second half of the decade. The CEE countries slow downed the economic growth rates in the 1980s, and afterwards began a period of radical political and economic changes and transition to a market type economy. Over the period 1980-2005 the total country set (42) marks even bigger divergence than in the period 1950-2005; the correlation coefficient is 0.61 (see Table 1). The more homogenous set of 30 developed countries marks convergence although slower from that for the previous period. The latter is due mainly to countries like Romania, followed by Bulgaria, the Czech Republic and others. From 1980 to 2005 divergence between the considered countries in Africa continues, although slower that in comparison with the whole second half of the 20th century, judging by the coefficients of correlation, which are respectively 0.35 and 0.58.

Table 1

Correlation between the initial levels of real GDP per capita and the rates of growth in 42 selected countries, 1900-2005

Periods	Total 42 countries	30 developed countries	12 less developed countries
1900-2005*	..	-0.31**	..
1900-1950*	..	0.22**	..
1950-2005	0.31	-0.62	0.58
1980-2005	0.61	-0.08	0.35
USA = 100			
1900-2005*	..	-0.36**	..
1900-1950*	..	0.16**	..
1950-2005	0.21	-0.63	0.30
1980-2005	0.47	-0.13	0.25

* There are not available data for the less developed countries in 1900-1950.

** Because of availability of data it is calculated on the basis of only 25 countries (30 without Cyprus, Iceland, Malta, Luxemburg and Turkey).

Convergence could be presented towards the initial level of income of the most developed country USA. This means the closer are the positions of the different countries to the diagonal at the scatter plot (slopping from the

upper left corner to the down right corner) the stronger convergence. In other words the closer is a given country to the diagonal, in the bigger synchrony with the USA growth marks it. The scatter plots and the coefficients of correlations of the 30 countries set for the two periods (1950-2005 and 1980-2005) give a good insight of convergence in terms of the USA level of income (see Table 1).

Regarding the less developed countries divergence was shown in the second half of the 20th century. The same tendency is observed following the levels of GDP per capita growth at USA=100.

Availability of data series in longer historical retrospective for the developed countries allows following the convergence over the first half of the 20th century as well as for the whole 20th century (see Table 1). Using the two described approaches a lack of convergence is observed in the first half of the 20th century.

In summary, we can state that if very different countries by level of income are taken in a set, it is difficult to measure and to speak about convergence. Depending on the purpose of a given study it makes more sense if we choose more homogenous countries.

Convergence among the EU countries by GDP by per capita in a historical retrospective

At the present stage of integration between the EU countries, it is interesting how the catching-up is going on in long-term perspective and Bulgaria's situation, in particular. Estimates of GDP per capita (Table 2) show the dynamics of economic progress of all 19 considered countries: 14, which form the so-called 'old" EU states and 5 in Central and Eastern Europe (CEE) – Bulgaria, Czechoslovakia, Hungary, Poland and Romania, which are chosen because there are estimates for them for the period 1913 до 2006. We can see that throughout the whole period under review GDP per capita in West European countries increased nearly 6.8 times, while this progress in CEE is only about 4.4 times.

According to our calculation on β-convergence for the whole period 1913-2006 β-coefficient is 0.021 at level of significance 5%, which means that during this period the less developed countries catch-up the income level (GDP per capita growth) of the rich countries annually on average by 2.1%. The results for the two sub-periods (1913-1939 and 1939-2006) confirm the observed phenomenon of more intensive convergence during the second than the first sub-period. For the EU-14 countries the annual rates of growth are higher than that in CEE countries. For the latter the rate of convergence over the sub-period 1939-1989 is rather lower than that for the West European countries.

Table 2

The EU countries: GDP per capita, 1913-2006 (based on PPPs, in 1990 prices, Geary-Khamis method, USD)

Country	1913		1939		1975		1989		2006	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Austria	3488	113	4123	99	11 724	106	16 305	108	22 725	108
Belgium	4130	134	5040	122	12 133	110	16 299	108	22 568	108
Danmark	3764	122	5766	139	13 104	119	17 620	117	24 871	119
Finland	2050	66	3310	80	11 098	100	16 676	111	23 191	111
France	3452	112	4748	114	13 101	119	17 457	116	22 615	108
Germany	3833	124	5549	134	13 034	118	18 015	120	19 982	95
Greece	1621	52	2687	65	7867	71	10 262	68	15 440	74
Ireland	2733	88	3116*	75	7117	64	10 270	68	28 360	135
Italy	2507	81	3444	83	10 558	96	15 650	104	19 591	94
Netherlands	3950	128	5409	130	13 037	118	16 024	107	23 094	110
Portugal	1354	44	1707*	41	6790	61	10 355	69	14 078	67
Spain	2255	73	2127	51	9151	83	11 752	78	18 811	90
Sweden	3096	100	5029	121	14 185	128	17 593	117	23 557	112
United Kingdom	5032	163	5979	144	11 701	106	16 288	108	22 933	109
*EU-14 (average)***	*3090*	*100*	*4145*	*100*	*11 043*	*100*	*15 040*	*100*	*20 951*	*100*
Bulgaria	1498	48	1603	39	5831	53	6217	41	7642	36
Czechoslovakia****	2096	68	2882***	70	7384	67	8729	58	11 436	55
Hungary	2098	68	2838	68	5805	53	6787	45	9231	44
Poland	..	..	2182*	53	5799	53	5685	38	8916	43
Romania	..	..	1242*	30	3761	34	3890	26	4285	20
CEE-5 (average)	*1897*		*2149*		*5716*		*6262*		*8302*	

Legend:
(1) - GDP per capita, based on PPPs in dollar, 1990 prices, Geary-Khamis method;
(2) - Index EU-14 = 100 (i.e. EU-15 without Luxemburg).

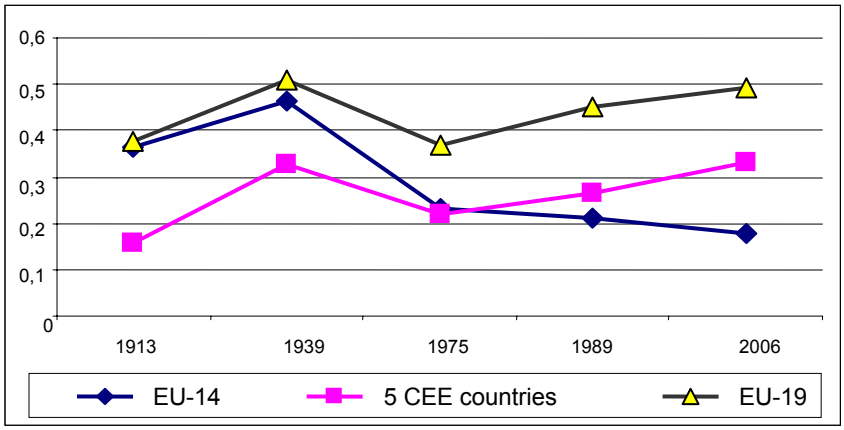
Notes: * 1938; ** without Luxemburg; *** 1937.

Source. Maddison, A. Monitoring the World Economy 1820-1992. OECD Development Center, Paris, 1995 Appendix D, Levels of GDP Per Capita, Table D-1(a,b,c,d), p. 194-201, www.ggdc.net

In Figure 6 the evolution of σ-convergence between the present EU countries is shown in a long-term retrospective. The countries under review are considered once taken as a whole set and second time divided into two sub-sets – 'old' and 'new' EU members. A common feature of three country-sets is that during the hard period of the First World War and later on the Great Depression (1929-1933 r.) until 1939 a divergence process is observed. In the following sub-period (1939-1975) a unidirectional change is observed also but this time it is opposite, i.e. convergence, as it is expressed stronger at the 'old" EU countries. The middle of the 1970s are marked by the economic history as the end of the most successful period for the two sub-sets of countries (as well as for the whole set), as well as by the first petrol crisis and the connected with it emerging challenges. Despite these events the sub-set of the EU-14 countries keeps marking convergence progress, although slower; this progress is observed even nowadays. Between the CEE countries significant divergence is outlined, what influences on the tendency of the total set (EU-19).

Figure 6

Sigma (σ) convergence between EU countries, on the basis of logarithms of GDP per capita



The same tendency in convergence between the considered countries is observed using the statistical indicator coefficient of variation towards GDP per capita (Table 3). For the CEE countries this coefficient decrease from 30.4% in 1939 to 25.1% in 1989 and afterwards it increases to 28.3% in 2006, while for the Western European countries it decreased respectively from 32.8% to 19% and keeps decreasing to 16.6%, which means that in the latter case the convergence is rather more expressed. The variation in the common set of countries reflects the two tendencies, but here the rational rule is confirmed, which means that if in a given sub-set other countries with lower level of development are added the convergence will meet difficulties and will reduce speed.

Table 3

Coefficients of variation for convergence in EU countries, 1913-1989 (%)

Country-groups	1913	1939	1975	1989	2006
EU-14	32.7	32.8	21.9	19.0	16.6
CEE-5	14.9	30.4	20.2	25.1	28.3
EU-19	35.8	41.4	15.0	36.5	37.1

* EU-14 means all the 'old' countries of EU without Luxemburg.

** In 1913 the total number of the considered countries in Western and CEE is 17, but in 1939 it is 19. This is because there are no data for Poland and Romania in 1913.

*** In 1913 the number of the CEE countries is 3 (Bulgaria, Czechoslovakia and Hungary), but in 1939 and 1989 it is 5 (including Poland and Romania).

Source. Calculated on the figures in Table 2.

Conclusions

• Convergence in terms of growth rates (so-called absolute β-convergence) is observed only within more or less homogeneous groups of countries or regions. Conditional β-convergence is more the rule, and is for that matter compatible with traditional neo-classical (so-called 'Solow') growth theory. Absolute or conditional β-convergence does not necessarily imply convergence in terms of the observed variance of per capita income within a group of countries or regions (so-called σ-convergence).

• Empirical studies on a set of 42 countries demonstrated inequalities across the world show no sign of narrowing down over the years considered. In this sense the Solow model failed on this account to predict the pattern of growth across the world.

• Although not refutable as such, traditional neo-classical growth theory fails to explain consistently how the lack of convergence may arise. On the background of this failure the new endogenous growth theories have been developed. In the focus are differences in savings rate but most notably also parameters of innovativeness: efforts devoted to R&D, R&D effectiveness, arrival rates and magnitude of innovations.

Appendix

Selected works on convergence among the countries in a long-term perspective

Authors and publications	Considered countries and/or essence of the study	Conclusions
1	2	3
Romer, P. M. (1986). Increasing Returns and Long Run Growth. - Journal of Political Economy, Vol. 94, p. 1002-1037.	●This is a theoretical study.	●In reality the growth rate of an economy appears to exhibit no correlation with the initial level of per capita income.

1	2	3
Baumol W. J. (1986). Productivity Growth, Convergence and Welfare: What the Long-Run Data Show. - The American Economic Review, December, Vol. 76, N 5, p. 1072-1085.	●The author looks for an explanation why convergence is observed between developed countries, but not if developing countries are included in the study. ●For this purpose he includes a variable for educational level into the regression analysis	●This changes the results – countries with closed level of education converge very consistently.
Barro, R. J. (1991). Economic Growth in a Cross Section of Countries. - Quarterly Journal of Economics, Vol. CVI, May, Issue 2, p. 407-443.	●Using data for 98 countries in the world scale for the period 1960-1985 and several different variables the author studies relationship between them and the rates of real income growth.	●Growth rates of the real income per capita correlate positively with the initial levels of human capital (measured by enrolment in school in 1960) and negatively with the initial levels of that income. ●Growth rates of income per capita are inversely related to the share of government expenditure in GDP, but income per capita correlates insignificantly with the share of public investment. ●Growth rates of income per capita are positively related to the political stability and inversely with a proxy variable for the market deformation.
Barro, R. J. and X. Sala-i-Martin (1992). Convergence. - Journal of Political Economy, Vol. 100, N 2, April, p. 223-251.	●Data for personal income per capita in 1840 and grow income from 1963 up to the end of 1980s are used. ●Two country samples are considered: the first one consists of 48 states in the USA and the another – of 98 states all over the world.	●The findings clearly show convergence related to the first sample, but the results could be connected only with very slow diminishing returns of capital.
Mankiw, G. N., P. M. Romer and D. N. Wail (1992). A Contribution to the Empirics of Economic Growth. - Quarterly Journal of Economics, Vol. CVII, May, Issue 2, p. 407-437.	●The augmented Solow production function is applied, including investment in human capital. ●Heston and Summers' estimates of GDP per capita are used for 121 countries over the period 1960-1985.	●The function is good enough to explain the differences in the living standards of the individual countries. Keeping the population growth and investment in capital constant the countries converge their rates of growth by proxy elasticity coefficient.
Caselli, F., Esquivel, G., and Lefort, F. (1996). Reopening the Convergence Debate: a New Look at Cross-country Growth Empirics. - Journal of Economic Growth, Vol. 1, N 3, p. 363-389.	●The authors discuss about existing or not of the phenomenon convergence. This is done on the basis of data for selected set of both developed and developing countries.	●They do not reach any principally new decisions.
Sala-i-Martin, X. (1996). Regional Cohesion: Evidence and Theories of Regional Growth and Convergence. - European Economic Review, Vol. 40, N 6, June, p. 1325-1352.	●The author studies theoretically the concept of β-convergence and σ-convergence as well the dependency between them, proving that the former is a necessary but not a sufficient condition for the latter. ●He uses a number of countries considered by their regions.	●The speed of convergence for the different regions and countries is surprisingly similar – nearly 2% annually. These estimates are stable and always statistically significant. ●The author denies the unified for all the countries estimates to be a result of measurement errors (or weakness on statistical measurement) or because of the small country sample.

1	2	3
Quah, D.T. (1996). Empirics for Economic Growth and Convergence. - European Economic Review, Vol. 40, N 6, June, p. 1353-1375.	●The author examines the previous article in this journal (1996), i.e. the study of Sala-i-Martin X. In particular the estimated 2% of β-convergence.	●The convergence speed by nearly 2% could be explained by measurement errors or existing endogenous relationship among the variables. ●This theory does not prove convergence, but proves that the rich countries get richer and the poor – poorer.
Galor, O. (1996). Convergence? Inferences from Theoretical Models. - The Economic Journal, Vol. 106, July, p. 1056-1069.	●The author studies the problems from a theoretical point of view.	●He tries to take into account the difference in the initial level of GDP per capita in the individual countries as well to connect this difference with the factors of the long-term economic growth.
Knack, S. (1996). Institutions and the Convergence Hypothesis: The Cross-national Evidence. Public Choice, Vol. 87, N 3-4, p. 207-228.	●The author describes the convergence process including proxy variables for the role of the institutions.	●A strong convergence is shown in income per capita in countries with the following characteristics: keeping property rights, created favourable conditions for savings, investment in the production.
Fischer, S., R. Sahay and C. A. Vegh (1998). How Far Is Eastern Europe from Brussels?. Washigton, D.C.: International Monetary Fund, IMF Working Paper, April, WP/98/53.	●β-convergence is estimated for 12 countries in Western Europe for the period 1937-1992.	●The authors' estimate for β-coefficient is 0.029 at 5% level of significance, which means that during the considered period the individual countries converge by nearly 3%.
Temple, J. (1999). The New Growth Evidence. - Journal of Economic Literature, Vol. 37, March, p. 112-156.	●This is an entirely theoretical study.	●The Solow model is an ideal tool to show divergence in the level of economic development between the countries, in particular to show that everything which is not connected with the rates of investment in the rich and the poor countries leads to widening of the gap between then in terms of the income per capita. ●The main reason for the different rates of growth among the countries is their different macroeconomic stability. This fact partially is due to the capital investment, and investment in equipment plays may be a special role.
Lucas Jr. R. E. (2000). Some Marcoeconomics for the 21st Century. - Journal of Economic Perspectives, Winter, Vol. 14, N 1, p. 159-168.	●The author investigates the question of the world economic growth and its uneven distribution by the individual countries and regions over the very long period 1800-2100. ●A simple model of Tamura (1996) for the world economy development is applied.	●The indicator measuring the inequality tends to increase from 1800 onwards, and hits the highest point around 1970. Afterwards the inequality between the countries by the income per capita began decreasing and the tendency is to approach to zero. The author qualified this phenomenon as one of the basic economic features of the 21st century.
Solow, R. M. (2000). Growth Theory. An Exposition, Second edition. Oxford: Oxford University Press.	●This is a theoretical study.	●The use of convergence criteria is only meaningful if one may assume that the countries involved have a significant number of features in common: the savings rate, demographical parameters, common entry to a stock of technological knowledge, etc.

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