Need for a new theory of real convergence
The case of transition economies

Matjaž Novak*

ABSTRACT

In this paper we discuss the main disadvantage of modern theory of economic growth, which is unable to predict the divergence of labor productivity growth between homogeneous economies. Under the term homogeneous economies we define the economies that possess the same human capital, have access to the same production technology, and experience equal growth of investments per labor-unit. In the article we describe that these conditions are significant for eight advanced transition economies that form EU8, and for 15 advanced market economies that form EU15. To overcome this basic disadvantage of modern growth theory we developed an original two-sector growth model and provide a theoretical analysis of divergence prediction between EU8 and EU15 economies.

The article is divided into six different parts. In the first part we describe growth performance of EU8 and EU15 economies and discuss the equality conditions. In the second part we define the technical inefficiency as the basic problem that impedes convergence of labor productivity between EU8 and EU15 economies. In the third chapter we compose our original two-sector growth model aimed at explaining the convergence/divergence of labor productivity between homogeneous economies. In chapter four its explanation power is described in detail, while in chapter five we use the model for analyzing the divergence prediction between EU8 and EU15 economies. Chapter six concludes the article with main findings and suggestions for future research activities.

Key-words: *Convergence, labor productivity, economic growth, transition economies.*

* University of Primorska, Faculty of Management Koper, Cankarjeva 5, 6000 Koper Slovenia.
Phone: ++386 (0)5 610 20 42, Fax: ++386 (0)5 610 20 39, e-mail: matjaz.novak@fm-kp.si

Introduction

The paper deals with the issue of real convergence of eight advanced transition economies of Central and Eastern Europe (Slovenia, Hungary, Poland, Czech Republic, Slovakia, Lithuania, Latvia and Estonia), which we term as EU8 economies, and 15 advanced market economies, which we term as EU15.[2] There is no doubt that the EU8 economies have reduced their gap in terms of real gross domestic product per labor unit with respect to EU15 economies. However an in-depth comparative analysis of the growth performance of EU8 and EU15 raises, from the theory of the economic growth point of view, interesting questions that attract our attention to set the question about the real convergence of EU8 with respect to EU15 economies as the main research issue.

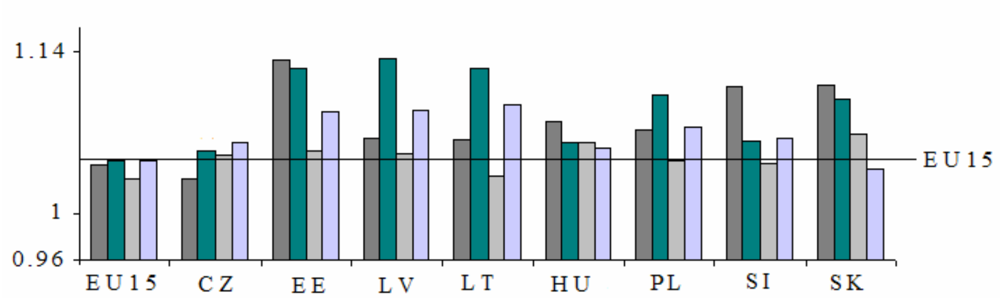
We recognize that EU8 economies tend to obtain a lower growth rate of labor productivity than EU15 economies at the same growth rate of investments per labor unit. Hence, the obtained convergence between EU8 and EU15 economies is the result of relatively higher growth of investments per labor-unit in EU8 economies. According to the modern theory of economic growth, this outcome can be explained through the differences in human capital and technological progress between economies, which should be in favor of EU15 economies. However, evidence on human capital indicators suggested that advanced transition economies are better endowed with human capital then advanced market economies.[3] Additionally to this we have to recognize that both groups of economies (EU8 and EU15) belong to the common economic integration (European Union) that stimulates transfer of technology between economies. Considering these facts, the relatively lower growth of labor productivity of EU8 economies with respect to EU15 economies, at the same growth of investment per labor-unit, is contrary to the theoretical predictions deduced from most recognized growth models of neoclassical and post-Keynesian growth theory. Hence, the modern growth theory is unable to predict divergence of productivity growth between economies in circumstances where they experience the same growth of investments per-labor unit, and have the same human capital and access to the same production technology. Therefore we regard the existing convergence theory as incomplete and discuss in the following content our original model aimed at upgrading the explanation power of modern convergence theory.

[2] EU-member countries before enlargement in 2004.
[3] See for instance Barro and Lee (2001, 541–563) or Campos and Coricelli (2002, 808).

1 Productivity growth performance between EU8 and EU15 economies

The central problem of EU8-countries with respect to EU15-countries can be clearly seen if we compare the growth of two main economic aggregates (investment per labor-unit and labor productivity) in the period 1996–2004. In Figure 1 are collected data on labor productivity growth for separate advanced transition economies and for EU15 economies as a whole. The results obtained are in line with our expectations – labor productivity growth in the period from 1996 till 2004 was higher in transition economies than in the advanced market economies. Henceforth, analyzing the official data on growth of output per labor-unit between EU15 and EU8 economies confirms the expected convergence.

Figure 1: Labor productivity growth

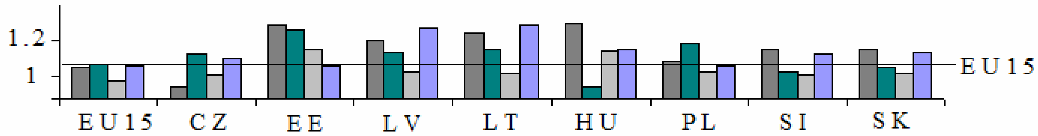


Note: – growth rate coefficient of real gross value added in pps per labor-unit 1997/1996,
– growth rate coefficient of real gross value added in pps per labor-unit 2000/1999,
– growth rate coefficient of real gross value added in pps per labor-unit 2002/2001,
– growth rate coefficient of real gross value added in pps per labor-unit 2004/2003.
The horizontal axis indicates each of the separate economies, the vertical axes measure growth coefficient for labor productivity.

Source: Own estimates on the basis of Eurostat data base.

Next we calculate growth of investments per labor-unit (see Figure 2). As in the case of labor productivity also in this case we can establish higher growth for advanced transition economies, which is in line with the expected positive effect of the integration process.

Figure 2: Growth of investments per labor-unit



Note: – growth rate coefficient of real investments per labor-unit 1997/1996,
– growth rate coefficient of real investments per labor-unit 2000/1999,
– growth rate coefficient of real investments per labor-unit 2002/2001,
– growth rate coefficient of real investments per labor-unit 2004/2003.

The horizontal axis indicates each of the separate economies, the vertical axes measure growth coefficient of investments per labor-unit.
Source: Own estimates on the basis of Eurostat data base.

But an in-depth comparative analysis of the growth performance of EU8 and EU15 raises, from the theory of the economic growth point of view, interesting questions that attract our attention. Namely, by comparing the results from Figure 2 with those in Figure 1 we have to emphasize that there is a large difference in maximum values of dynamic coefficients. In the case of labor productivity growth the highest coefficient is approximately 1.14, where in the case of investments per labor-unit growth this value is more than 1.2. Therefore, to make our inferences more plausible we calculate two relative coefficients, termed as relative labor productivity growth ratio (*rygr*) and relative investments per labor-unit growth ratio (*rigr*):

$$rygr = \frac{ygr^{EU8}}{ygr^{EU15}}, \tag{1}$$

$$rigr = \frac{igr^{EU8}}{igr^{EU15}}. \tag{2}$$

Symbols: $rygr$ – relative labor productivity growth ratio,
ygr – labor productivity growth rate,
$rigr$ – relative investments per labor unit growth ratio,
igr – investments per labor-unit growth rate,
$EU8$ – EU8 economies,
$EU15$ – EU15 economies.
Source: Own composition.

The relative labor productivity growth ratio (*rygr*) measures the growth of labor productivity in EU8 with respect to the growth of labor productivity in EU15. If $rygr > 1$, then the growth of labor productivity is higher in EU8, and *vice versa* if $rygr < 1$. The relative investments per labor-unit growth ratio (*rigr)* measure the growth of investment per labor-unit in EU8 with respect to the growth of investment per labor-unit in EU15. If $rigr > 1$, then the growth of investment per labor-unit is higher in EU8, and *vice versa* if $rigr < 1$.

Using these two relative coefficients we can establish the extent by which the growth rates of investment per labor-unit and the growth rates of labor productivity were higher or smaller in EU8 with respect to EU15.

Figure 3: Relative growth ratio of investments per labor-unit and relative growth ratio of labor productivity

Symbols: *rigr* – relative investments per labor-unit growth ratio,
rygr – relative labor productivity growth ratio.

Note: The horizontal axis indicates each separate economies, the vertical axes measures relative growth coefficient of investments per labor-unit and of labor productivity.
Growth rates for EU8 and EU15 economies were estimated as the weighted geometric mean, where share of labor force in a separate economy was used as weight.

Source: Own estimates.

Graphical presentation of relative investments per labor-unit growth indicates that in the first two years this growth was faster in the case of EU15 economies. This is related with the fact that the two largest economies of the EU8 group experienced in 1997 and 1998 a decline of investments per labor-unit growth rates. However in the following years the growth rate of investments per labor-unit was continuously lower in EU15 economies with respect to EU8. On the other hand the labor productivity growth in the whole period was higher in the case of EU8 economies. Following this we accept two basic conclusions:

- first, the growth of investment per labor-unit in EU8 was higher than in EU15, and furthermore the difference had grown during the period 1996–2004;
- second, the growth of labor productivity in EU8 was higher than in EU15, but this difference was diminishing during the period 1996–2004.

So far, nothing unusual can be recognized from the presented empirics. But, if we compare the relative investments per labor-unit growth rate with relative labor productivity growth rate, we recognize an interesting picture reflecting the growth performance of EU8 economies with respect to EU15. On the one hand we establish that the growth of investment per labor-unit in EU8 becomes higher from year to year, but on the other hand the growth of labor productivity in EU8 diminishes from year to year with respect to EU15, and this in the circumstances where the selected former transition countries achieved on average approximately only 60 % of the labor productivity level, which holds on average for selected advanced EU15 countries. Hence the central problem is the diminishing dynamic of real convergence between EU8 and EU15 countries under circumstances of growing disparities in investment growth per labor-unit in favor of EU8 countries and the significant distance of labor productivity in EU8 with respect to EU15.

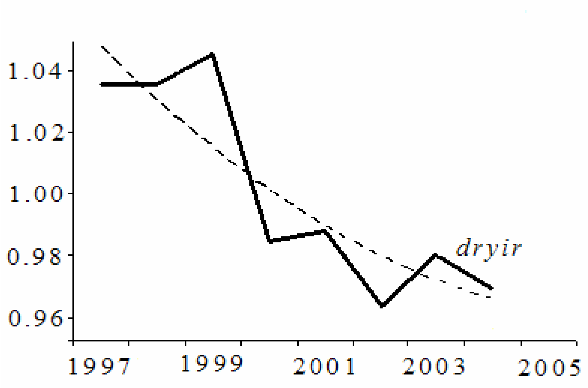
To describe the problem more explicitly, we calculate an additional indicator that is a derivative from the relative real gross domestic product growth ratio (*rygr*) and from the relative investment growth ratio (*rigr*). We term it as the derivative relative output-investment growth ratio (*dryigr*):

$$dryigr = \frac{rygr}{rigr}, \tag{3}$$

Symbols: *dryigr* – derivate relative output-investment growth ratio,
rygr – relative labor productivity growth ratio,
rigr – relative investments growth ratio,
Source: Own composition.

We calculate the derivative relative output-investment ratio (*dryigr*) for the selected groups of economies (EU8 with respect to EU15) for the period 1996–2004 (see Figure 4) and establish that at the beginning of the period the coefficient was greater than one, but has been continuously diminishing, and after the year 1999 becomes smaller than 1. After the year 1999, the higher growth of investment per labor-unit in EU8 with respect to EU15 has not spilt over into the higher growth of real gross domestic product per labor-unit.

Figure 4: Ratio between the growth of labor productivity and growth of real investment per labor-unit in EU8 with respect to EU15



Note: For calculations we use the data from the Eurostat database. The initial data on real gross value added and real gross capital formation (investment) are measured in millions of 1995 euros (in converting the values from national currencies into euros the purchasing power parity standard exchange rate was used). Initial data on the labor force were measured in thousands of employees adjusted for the full-time equivalent.
The full line indicates the actual value of the derivative relative coefficient, and the interrupted line indicates estimated values of the polynomial time-trend.
The horizontal axis measures the time in years (*t*), and the vertical axis measures the value of the derivative relative labor productivity-investments growth ratio (*dryigr*).
Source: Own calculations.

A value of the derivative relative output-investment growth ratio (*dryigr*) that is less than 1 indicates that, if the growth of investments per labor-unit in EU8 exceeds the growth of investment per labor-unit in EU15 by 1 index point, then the growth of labor productivity in EU8 will exceed the growth of labor productivity in EU15 by less than 1 index point. The latter statement implies that if the growth of investments per labor-unit were to be identical in both economies (EU8 and EU15), then the growth of labor productivity would be higher in the EU15, although because of the integration process the main obstacles to technology transfer, mobility of physical capital, differences in institutions (legislations) and human capital composition between the EU8 and the EU15 have been removed.

As we highlighted in the introduction, this outcome is contrary to the theoretical expectations, since both group of economies have access to the same production technology and dispose with the same amount of human capital. Due to the constraints of length, we omit an in-depth analysis on this assumption. However, the analysis by Barro and Lee (2001) confirms that transition economies obtained the same human capital as advanced market economies. Also Žižmond and Novak (2006) and Žižmond and Novak (2007) have provided explicit empirical evidence about technology convergence between EU8 and EU15 economies. Therefore we take the assumption on equalities between EU8 and EU15 economies to be appropriate.

2 Technical inefficiency as an impeding factor of real convergence between EU8 and EU15 economies

As we highlighted in the introduction, the divergence prediction of labor productivity growth between economies under the homogeneity conditions is contrary to the modern growth theory. By developing our original theoretically consistent solution to the described problem, our starting point was the belief that the main factor for different growth outcomes is technical inefficiency, despite the existence of identical initial conditions.

Technical inefficiency is a characteristic of a production process, which indicates that the actual point of production by the given amount of used production factors lies below the production possibility frontier. Furthermore, the problem of technical inefficiency is also in line with empirical comparison of the economic growth characteristics between selected groups of economies (EU8 and EU15) in the period 1996–2004 (see Figure 4), where the increase of the relative investment growth rate per labor-unit and decrease of relative real gross domestic product growth rate per labor-unit is significant for the selected time period.

Most macroeconomic empirical analyses of an aggregate production that permits technical inefficiency, and hence decomposition of the total factor productivity growth into the technological progress and the growth of technical efficiency, were done for USA (Färe et al. 1994, Pires and Garcia 2004), for East-Asia countries: South-Korea, Singapore, Taiwan and Japan (Sun 2002, Bloch and Tang 1999, Chen 1997, Felipe 1999, Kim and Lau 1996, Mahadevan and Kalirajan 1999, Mahadevan 2002), for former centrally planned economies (Nishimizu and Page 1982, Sickles, Good and Getawech 2002) and for developed market economies in West Europe (Sickles, Good and Getawech 2002).

If we summarize the central findings of the quoted references, we can establish that:

- the main impact of technical efficiency growth on the economic growth is significant for Taiwan, South-Korea, Singapore;
- economic growth of the USA and of developed market economies in West Europe was mainly determined by the technological progress and not by the growth of technical efficiency – this implies that the actual point of production in these economies was close to the production possibility frontier; and
- technological progress had a significant impact on economic growth of the centrally planned economies, although their actual point of production was significantly below the production possibility frontier – especially in the period 1980–1990, which indicates rising technical inefficiency.

The final conclusions fully support the idea about the importance of technical efficiency for the economic growth of former transition countries and for convergence of their real gross domestic product per labor-unit with respect to advanced market economies.

However, in order to apply the concept of technical in(efficiency) to the analysis of economic growth at the aggregate level, we have to divide a national economy into different sectors (industries), since the central cause for technical inefficiency is inefficient employment of disposable production factors into different productions. The analysis of economic growth by dividing the economy into separate sectors of production (or industries) is not new in economic theory. The same concept was used by Romer (1987 and 1990), who divided the economy as a whole into two different sectors. The first sector produces specialized intermediate goods, equipped with progressing new technology (this is the R&D sector), and the second sector produces goods aimed at final consumption by using the advanced intermediate products from the R&D sector. The growing employment of labor in the first sector expands the number of new technologically advanced products that avoid the tendency of diminishing returns and assure sustainable permanent long-run economic growth of an economy.

Romer has developed a convenient framework for explaining the sources of technological progress that was adapted to the neoclassical growth theory, but this framework omits the impact of technical inefficiency. For these reasons we search for solutions within the alternative and/or supplementary post-Keynesian theory of economic growth, founded on approval from Bellais (2004) which recognizes the investment of a single firm into development and/or adoption of new technology as the driving force for long-run growth. According to this statement it is not meaningful to divide firms and hence industries by the criteria of whether they produced new, technologically advanced intermediate goods or services, or not. Much more important is the question of whether each firm, regardless of whether or not it produced new technology intended for intermediate consumption or goods intended for final consumption, has the ability to finance the development or adoption of a new technology or not. The firm that has this ability has also the perspective of further development and growth. Following this interpretation we can cluster all firms in an economy into two separate sectors; the first sector, termed as propulsive industries, comprises all firms that have the ability and possibility to finance investments in new technology, and the second sector, termed as degressive industries, includes firms without this ability.

The approach, dividing industries into degressive and propulsive, and not according to Romer (1987, 1990) into R&D and non-R&D, enables us to define technical inefficiency at the aggregate level as an inefficient allocation of production factors (physical and human capital) between propulsive and degressive industries. Because propulsive industries assure a perspective of future growth and hence higher returns with respect to degressive industries, the physical capital (investments) is concentrated in the propulsive industries; consequently these industries do not confront the problem connected with the possibility of financing new investments and adopting new available technology. But physical capital, as a production factor, determines only the potential amount of new technology adoption. Whether this potential will also be turned to advantage depends on the disposable human capital. And if the vast amount of human capital is concentrated in the degressive industries,[4] the propulsive industries face the problem of absorptive capacities of new technologies although they have the ability to finance investments in new technologies. As the opposite to this, the degressive industries have an excess capacity of human capital but are short of physical capital to finance new technologies.

The described allocation of production factors (physical and human capital) between propulsive and degressive industries, pictures out the problem of technical inefficiency from the point of view of national economy. Namely, if we could reallocate physical capital from the propulsive towards degressive industries, the latter would no longer face the problem of financing investments for new technologies, and – because they have at their disposal sufficient amounts of human capital – nor would the absorption of new technologies be restricted.

Reallocation of physical capital from industries with a relatively small amount of human capital towards industries with a relatively large amount of human capital will raise technical efficiency and hence economic growth. The same effect (the growth of technical efficiency and hence economic growth) will be realized also, if the human capital is reallocated from degressive towards propulsive industries. In this case, the amount of human capital in degressive industries will diminish, which will be in line with the relatively smaller amount of physical capital, but will rise in propulsive industries that will advance the absorptive capacities of new technology in these industries and accelerate the economic growth from the aggregate point of view.

Obviously a decrease in technical inefficiency or an increase in technical efficiency can be achieved through the reallocation of production factors between propulsive and degressive industries. The question that remains open is: the reallocation of which one of the exposed production factors is crucial? Probably, the acknowledgement that physical capital moves towards industries with relatively high returns and prospects for future growth, is not questionable. Therefore it will be an illusion to expect that physical capital will be reallocated

[4] Brown and Earle (2002) gave proof for this in the case of transition countries.

from existing propulsive industries towards existing degressive industries. Hence the weight of reallocation is placed on human capital from degressive towards propulsive industries.

3 Composition of the two-sector growth model

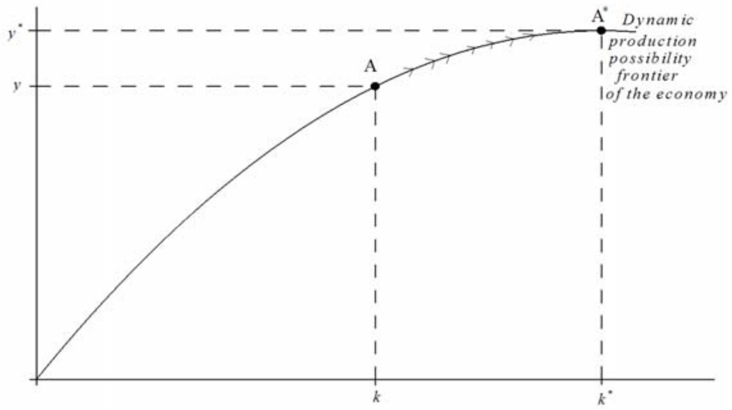
The approach aimed at modeling aggregate economic growth on the basis of the sectoral model is not new but has been widely used for instance by Uzawa (1965), Lucas (1988) and Romer (1990). But introduction of the sectoral component into the growth models, aimed at explaining a convergence or even more a divergence of economic growth between economies, is connected with expansion of differences in initial conditions. In contrast to this approach our original hypothesis is focused on prediction of a divergence between economies with the same initial conditions and with equal growth of physical capital. According to this, the aim of this chapter is to develop a two-sector growth model that will be in line with the defined hypothesis.

The evaluation base of the original growth model is a clustering of industries of an economy into two separate sectors. The first sector comprises all industries with their ability and possibility to finance investments in new technology that enhance the future growth. These are the so-called propulsive industries. The second sector comprises all industries without this ability, termed as degressive industries.

An economy as a whole has at its disposal the technology level *T* (that determines the static production possibility frontier for both sectors and for the economy as a whole), amount of human capital H (that determines the dynamic production possibility frontier), amount of physical capital K and amount of workers, which form jointly with their human capital (*HC*) the disposable amount of effective labor force (ELF).

The initial conditions and the frontiers of economic growth of this economy are graphically presented in Figure 5 below. According to the disposable technology and to the disposable amount of human capital, the economy can reach a potential level of gross domestic product per labor-unit at y^* if it employs k^* units of physical capital per labor-unit; i.e. due to disposable technology and human capital at the aggregate level the potential production point is $A^*\left(k^*, y^*\right)$.

Figure 5: Impact of capital deepening on economic growth



Symbols: y – labor productivity,

k – capital-labor ratio,

Note: We use the term dynamic production possibility frontier due to the fact that its shape is determined at the different levels of production technology. The static production possibility frontier will be pictured as a horizontal line at a certain level of labor productivity.

Source: Own composition.

The actual point of production $A(k, y)$ lies below the potential one (but still on the dynamic production possibility frontier, which implies that all available technology is incorporated into the physical capital), due to the fact that $k < k^*$. Consequently there exists a potential for economic growth solely on the basis of capital deepening that will not encounter the problem of negative marginal productivity of physical capital.

Next we divide the economy into two different sectors: propulsive industries and degressive industries. Both industries have at their disposable the technology level *T*, but physical and human capital are allocated among both industries according to the following condition:

$$K = K_p + K_d \,, \qquad (4)$$
$$ELF = ELF_p + ELF_d \,.$$

Symbols: K – amount of physical capital at the aggregate level,

K_p – amount of physical capital in propulsive industries,

K_d – amount of physical capital in degressive industries,

ELF – amount of effective labor force at the aggregate level,

ELF_p – amount of effective labor force in propulsive industries,

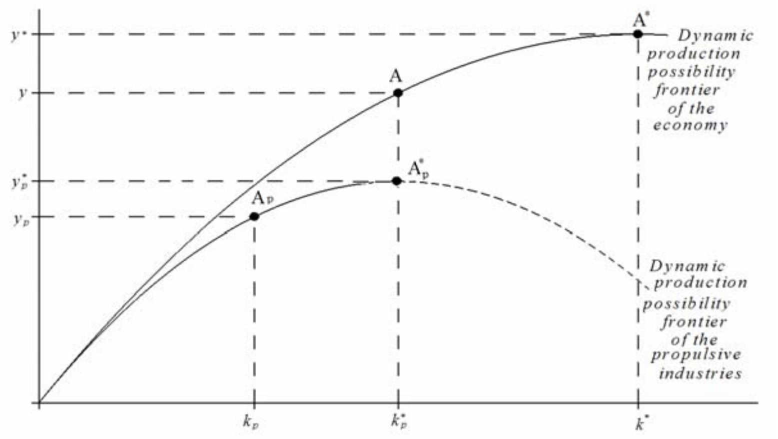
ELF_d – amount of effective labor force in degressive industries,

t – time period.

Source: Own composition.

We start with the sector of propulsive industries which employs K_p units of physical capital and HC_p units of human capital, henceforth the physical capital per labor-unit of propulsive industries equals k_p. The shape of the dynamic production possibility frontier of propulsive industries is determined by the disposable amount of human capital of these industries. While a part of human capital is employed also in degressive industries, the shape of the sectoral production possibility frontier lies below the shape of the aggregate dynamic production possibility frontier (Figure 6 below).

Figure 6: Dynamic production possibility frontier for the sector of propulsive industries

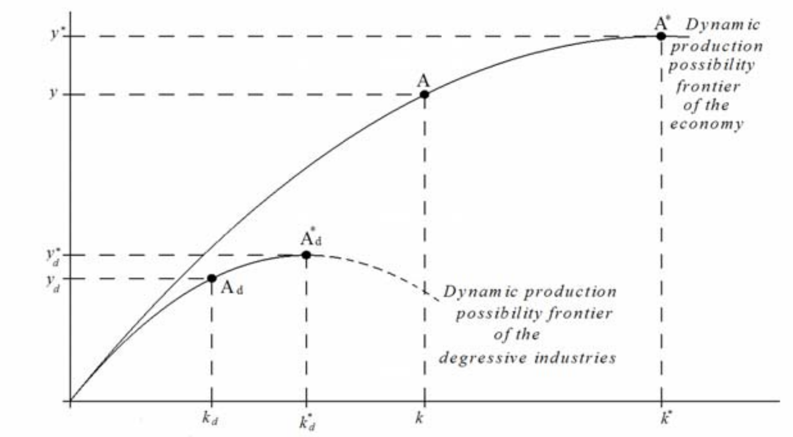


Note: For explanation of symbols see Figure 5.
Source: Own composition.

The aggregate dynamic production possibility frontier from Figure 6 is the same as in Figure 5, with the actual point of production $A(k, y)$ and a potential one $A^*(k^*, y^*)$. The second dynamic production possibility frontier in Figure 6 is aimed at propulsive industries. The actual point of production of these industries measures the amount of gross domestic product per labor-unit of effective labor force (y_p) that is produced by the given amount of physical capital per labor-unit (k_p). The actual point of production of propulsive industries $A_p(k_p, y_p)$ lies below the potential one, due to the fact that $k_p < k_p^*$. Additional investments into physical capital by the given amount of human capital and by the given technological frontier, will stimulate the growth of gross domestic product per labor-unit. But additional investments in propulsive industries have a positive impact on economic growth until $k_p < k_p^*$ by regarding the technology and amount of human capital as unchanged. If the physical capital-labor ratio exceeds the level k_p^* the propulsive industries will face the problem of negative marginal productivity of physical capital. This is an important implication, which indicates that growth of investments obtained at the aggregate level does not necessarily have a positive impact on aggregate growth. A positive impact of investments on the aggregate economic growth depends on their distribution among industries. Furthermore, this finding has important implications also for convergence predictions and brings to the forefront the impact of production factors growth allocation among industries. Next, following this issue, we describe the production possibility frontier of degressive industries.

Degressive industries have also the technology level T at their disposal and employ K_d amount of physical capital and HC_d amount of human capital. As we know, the amount of disposable human capital forms the shape of the dynamic production possibility frontier. Due to the fact that a certain amount of an economy's human capital is employed in propulsive industries, the shape of the dynamic production possibility frontier of degressive industries is below the shape of the aggregate dynamic production possibility frontier (Figure 7).

Figure 7: Dynamic production possibility frontier for the sector of degressive industries



Note: For explanation of symbols see Figure 5.
Source: Own composition.

By the given amount of physical capital per unit of effective labor force (k_d), degressive industries' gross domestic product per labor-unit amounts to y_d. Regarding the disposable amount of human capital employed in degressive industries the potential amount of gross domestic product per unit of effective labor force is at y_d^* and will be reached if the physical capital-labor ratio increases from k_d towards k_d. However, if the capital-labor ratio exceeds the level k_d^*, then negative impact on economic growth will occur. In this case the disposable amount of human capital will be fully exhausted, hence the law of negative marginal productivity of physical capital applies in case of its growth extending over the desired level k_d^*.

Up to this point the actual production point $A(k, y)$ lies below the potential production point $A^*(k^*, y^*)$, which implies that the economy can enhance its economic growth solely on the basis of additional investments. Due to the technology and human capital constraints the maximum growth of physical capital per labor-unit is from k towards k^*. But, as we emphasized by description of the dynamic production possibility frontier for propulsive and for degressive industries, not only the growth of physical capital per labor-unit affected the aggregate growth, but so too did the allocation of additional units of physical capital among propulsive and degressive industries. At the aggregate level the potential production point $A^*(k^*, y^*)$ will be achieved only if the physical capital-labor ratio in propulsive industries rises from k_p towards k_p^* and at the same time in the degressive industries from k_d towards k_d^* by the given allocation of human capital among these two sectors.

4 Convergence – divergence prediction

Following the established two-sector growth model, the sectoral allocation of human capital and physical capital between propulsive and degressive industries importantly affects the impact of new investments on the economic growth at the aggregate level. If we continue our analysis from the previous chapter we recognize that the actual production point (A) of the economy lies below its potential level (A^*), where solely the growth of physical capital – which will close the gap between k and k^* – can move the actual production point towards the potential one. We mark the change of physical capital per unit of effective labor force at the aggregate level as Δk that equals $k^* - k$.

The supposed growth of physical capital at the aggregate level can be obtained also at the sectoral level. We work with two sectors, the propulsive one and the degressive one, where the aggregate growth of physical capital is allocated among these two sectors according to the following condition: $\Delta k = \Delta k_p + \Delta k_d$. This condition implies that the sum of sectoral growth of physical capital per unit of effective labor force can not exceed the growth of physical capital per unit of effective labor force at the aggregate level.

By the given level of technology (which is the same for both sectors and for the economy as a whole) and by the given amount of human capital, each of the two sectors has a desired amount of physical capital per labor-unit that should not be exceeded. If it is, the law of negative marginal productivity applies, which impedes the aggregate economic growth.

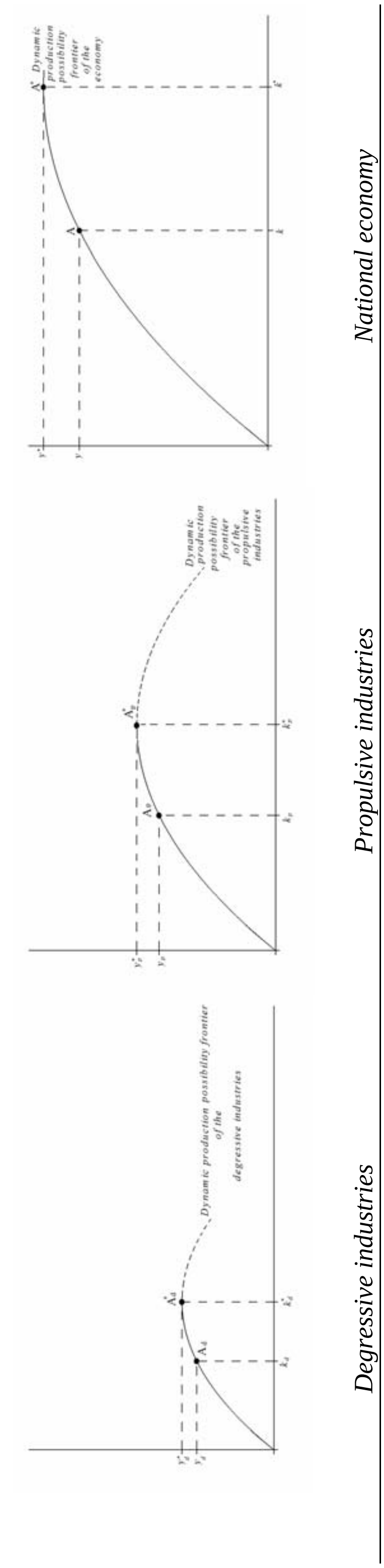
As we know, in our case, the physical capital-effective labor force ratio in degressive industries should not exceed the level k_d^* and in the case of propulsive industries the level k_p^*. The principal problem is that there is no automatic assurance that the change of physical capital per unit of effective labor force will be allocated among both sectors according to the conditions: $k_p + \Delta k_p \le k_p^*$ and $k_d + \Delta k_d \le k_d^*$, where it holds that $\Delta k_p + \Delta k_d ,= \Delta k.$ It is quite possible that the greater part of physical capital per labor-unit growth will be allocated to the propulsive industries which exceeds the level k_p^*. On the other hand, the growth of physical capital per unit of effective labor force is minor in degressive industries, consequently the physical capital-effective labor force ratio remains below its desired level k_d^*.

An economy can experience three different proportions of allocation of the aggregate growth of physical capital per labor-unit:

- First, the Δk is allocated among propulsive and degressive industries according to the following conditions: $k_p + \Delta k_p = k_p^*$ and $k_d + \Delta k_d = k_d^*$, where $\Delta k = \Delta k_p + \Delta k_d$.
- Second, the Δk is allocated among propulsive and degressive industries according to the following conditions: $k_p + \Delta k_p \ge k_p^*$ and $k_d + \Delta k_d \le k_d^*$, where $\Delta k = \Delta k_p + \Delta k_d$.
- Third, the Δk is allocated among propulsive and degressive industries according to the following conditions: $k_p + \Delta k_p \le k_p^*$ and $k_d + \Delta k_d \ge k_d^*$, where $\Delta k = \Delta k_p + \Delta k_d$.

Let us suppose, first, that the economy experiences the distribution of physical capital per unit of effective labor force growth which maximizes aggregate economic growth. Graphically this is presented in Figure 8 below.

Figure 8: Propulsive – degressive industries and maximum growth of labor productivity

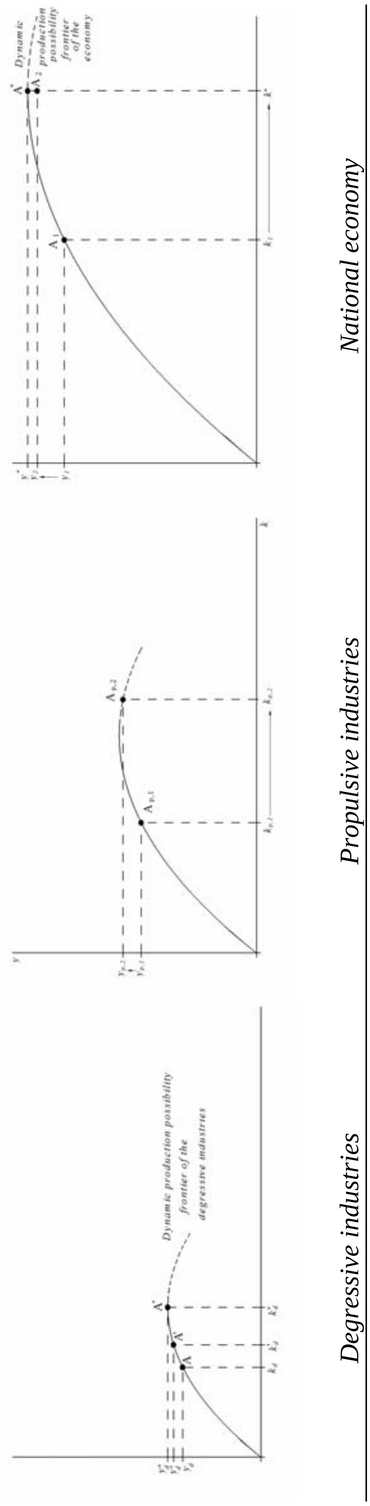


Note: For explanation of symbols see Figure 5.
Source: Own composition.

Initially the amount of gross domestic product per labor-unit is equal to the y^* which is the total of gross domestic product per labor-unit produced in propulsive industries (y_p) and in degressive industries (y_d). Next, the amount of physical capital per labor-unit in degressive industries rises from k_d towards k_d^*. Consequently the gross domestic product per labor-unit rises from y_d towards y_d^*, which is equal to the potential amount of gross domestic product per unit of effective labor force in degressive industries due to the disposable amount of human capital and at the given technology. The physical capital-labor ratio rises also in propulsive industries from k_p towards k_p^*, thus generating the growth of gross domestic product per labor-unit in propulsive industries from y_p towards y_p^*, which is the potential level in propulsive industries due to the disposable amount of human capital and to the given technology. If we sum up the changes of physical capital-labor ratios between both sectors we obtain the aggregate growth of this ratio: $\Delta k_p + \Delta k_d = \Delta k$. At the aggregate level the obtained growth of physical capital per labor-unit is related with the change of gross domestic product per unit of effective labor force from y towards y^*.

This is the potential production point determined by the given amount of human capital and disposable production technology at the aggregate level. Additional growth of physical capital above the level k^* will be unproductive, and negative marginal productivity of physical capital will occur.

Figure 9: Growth of labor productivity when propulsive industries experiences to large growth of investments



Note: For explanation of symbols see Figure 5.
Source: own composition.

In the above described case the change of physical capital per labor-unit at the aggregate level was allocated among propulsive and degressive industries according to the conditions: $k_p + \Delta k_p \leq k_p^*$ and $k_d + \Delta k_d \leq k_d^*$, where $\Delta k_p + \Delta k_d, = \Delta k$. In this case, gross domestic product converges from the initial level towards the potential level on the basis of capital deepening.

Next we assume that the growth of physical capital per labor-unit is allocated among propulsive and degressive industries according to the following conditions: $k_p + \Delta k_p \geq k_p^*$ and $k_d + \Delta k_d \leq k_d^*$. Graphically this is presented in Figure 9. Growth of physical capital per labor-unit at the aggregate level is in this case the same as previously (from k_1 towards k^*), but irrespective of this, the growth of gross domestic product per labor-unit is smaller (from y_1 towards y_2 where $y_2 < y_1$). The actual point of production after the increase in the physical capital-labor ratio stays below the potential production point $\left(A^*\right)$, where the difference between $\left(A^*\right)$ and $\left(A_2\right)$ is a measure of technical inefficiency at the aggregate level.

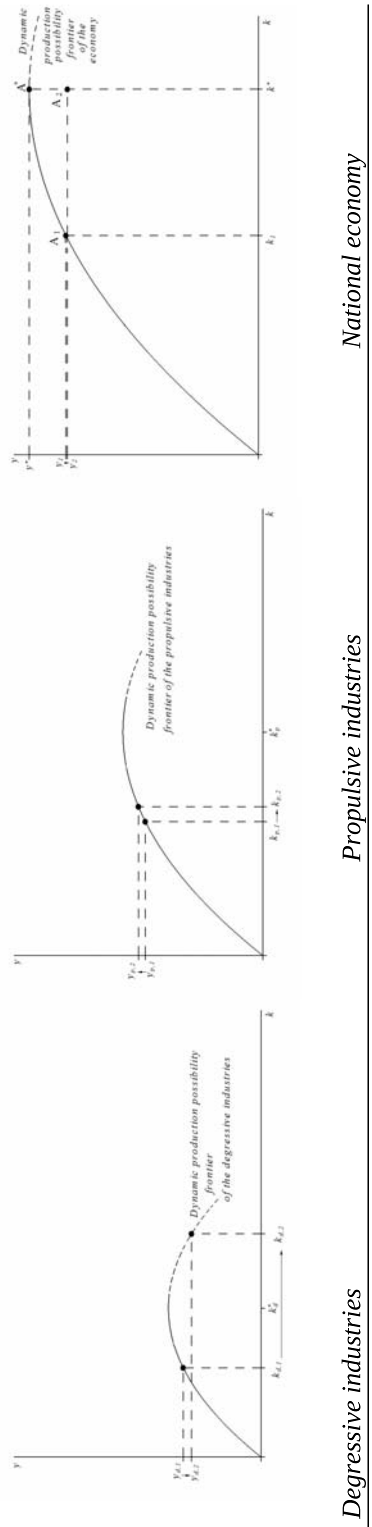
The obtained technical inefficiency at the aggregate level has occurred because of unbalanced distribution of physical capital growth at the aggregate level between propulsive and degressive industries. The optimality criteria are defined by the amount of human capital that is disposable to each sector. The sector with the greater extent of human capital has the greater ability productively to absorb technologies incorporated in physical capital. In our case, propulsive industries possess a greater amount of human capital than degressive industries, henceforth the greater part of physical capital per labor-unit growth should be realized in these industries. This was also realized but, unfortunately, the increase of physical capital- labor ratio in propulsive industries was too extended. Hence the amount of physical capital per labor-unit in these industries exceeds the desired level k_p^* and allows the law of negative marginal productivity of physical capital to be applied. In contrast to the produced amount of gross domestic product per labor-unit is smaller than its potential amount.

On the other hand, degressive industries face the opposite constraints. They have at their disposal a sufficient amount of human capital, but they face insufficient increase of the physical capital-labor ratio. The ratio has grown from $k_{d,1}$ towards $k_{d,2}$, which is below the desired level k_d^*. Consequently, the actual production point stays below the potential one. Both sectors produce less than potentially they could by the given growth of physical capital in the economy – one sector is overloaded with physical capital per labor-unit (due to the human capital constraints) and the other one suffers from the low value of physical capital with respect to disposable human capital.

Finally, we assume that the aggregate growth of physical capital per labor-unit from k_1 towards k^* is allocated among propulsive and degressive industries according to the following conditions: $k_p + \Delta k_p \le k_p^*$ and $k_d + \Delta k_d \ge k_d^*$. Graphically this is presented in Figure 10.

As in both previous cases, growth of physical capital per labor-unit at the aggregate level is also in this case the same (from k_1 towards k^*), where the greater part of physical capital-labor ratio growth is allocated into degressive industries. Consequently the achieved level of physical capital per labor-unit in degressive industries exceeds its desired level k_d^*, which enhances the negative marginal productivity of physical capital. In contrast to the degressive industries, propulsive industries in this case suffer from too low amount of physical capital per labor-unit due to the disposable amount of physical capital. In propulsive industries the physical capital-labor ratio rises from $k_{p,1}$ towards $k_{p,2}$, that is below the desired level k_p^*, therefore the actual production point of these industries stays below the potential one.

Figure 10: Growth of labor productivity when degresive industries experiences to large growth of investments



Note: For explanation of symbols see Figure 5.
Source: own composition

If we total the sectoral levels of gross domestic product per labor-unit and relate this sum with the aggregate growth of physical capital we obtain the actual production point (A_2) which is below the potential production point (A^*); i.e. due to inappropriate allocation of physical capital growth between propulsive and degressive industries with respect to allocation of human capital, the capital deepening accelerates divergence of the actual production point from its potential level.

However, we have to be aware that the extent of technical inefficiency at the aggregate level in the last two cases was different although the aggregate change of physical capital-labor ratio was the same. The obtained difference in extent of technical inefficiency is related to the difference, depending on which sector was overloaded with physical capital. First, the propulsive industries were overloaded with physical capital per labor-unit. Due to the inappropriate amount of human capital, the disposable amount of physical capital could not have been efficiently used, hence in propulsive industries the negative marginal productivity of physical capital applied. Irrespective of this, at the aggregate level gross domestic product per labor-unit of effective labor force grew from y_1 towards y_2 (Figure 9). And in cases when degressive industries were overloaded with physical capital per labor-unit, this sector faced the problem of negative marginal productivity of physical capital (Figure 10).

However in this case at the aggregate level we obtained only a minor growth of gross domestic product per labor-unit. This clearly indicates that if the greater part of aggregate physical capital growth per labor-unit is allocated into the sector with a smaller amount of disposable human capital, the divergence accelerates and *vice versa*.

Three major conclusions can be drawn from the above described analysis:

- First, an economy will converge from its actual point of production towards its potential point on the basis of capital deepening only when the aggregate growth of physical capital per labor-unit will be allocated among propulsive and degressive industries according to their endowment with human capital.
- Second, capital deepening in case of its inappropriate distribution among propulsive and degressive industries, which is not in line with their human capital endowment, causes convergence of the actual production point with respect to the potential production point.
- Third, divergence of the actual production point with respect to its potential level accelerates when the greater part of aggregate physical capital per labor-unit growth is allocated into industries with a relatively small amount of human capital.

5 Theoretical prediction of real convergence between EU8 and EU15 economies by using the two-sector growth model

In the previous chapter we developed and used the two-sector growth model for analyzing the convergence (divergence) prediction of the actual production point towards (away) from its potential level theoretically. In this chapter we use all previously obtained conclusions with the aim of predicting divergence between EU8 and EU15 economies under the assumption that both economies face the same endowments with human capital, have access to the same production technology, and experience equal growth of investments per labor-unit.[5]

[5] These conditions are in line with those we realized in the introduction as we described the basic problem of real convergence between EU15 (i.e. benchmark) economies and EU8 (i.e. initial) economies. We established that relatively higher growth of investments per labor-unit in EU8 economies with respect to EU15 economies has not spilt over into the relatively higher growth of real gross domestic product per labor-unit. The recognized convergence problem between EU15 and EU8 economies can also be expressed as a problem where both groups of economies (EU8 and EU15) have the same initial production point and experience the same growth of physical capital, although the outcomes of gross domestic product per labor-unit growth are different and in favor of the EU8 economies.

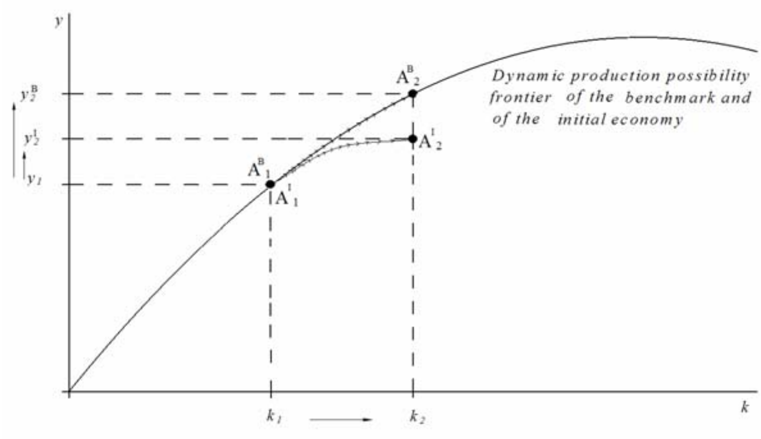
As we recognized by reviewing the growth literature, the divergence in such a case where two economies have the same initial production point and the same growth of physical capital per labor-unit is possible due to following reasons:

- there exists a difference in disposable production technologies and/or
- there exists a difference in amount of human capital and/or
- there exists a difference in institutional framework.

If only one of the above recognized differences holds, any model recognized in the growth theory (aggregate as well sectoral) will predict divergence. But if we restrict the prediction with the assumption that there are no differences in initial conditions between EU15 and EU8 economies, these models will predict convergence, not divergence.

However, the two-sector growth, which distinguishes between propulsive and degressive industries, enables us to predict divergence between two homogeneous groups of economies. The divergence between them can occur due to differences in technical inefficiency that are caused by the unbalanced distribution of physical capital with respect to the human capital between propulsive and degressive industries. Graphically, the described problem is presented in Figure 11 below.

Figure 11: Convergence prediction between the initial and benchmark economy



Note: For explanation of symbols see Figure 5.
Source: Own composition.

In the case of a benchmark economy that is treated as the technology leader, and the initial economy is the technology follower. According to our assumptions both economies have the same dynamic production possibility frontier and the same initial production point (A_1) at the initial physical capital-labor ratio (k_1). However, the initial economy has the greater part of its human capital concentrated in degressive industries, which causes a relatively greater extent of technical inefficiency at the aggregate level with respect to the benchmark economy. Subsequently the same growth of physical capital per labor-unit generates relatively greater labor productivity growth in the case of the benchmark economy than in the case of the initial economy.

6 Conclusions

The aim of this article was to expose the weaknesses of modern theory of economic growth in the segment that deals with convergence prediction between economies. Our main critique of the present growth models aimed at predicting convergence between economies is that they suffer from a basic disadvantage – they are unable to predict the divergence between homogeneous group of economies.

As we described in the first chapter, we recognize this disadvantage by analyzing labor productivity growth performance between 8 advanced transition economies that joined the EU in May 2004, and 15 advanced market economies that constituted the EU till May 2004. We accept the critique that EU8 and EU15 economies are not fully homogeneous, however we have to take into account that both groups of economies form the common economic integration (European Union), therefore the differences between these economies have been diminishing over time.

In the paper we present an original solution to the obtained problem, and have presented the so called two sector growth model that distinguishes between the propulsive and the degressive industries. As we highlighted, the approach to modeling aggregate growth by implementing the sectoral approach to economic growth is not new, however, one may consider as original the idea about the propulsivity of an industry. And as we demonstrated, this model is able to predict the divergence of labor productivity growth between economies that possess the same human capital, have access to the same production technology, and experience the same growth of investments per labor unit. We believe that, from the economic theory point of view, the developed model exhibits consistency and appropriate explanation power for convergence or divergence prediction, therefore the forthcoming research efforts will be focused on its empirical evaluation.

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