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Catching up in Czech Republic, Hungary and Poland

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Abstract

The paper summarizes the convergence of the Polish, Hungarian and Czech economies with the German economy and to their steady states in the period between 1995 and 2013. The growth of relative output is decomposed into growth of capital, labour input, human capital and TFP. The paper also proposes a simple new method that takes advantage of the availability of the data on relative factor prices to separate the effect of increased share of well-educated workers and the effect of increased productivity of a more abundant educational group. The results suggest a massive contribution of TFP convergence in the GDP convergence. The accumulation of physical capital was sluggish, particularly before 2007.

Keywords: economic convergence, growth accounting, human capital

JEL: E24, O11, O47

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1. Introduction

At the beginning of the 1990s, when it became clear that a group of economically backward countries from Central and Eastern Europe would strive to join the European Union, allow trade and investment from abroad and adopt stable institutions, many economists anticipated a textbook example of economic convergence. A number of economists rushed to form predictions about the speed of convergence and warn of potential problems (Sachs 1994; Fisher, Sahay, Vegh 1998a, 1998b; Boldrin, Canova 2001; Caselli, Tenreyro 2005). Today, twenty five years after the economies embarked on the convergence path, it is a good moment to examine where the countries stand, how far they went and what they can expect in the future. For economists, this is an interesting opportunity to confront their expectations with true outcomes, as well as to evaluate the predictions of various models such as the Solowian convergence model (Solow 1956) or technology imitation models (Nelson, Phelps 1966; Barro, Sala-i-Martin 1997; Howitt 2000). For the policymakers, it might reveal what sources of convergence are already exploited and what sources still remain potential (possibly still not activated) engines of growth.

The strategy for this paper is to first identify the various theoretical sources of convergence (e.g. capital differences between Poland and Germany), then, to examine to what extent these sources were exploited (e.g. by looking at the growth rates of capital between 1995 and 2013), and finally to assess the potency of the sources for the future (e.g. by comparing levels of capital in 2013).

The sources of convergence are identified by decomposing GDP growth into growth of labour input (total hours worked), physical capital and a term that combines human capital and TFP growth. To further decompose the growth of this last term, a new method is proposed that takes advantage of the availability of the data on relative wages of workers with different educational levels. This method allows me to separate the effect of increased share of well educated workers and the effect of the increase in relative productivity of a more abundant educational group.

2. Related literature

The growth accounting for Central and Eastern European regions was introduced earlier in the World Bank Report on Productivity Growth in Eastern Europe and Former Soviet Bloc by Alam et al. (2008). The report clearly shows that TFP growth was the key driver of growth in Eastern European and former Soviet Union economies. This decomposition exercise is performed at the regional level and does not evaluate the growth decomposition for particular countries. Similarly, a central role of TFP growth has been found in Doyle, Kuijs and Jiang (2001), who conducted growth accounting for Poland, Czechia (short country name for Czech Republic), Hungary, Slovakia and Slovenia. Their analysis covers data until 1999. The importance of TFP is confirmed in Iradian (2007), who presents growth accounting for former Soviet Union states.

Gradzewicz et al. (2014) present a growth accounting exercise for Poland for the three years following the global financial crisis. The performance of the Polish economy in this period was exceptionally good – Poland was the only EU country which did not report a negative growth rate. The purpose of the study by Gradzewicz et al. was to analyse which supply side factors enabled this positive growth. The authors find that during the crisis years Polish growth was fuelled by capital accumulation. In contrast to other European economies, the productivity of factors of production kept increasing for almost the entire period between 2008 and 2010.

Kolasa and Strzelecki (2007) used microeconomic data about the labour force to analyse how an improvement in the quality of labour input contributed to economic growth in Poland between 1994 and 2006. They find that the quality improvement lead to 0.6% of annual GDP growth. Most of the improvement could be explained with the increased share of educated workers.

Some studies examined the catching-up process using the beta-convergence model. Prochniak and Witkowski (2013) present a beta-convergence analysis for a set of 25 countries including Poland, Hungary and Czechia during the period between 1960 and 2009. The estimates from the econometric regressions suggest that a country needs 40 years to reduce the income gap to its steady state by half. The steady state income level of each country depends primarily on the level of human capital.

The positive impact of the school enrolment rate on economic growth in Central and Eastern European countries was also found in the study by Amplatz (2003), who performed one of the first beta--convergence analyses for the region. Interestingly, Amplatz did not find evidence for the convergence between the economies in the region and Western European economies. The analysis covers a very short period of four pre-EU-accession years between 1996–2000.

Forgo and Jevcak (2015) summarize the convergence between the 10 new members of the European Union and 12 members of the euro area between 2004 and 2014. In this period, average GDP per capita in the region increased from 50% to 64% of the income level in the euro area. One of the key factors contributing to this convergence was the relatively fast capital formation. The authors also examine which sectors had the largest contribution in the economic expansion and find that, at least in the pre-crisis years, the economic growth was primarily driven by the growth in market services and, to a smaller extent, growth in industry and construction.

A similar exercise was done by Dabrowski (2014), who compared the path of GDP for a set of Central and Eastern European countries vis-à-vis Germany between 2001 and 2013. The author stresses the role of TFP growth in this convergence and notes that, particularly in the latter years, the investment rates are too slow to sustain the catching-up of the region.

Konopczak (2013) uses a vector error correction model to estimate the speed of convergence with the economies of the Schengen area for Poland, Slovakia, Czechia and Hungary. The analysis covers the period between 1995 and 2005. The estimates suggest that Czechia and Slovakia will achieve the average income level of euro area GDP in 2030, while Poland will achieve this level in 2038. The author does not find evidence for the convergence of the Hungarian economy in the last years of his analysis (between 2006 and 2010). Two articles, Baran (2013) and Growiec (2008) show the results on the convergence of Central and Eastern European growth using the data envelopment analysis, which is an interesting alternative to the approach followed in this paper.

3. Data

3.1. Data for factor accumulation and TFP growth decomposition

The baseline decomposition is performed for the period between 1995 and 2013. There are two reasons for selecting 1995 as the starting year: first, the data on the number of hours worked by persons engaged are available in the WIOD database only from 1995. The second reason is that during the first years of the transition the three economies experienced GDP decline. Since the aim of this paper is to explore the forces driving long-term convergence, it was decided to leave the early transition dynamics aside.

Real GDP (2010 prices in international dollars after PPP conversion) data for years between 1995 and 2013 are taken from the 2015 national accounts stats.OECD database. The number of hours worked and the total number of persons engaged (employees and the self-employed) between 1995 and 2011 comes from the WIOD dataset. The values for 2012 and 2013 are computed by extrapolating the trends from the four preceding years. The most problematic task was the computation of capital levels for the three countries. This computation involved the use of data from 1970 onward. The detailed method of computing capital series and the sensitivity analysis is described in the following subsection.

3.2. Capital time series

The standard method to obtain the time series for capital is the perpetual inventory method: given the initial level of capital, each capital level is constructed by taking the previous capital level, adding investment and subtracting depreciation. The construction of the capital series has been done in three steps.

In the first step, the initial capital level is computed. The derivation of the initial level of capital is based on the assumption that the economy is on the balanced growth path. In this case, the growth of capital is equal to the growth of investment and initial capital is given by:

$$K_0 = \frac{I_0}{g + \delta}$$

where g is the growth rate of investment and δ is the depreciation rate.

This follows from: $K_1 = K_0(1 - \delta) + I_0$. Rearranging, $(-\delta) + I_0/K_0 = (K_1 - K_0)/K_0 = g$.

The growth rate (g) is computed by taking the average across the annual growth rates in the years 1970–1974, and following Iradiam (2007), centre the initial level of capital is centred in the middle of this period, which is 1972. The depreciation rate in this period is assumed to be 0.06 (the same depreciation rate was used in Barro, Mankiw and Sala-i-Martin (1995), Nehru and Dhareshwar (1993), Caselli and Tenreyro (2005), and Iradian (2007).

In the second step, the capital series is computed for the years 1973–1991 following the standard inventory method. The data on investment for this period is taken from the Penn World Tables (the data are available at PPP converted 2005 constant dollar prices). To compute the series for Czechia the analogous data for Czechoslovakia from the national accounts in the UN database is used and it is assumed that throughout the period the ratio of Czech investment to Czechoslovakia investment is constant and equal to the value of this ratio in 1991. Following Barro, Mankiw and Sala-i-Martin (1995), Nehru and Dhareshwar (1993), Caselli and Tenreyro (2005), and Iradian (2007), it is also assumed that in this period the depreciation in all three economies is equal to 6% of the previous capital level.

In the last step, the series for the period 1991–2013 is computed. For this period, instead of deducting the previous capital level multiplied by the 6% depreciation rate, the gross consumption of capital which is provided in the stats.OECD dataset is deducted (the series is presented in Figure 1). Relaxing the assumption on the 6% depreciation rate is important for this period since, as indicated in the OECD data for Poland, the depreciation levels at the beginning of the 1990s were way above the standard level observed in other countries.

In the case of Poland, the OECD data from 1991 is used. In the Hungarian case, the data on capital consumption is available only from 1995. Since, bearing in mind the Polish case, 6% depreciation between 1991–1994 appears to be over-optimistic, it is assumed that in this period the ratio of consumption of capital to GDP is at the level of the average ratio in the period of 1995–1999 (20% of GDP).[1] In the case of Czechia, the data on capital consumption are available from 1992. It is assumed that in 1991 the consumption of capital (as % of GDP) is at the level of average consumption in the period of 1992–1995 (i.e. 22% of GDP).

There are two critical assumptions underlying the derivation of the capital series. The first assumption, necessary to derive the initial level of capital, is that the economies at the beginning of the 1970s were on the balanced growth path. The communist central planner did push for the rapid physical capital accumulation from the early post-war period, which might suggest that by the early 1970s the steady state of capital was restored. On the other hand, anecdotal evidence indicates that the 1970s witnessed the construction of impressive factories (an example is the Katowice steelworks project) whose purpose was capital formation far beyond replacing depreciated capital and keeping pace with TFP growth. As a result, the growth rate of capital might be biased downward (and so the initial level of capital would be biased upward). However, this problem should not alter the results since the effect of miscalculation of the initial capital level diminishes over time, and the first capital observation used is in 1995 – a quarter of a century after the estimation of the 1970 capital level.

To check the sensitivity of the capital series to the assumption on the initial level of capital two alternative versions of the series were computed: one for the initial capital 25% above the baseline level and one for the initial capital 25% below the baseline level. The results for Poland are presented in Figure 2. The results for the Czech Republic and Hungary are similar and are available upon request. Clearly, the level of capital in 1972 has a very small impact on the results of the growth of capital between 1995 and 2013.

The second assumption concerns the depreciation of capital in the period 1973–1991. One may argue that after the wave of postwar investment projects, the capital in the 1970s and 1980s was relatively new and its depreciation was slow. On the other hand, if the quality of this capital was poor, its depreciation would be relatively high. In Figure 3 the alternative capital time series is presented, which assumes the depreciation rate of 4% and 8% in the period 1973–2013). Again, only the results for Poland are reported. The average annual growth of capital is 3.5% under 4% depreciation assumption and 4.9% under 8% depreciation assumption. Under the baseline assumption of 6%, the annual growth of capital was 4.2%.

Figure 4 compares the capital series obtained by me with the capital series provided in the stats.OECD and WIOD database. In the case of Poland and Czechia, the three estimates are very close. In the case of Hungary, the OECD and WIOD series predict slower accumulation of capital, particularly after 2000. Closer inspection of the data reveals that the high growth of Hungarian capital in the years 2000–2005 is due to the low levels of capital consumption (the depreciation rate in this period was 1 percentage point lower than in the years 1995–2000).

The capital-output ratios for the years 1995, 2007 and 2013 are reported in Tables 1, 2 and 3.

[1] Since in Poland depreciation between 1995–1999 was lower than between 1991–1994, such an approximation might still be over-optimistic.

3.3. Data for skill upgrading decomposition

As mentioned earlier, to compute the effect of skill upgrading, the data on relative wages of high--skilled, medium-skilled and low-skilled workers is used. The data on hourly wages for these three groups is again taken from the WIOD dataset. The dataset labelled as high-skilled workers those who have received university degrees, while medium-skilled workers were those with high school degrees and low-skilled workers were the remaining group. In this paper, medium-skilled and high-skilled workers are combined to form the group that from now on will be labelled as high-skilled workers. This is based on the presumption that a high school or vocational diploma indicate skills that go beyond basic literacy and simple arithmetic skills. Thus those workers with at least a high school degree might be used for very different tasks than those without a high school degree.

4. Factor accumulation and TFP growth decomposition

4.1. Theoretical engines of growth

Throughout the paper it is assumed that the final output is produced with a Cobb-Douglas production function:

$$y = \left(AL\right)^{1-\alpha} K^{\alpha} \tag{1}$$

where α can be interpreted as capital share of income. Under this assumption, growth of output can be broken into growth of factors of production weighted by the income shares:

$$\frac{\Delta Y}{Y} = \left(1-\alpha\right)\frac{\Delta A}{A} + \left(1-\alpha\right)\frac{\Delta L}{L} + \alpha\frac{\Delta K}{K} \tag{2}$$

Equation (2) allows to decompose growth into growth of labour input, physical capital and the residual ($(1-\alpha)\Delta A/A$) capturing, among others, human capital and technological progress.

The theoretical literature on economic growth highlights two primary engines of growth in catching-up countries: accumulation of physical capital and technology imitation and adoption.

The role of physical capital along the transition is spelled out in the seminal paper by Solow (1956). The model is based on the assumption that households devote a constant fraction of their income for investment. Thus, the capital accumulation is determined endogenously with the following law of motion:

$$K_t = \left(1-\delta\right)K_{t-1} + sY_t$$

where K_t and Y_t is the level of capital and income at time t and δ is the depreciation rate of capital.

If productivity, A, and labour input are constant, the model predicts that the economy starting from a low level of capital stock will keep accumulating capital (and hence experience economic growth) until the steady state level of capital is reached. The steady state level of capital is equal to $K^* = \left(s/\delta\right)^{\frac{1}{1-\alpha}} AL$.

If A and L grow (exogenously) at the constant rates, g and n, respectively, then the model predicts that the capital stock will grow at a rate which is greater than $g + n$, until $K/(AL) = (s/(\delta + g + n))^{\frac{1}{1-\alpha}}$.

As will be demonstrated in the next subsection in Poland, Czechia and Hungary, the ratio *K/(AL)* in 1995 was below its steady state level. Thus, following the Solow model prediction, we should expect a rapid capital accumulation and shift of the ratio towards its steady state level.

Although the predictions of the Solow model are built on the assumption that the economy is closed, a similar prediction can be easily derived for the small open economy. As noted by Lucas (1990), one should expect an inflow of capital to countries with marginal product of capital which is higher than in developed countries. For the neoclassical production function in (1), the marginal product of capital is given by $dY/dK = \alpha(K/(AL))^{-(1-\alpha)}$, i.e. the decreasing function of capital per efficiency units. Countries with relatively low levels of capital per efficiency unit should therefore experience an inflow of capital until the capital per efficiency unit equalizes its level in more developed countries. This should be the case for Czechia, Hungary and Poland, whose capital per efficiency unit was smaller than in Germany (see Table 1).

Another strand of literature, which was built on endogenous growth theory (Romer 1990; Grossman, Helpman 1991; Aghion, Howitt 1992) stresses the role of technology adoption and diffusion in the catching-up proces. An illustrative example is the model by Barro and Sala-i-Martin. In the model, firms in the catching-up countries have the possibility to imitate the technologies employed in a country at the technological frontier. The firm incurs a cost for any idea it wishes to imitate, although the imitation costs are lower than the innovation costs. The model assumes also that the imitation cost increases when the number of ideas which have already been imitated relative to the total pool of available ideas increases. This could reflect that the ideas whose adaptation requires the least effort are copied first. In this case, the model predicts the same pattern of convergence as the Solow model: the imitating country grows faster than the country at the frontier and the convergence speed increases with the initial distance between the imitating and the frontier country.

4.2. Baseline decomposition of growth

The process begins with the most standard decomposition of growth into growth of physical capital, labour input and the residual predicted by equation (2). The capital share of income is assumed to be 0.33 – as normally assumed in the literature.

The first decomposition, pictured in Figure 5 indicates that the growth in the years 1995–2013 was primarily driven by increases in TFP. In Poland productivity increased by 69%, explaining two thirds of total GDP growth in this period. In Hungary and in Czechia the pattern was similar. During 18 years, capital stock in Poland grew by 110%, however due to decreasing returns this translated to 37% growth of GDP. In Hungary and in Czechia capital can explain 17 and 19 percentage points of GDP growth, respectively. The contribution of labour supply input was negligible.

A more detailed analysis in Figure 6 reveals substantial differences between the pre- and post-crisis periods. In the years 1995–2007, the difference between capital and TFP contribution to GDP growth was very large. In Poland the contribution of TFP can explain 3.6 percentage points of GDP growth per annum. The contribution of capital in GDP growth during this period was only 1.2 percentage points per annum. In Hungary, the pattern of growth for the years 1995–2007, resembling the Polish case, features very high growth of TFP (explaining 2.4 percentage points of increase per annum) and capital growth that did not keep pace with productivity (explaining only 0.9 percentage points of GDP increase per annum). In Czechia, while the contribution of TFP explains 2.6 percentage points of GDP growth, capital can explain only 0.9 percentage points.

In the second period, the role of capital became much more significant. The productivity growth slowed down substantially in all three economies (and became negative in the case of Hungary). In turn, the growth of capital did not change significantly in comparison to the previous period in Czechia and Hungary and it speeded up in the case of Poland. As a result, capital became the major driving force for all three economies in the post-crisis years.

4.3. Baseline decomposition of convergence

To decompose convergence in GDP with Germany, the same strategy is used, except now each variable is replaced with its value relative to Germany (thus, e.g. y becomes Polish GDP divided by German GDP). Since labour input did not change much in any country, the focus is on the values per hour of person engaged (p.h.p.e.). The results are presented in Figure 7 and in Tables 1, 2 and 3.

In the period 1995–2007 in Poland, the relative GDP p.h.p.e. increased by 43% (from 0.32 to 0.45). The relative capital p.h.p.e. increased by 20% (from 0.18 to 0.24), and the relative residual (TFP) increased by 33% (from 0.55 to 0.73). Translating this into contributions in the convergence of output (by weighting capital with its share in income), the 43% increase in relative output may be decomposed into a 33% increase (2.3% per annum) due to residual growth and a 10% increase (0.8% per annum) due to capital accumulation. This is in line with the conclusions from the previous paragraph that Poland's catching up to the German economy cannot be explained by capital accumulation.

Over the 12-year period, the ratio of Hungarian GDP p.h.p.e. to German increased by 20% (from 0.40 in 1995 to 0.48 in 2007), which – as in the Polish case – was primarily fuelled by the increase in relative TFP (increase from 0.59 in 1995 to 0.68 in 2007) and, to a significantly lower extent, by growth in relative capital (from 0.31 to 0.35).

Czechia had almost exactly the same starting point as Hungary – in 1995 its GDP was 38% of German GDP. Compared to Hungary, it grew slightly faster to reach 49% of German GDP in 2007. Its capital stock relative to Germany increased from 0.37 in 1995 to 0.44 in 2007. Relative productivity grew substantially – in line with the technology transfer hypothesis – from 0.54 to 0.64.

In the second analysed period (2007–2013) all three economies kept decreasing the distance to Germany, however the pace of convergence was lower. As shown in Figure 7, in this period the primary engine for convergence was capital accumulation. Productivity relative to Germany decreased in Hungary in Czechia.

The sluggish accumulation of capital compared to the rapid growth of productivity also has a consequence on evaluating how well the Solow model might explain the rate of growth of the three economies. As highlighted in Subsection 4.1, the model predicts that the capital per efficiency unit $K/(AL)$ should converge to its steady state level, given by:

$$K/(AL) = \left(s/(\delta + g + n)\right)^{\frac{1}{1-\alpha}}$$

where:

s – the saving rate,

δ – the depreciation rate,

g – the TFP growth rate,

n – the labour input growth rate.

The average value of savings rate s (investment over GDP) in Poland between 1995 and 2013, is 0.205, the average annual TFP growth (g) in this period was 4.05%, the annual growth of hours of persons engaged (n) was negligible (less than 0.01% per annum). The depreciation rate (δ) is assumed to be 6%. Given these values, one can compute the steady state level of capital per efficiency unit in Poland to be 2.90. The observed value of capital per efficiency unit, $K/(AL)$, in 1995 was 2.46, below its steady state level. Therefore, following the Solow model prediction we should expect growth of capital per efficiency unit. Instead of moving in this direction, in the first period (until 2007) the capital per efficiency unit in Poland was actually declining, reaching the value of 2.07 in 2007. Only in the last period (2007–2013), partly due to a more sluggish TFP growth, did the capital per efficiency unit start to increase, reaching the value of 2.57 in 2013. The evolution of capital per efficiency units is portrayed in Figure 8.

If one considers the version of the Solow model with free flow of capital between countries, discussed in the previous subsection, one should expect that capital per efficiency unit gap between countries should be closing in order to equalize the return from capital in both countries. Again, however, this has not happened. In 1995 capital per efficiency unit in Poland and in Germany took the values 2.14 and 5.47, respectively. After 12 years, these values were 1.78 and 5.68, respectively.

The same trend is confirmed in the case of Hungary and Czechia. In Hungary in 1995, the observed capital per efficiency unit was 3.83, which is higher than in Poland but way below the Hungarian theoretical steady state level of 5.82[2] or the German level of 5.47. The theory would therefore predict an increase of capital per efficiency unit. Instead, its value dropped over the 12-year period to 3.38 in 2007. Only after 2007 did the ratio start to increase, reaching the level of 4.14 in 2013.

Czechia had the highest value of capital per efficiency unit, which was 5.16. Its theoretical steady state value of capital per efficiency unit was 8.25. As in the other two countries, the Czech economy increased the distance from its steady state. In 2007, the capital per efficiency unit was 4.64. As in other countries, after 2007 capital per efficiency unit increased. In 2013 it took the value of 5.60.

A closer inspection of the data reveals the reason for the failure of the Solowian prediction. The simple Solow model assumes that the saving rate, depreciation and TFP growth are constant over time. Since in reality they did vary significantly, the Solow model is not able to explain some of the dynamics for the three economies. For example, in Poland the reason why capital per efficiency unit was moving away from its steady state in the years 1995–1997 was that during this period depreciation was higher than its assumed steady state level and the rate of TFP growth was higher than its long-run rate. The capital per efficiency unit was again moving away from its steady state in the years 2002–2007. In this period the saving rate was lower than its long-run average.

On the other hand, the failure of the open economy model to match the data does not have to be driven by capital accumulation that is too slow. The reason why capital per efficiency unit in the three countries did not converge to the value of Germany was a rapid growth of productivity.

2 The high steady state level of capital per efficiency unit in Hungary and Czechia results from a very high savings rate (investment-to-GDP ratio) in this period.

To conclude, the decomposition exercise shows the weakness of using Solowian or capital flow models alone and highlights the importance of supplementing them with the technology convergence models described at the end of the Subsection 4.1.

4.4. Future growth

To explore the potential sources of future growth, let us now focus on the levels of capital and TFP in 2013. Table 3 presents the levels of GDP, capital and TFP in 2013 for the three economies relative to the level in Germany. While TFP reached almost the same level as in Germany, the stock of capital lags behind. This is particularly clear in the case of the Polish economy. Scholars who study the theory of economic growth will find it surprising that while the TFP of one country is about three quarters that of the other country, its capital per labour is three times smaller. The optimistic view would be that TFP growth was so rapid during these years that capital simply could not keep pace. This would imply that the coming years are yet to witness capital accumulation and the continuation of convergence is almost guaranteed. The pessimistic view is that there are some substantial barriers for capital accumulation that slowed down convergence and, unless resolved, will continue to slow down the economy in the future. Obstacles for capital accumulation could include high financing costs (e.g. due to underdeveloped financial markets), uncertainty and over-regulation (OECD 2015).

4.5. Human capital and technology decomposition

Given the spectacular increase in the residual, it might be worth attempting to add some additional explanatory power to the model. The data on the number of workers in each educational group and their wages might allow exploration of the extent in which growth comes from an increased share of more educated workers and if the technological progress was concentrated on the growth of productivity of high-skilled or low-skilled workers.[3]

The form and the calibration of the production function

To accommodate the differences in the productivity of different types of workers, a CES production function is used of the form:

$$y = B^{1-\alpha}\left(\pi\left(L^h\right)^\sigma + (1-\pi)\left(L^l\right)^\sigma\right)^{\frac{1-\alpha}{\sigma}} K^\alpha \tag{3}$$

where B stands for skill-neutral technology parameter and π stands for CES distribution parameter, which determines the skill-bias of the technology (larger π corresponds to higher demand for high--skilled workers).

Note that this production function is analogous to that in Caselli and Coleman (2006) and Ottaviano and Peri (2008). These authors use the function of the form $y = \left(\left(A^h L^h\right)^\sigma + \left(A^l L^l\right)^\sigma\right)^{\frac{1-\alpha}{\sigma}} K^\alpha$.

[3] The idea to use data on relative factor prices in accounting for cross-country productivity differences was first suggested by Caselli and Coleman (2006).

This is the same as equation (3) with $A^h = B\pi^{\frac{1}{\sigma}}$ and $A^l = B(1-\pi)^{\frac{1}{\sigma}}$.

Isolating the total labour input:

$$y = B^{1-\alpha}\left(\pi\left(s^h\right)^{\sigma} + (1-\pi)\left(s^l\right)^{\sigma}\right)^{\frac{1-\alpha}{\sigma}} L^{1-\alpha}K^{\alpha} \tag{4}$$

where s^h is the share of high-skilled workers in the total labour supply, s^l is the share of low-skilled workers.

The values of π and B can be recovered from the data on labour compensation as follows: if factor prices are equated with their marginal products (as implied by representative firm first order conditions for optimal choice of inputs), the following condition is obtained:

$$\frac{w^h}{w^l} = \left(\frac{s^h}{s^l}\right)^{-(1-\sigma)}\left(\frac{\pi}{1-\pi}\right) \tag{5}$$

where w^h and w^l denote wages of high-skilled and low-skilled workers respectively.

Note that equating wages with the marginal product of workers, although standard in neoclassical literature, involves the assumption that the changes in bargaining power between employers and workers did not play a significant role in the analysed period in the three economies. Relaxing this assumption is beyond the scope of the paper, although it is an interesting theme for future research.

Combining this with the production function, π and B can be expressed in terms of observable w^h, w^l, s^h and s^l:

$$\pi = \frac{w^h\left(s^h\right)^{(1-\sigma)}}{w^l\left(s^l\right)^{(1-\sigma)} + w^h\left(s^h\right)^{(1-\sigma)}}$$

$$B = \frac{y^{\frac{1}{1-\alpha}}K^{\frac{-\alpha}{1-\alpha}}}{L}\frac{w^l\left(s^l\right)^{1-\sigma} + w^h\left(s^h\right)^{1-\sigma}}{\left(w^l s^l + w^h s^h\right)^{\frac{1}{\sigma}}}$$

Since the calibration of σ has a crucial impact on the results, this will be described in more detail. One of the first – and so far the most popular – estimates of σ was delivered by Katz and Murphy (1992), who found that the value of elasticity of substitution, i.e. $1/(1-\sigma)$, is equal to 1.41. They obtain it from a simple regression derived from equation (5):

$$\log\left(\frac{w^h}{w^l}\right) = -(1-\sigma)\log\left(\frac{L^h}{L^l}\right) + \log\left(\frac{\pi}{1-\pi}\right) \tag{6}$$

Katz and Murphy estimate this regression using US data between 1963 and 1997. To proxy for the last term they control for a linear trend.

However, simple intuition questions the validity of the estimates. If relative labour supply responds to relative efficiency deviations from the linear trend, then the explanatory variable is correlated with the error term and the regression estimates are biased. Since it is expected that there will be a positive response of relative supply to positive relative efficiency shock, the coefficient on relative supply is likely to be biased upwards (towards zero) – intuitively, since higher relative efficiency and higher relative labour supply tend to go together, a negative response of wages to the higher relative labour supply cannot be observed. Thus, the bias is towards higher substitutability across two types of workers.

Equation (6) has received a lot of attention in the labour literature, and various authors have tried to find instruments that could help to avoid the endogeneity bias described above. One of the convincing IV estimates was presented by Ciccone and Peri (2005), who instrument relative labour supply with compulsory school attendance laws (at state level) and arrive at the value of 1.5. The time series they use covers the period of 1950–1990 in the US – similar to the one from Katz and Murphy. Thus, it seems that if there is an endogeneity bias in the US, it is not very significant.

However, it is not clear whether the estimates obtained from this literature can be used for Central and Eastern Europe. Author's estimates of sigma in Europe (both in Germany and Poland) are significantly different, even though the estimates for the US match the evidence from the Ciccone and Peri and Katz and Murphy papers. When equation (6) is regressed using the EU KLEMS data for Poland between 1995 and 2005 (and as Katz and Murphy, control for linear trend), the coefficient on relative labour supply is very close to zero: 0.15 (and not statistically significantly different from zero). This implies a very high elasticity of substitution.

The results for both cases are presented below: if it is assumed that $\sigma = 1$, i.e. if high-skilled and low-skilled workers are perfect substitutes, and if it is assumed that σ is at the US level (estimated by Katz and Murphy).

Growth decomposition using wages for high-skilled and low-skilled workers

Given all the information on the production function form and its key parameters (B, π and σ), additional information about the nature of convergence can be recovered. Using equation (4), it is possible to immediately arrive at the simplest decomposition of growth rates:

$$\frac{y_{t+1}}{y_t} = \left[\frac{B_{t+1}\left(\pi_{t+1}\left(s_{t+1}^h\right)^\sigma + \left(1-\pi_{t+1}\right)\left(s_{t+1}^l\right)^\sigma\right)^{\frac{1}{\sigma}}}{B_t\left(\pi_t\left(s_t^h\right)^\sigma + \left(1-\pi_t\right)\left(s_t^l\right)^\sigma\right)^{\frac{1}{\sigma}}}\right]^{1-\alpha} \left(\frac{L_{t+1}}{L_t}\right)^{1-\alpha} \left(\frac{K_{t+1}}{K_t}\right)^{\alpha}$$

The comparison with the equation reveals that in the previous analysis the first term in the above equation was captured as a residual. Now the additional information on A's might help to decompose this residual into further elements. The first step is to decompose it in the manner similar to the way nominal GDP growth is decomposed into real GDP growth and inflation (by Paasche or Laspeyres decomposition). Thus the expression in the square brackets above can be decomposed into three factors:

$$\frac{\left(\pi_t\left(s_{t+1}^h\right)^\sigma + \left(1-\pi_t\right)\left(s_{t+1}^l\right)^\sigma\right)^{\frac{1-\alpha}{\sigma}}}{\left(\pi_t\left(s_t^h\right)^\sigma + \left(1-\pi_t\right)\left(s_t^l\right)^\sigma\right)^{\frac{1-\alpha}{\sigma}}} \tag{7}$$

$$\frac{\left(\pi_{t+1}\left(s_{t+1}^{h}\right)^{\sigma}+\left(1-\pi_{t+1}\right)\left(s_{t+1}^{l}\right)^{\sigma}\right)^{\frac{1-\alpha}{\sigma}}}{\left(\pi_{t}\left(s_{t+1}^{h}\right)^{\sigma}+\left(1-\pi_{t}\right)\left(s_{t+1}^{l}\right)^{\sigma}\right)^{\frac{1-\alpha}{\sigma}}} \tag{8}$$

and

$$\left(\frac{B_{t+1}}{B_t}\right)^{1-\alpha} \tag{9}$$

This decomposition resembles a counterfactual exercise: the first term shows what the change in output would be if the distribution parameter was fixed at its initial level, but the shares of high-skilled and low-skilled workers is allowed to change to their new levels. Thus, the term captures the growth coming from the increased share of a more productive factor.

The second term states what the growth of output would be if the distribution parameter, π was allowed to jump to the new levels while keeping the share of high-skilled and low-skilled labour fixed across two periods. It can be interpreted as growth that originates from the fact that the more abundant factor becomes relatively more productive.

Finally, the third term will capture the skill-neutral productivity growth.

Decomposition results for Poland, Hungary and Czechia

Since WIOD data on wages for various types of labour are available only until 2009, in this section the analysis is focused on the convergence between 1995 and 2009. The analysis is performed for the two subperiods – before and after 2007 and its outcome is presented in Figure 9.

The process begins with the results under the assumption of $\sigma = 1$, i.e. if high-skilled and low-skilled workers are considered perfect substitutes. Recall that the annual growth of the residual between 1995 and 2007 in Poland (earlier labelled as TFP) was equal to 3.6%. This might be decomposed as follows. The expression in (7), which captures the effect of the change in labour composition (i.e. growth due to a higher share of a more productive factor, in this case – increasing the share of high-skilled workers) implies an average annual growth of 0.1%, a rather modest contribution. The expression in (8), which captures the favourable bias of technological change (i.e. growth due to an increase in relative productivity of a more abundant factor – in the Polish case, high-skilled labour) implies an annual growth of 0.6%. Finally, the expression in (9) that captures the improvement in skill-neutral technology brings a growth of 2.8% per year.

If the value of $\sigma = 0.3$ (corresponding to $1/(1 - \sigma) = 1.4$ is used, as estimated by Katz and Murphy), the role of skill upgrading diminishes to nil. Also, the growth due to an increase in relative productivity of a more abundant factor is very modest. The entire remaining growth is attributed to the residual, i.e. skill-neutral productivity improvement (expression (9)).

In the years 2007–2009, the results of the decomposition are similar – most of the growth in residual cannot be explained either by the labour composition effect (expression (7)), or by the favourable bias in technological change (expression (8)). Interestingly, if $\sigma = 1$, in this period the technological change reduced the productivity gap between high-skilled and low-skilled workers. This exerted a negative force on TFP in Poland.

Under the assumption of $\sigma = 1$, in Hungary, the skill upgrading did not contribute to a change in TFP either before or after 2007. In the first period, almost the entire residual growth could be attributed to the skill-neutral productivity improvement (expression (9)). In the second period, the fall in productivity was offset by a favourable skill-biased technological change. Similar results are achieved under the assumption of $\sigma = 0.3$.

In Czechia in both periods neither labour composition (expression (7)) nor favourable technological bias (expression (8)) can explain changes in the residual of TFP. This result is obtained for both values of sigma considered.

5. Summary

In the first part of the paper, economic growth in Poland, Hungary and Czechia is decomposed into three elements: growth of capital, growth of labour supply and the total factor productivity term that captures the increase of human capital, transfer of technology and institutional change. Since in 1995 in all three countries the levels of capital and the TFP were very low relative to German levels, the Solow model and the technology imitation models predicted capital accumulation and an increase in residuals that are larger than in Germany. Indeed, over the 18-year period between 1995 and 2013, both the level of capital and TFP has converged to German levels in all three countries. However, the convergence of capital has been substantially slower than the convergence of TFP. In fact, contrary to the prediction of the Solow model, the distance between observed capital per efficiency unit and its steady state level increased in the pre-crisis period (between 1995 and 2007). Only in the last five years (between 2007 and 2013) did capital per efficiency unit start to increase. The results therefore imply that the Solow model alone is too weak to explain the observed pattern of convergence between countries and it must be supplemented with the technology transfer model.

Given the extraordinary role of the TFP growth, it is further decomposed into the increased share of high-skilled (better educated) workers, the increase in relative productivity of a more abundant type of labour and skill-neutral technological progress. The first factor played only a minor role in all three countries. Most of the growth could be explained with the skill-neutral productivity improvement.

References

Aghion P., Howitt P. (1992), A model of growth through creative destruction, *Econometrica*, 60(2), 323–351.

Alam A., Anós C.P., Khan F., Udomsaph Ch. (2008), *Unleashing prosperity: productivity growth in Eastern Europe and the former Soviet Union*, World Bank, https://openknowledge.worldbank.org/handle/10986/6588.

Amplatz Ch. (2003), The economic convergence performance of Central and Eastern European countries, *Economics of Planning*, 36, 273–295.

Baran K. (2013), The determinants of economic growth in Hungary, Poland, Slovakia and the Czech Republic in the years 1995–2010, *Equilibrium*, 8(3), 7–26.

Barro R.J., Mankiw N.G., Sala-i-Martin X. (1995), Capital mobility in neoclassical models of growth, *American Economic Review*, 85(1), 103–115.

Barro R.J., Sala-i-Martin X. (1997), Technological diffusion, convergence, and growth, *Journal of Economic Growth*, 2(1), 1–26.

Boldrin M., Canova F. (2001), Inequality and convergence in Europe's regions: reconsidering European regional policies, *Economic Policy*, 16(32), 205–253.

Caselli F., Coleman II W.J. (2006), The World Technology Frontier, *American Economic Review*, 96(3), 499–522.

Caselli F., Tenreyro S. (2005), *Is Poland the next Spain?*, CEPR Discussion Papers, 4877.

Ciccone A., Peri G. (2005), Long-run substitutability between more and less educated workers: evidence from U.S. States, 1950–1990, *The Review of Economics and Statistics*, 87(4), 652–663.

Dabrowski M. (2014), Central and Eastern Europe: uncertain prospects of economic convergence, *Bruegel Blog Post*, http://bruegel.org/2014/12/central-and-eastern-europe-uncertain-prospects-of-economic-convergence/.

Doyle P., Kuijs L., Jiang G. (2001), *Real convergence to EU income levels. Central Europe from 1990 to the long term*, IMF Working Papers, 01/146, International Monetary Fund.

Gradzewicz M., Growiec J., Kolasa M., Postek L., Strzelecki P. (2014), *Poland's exceptional performance during the world economic crisis: new growth accounting evidence*, NBP Working Papers, 186, Narodowy Bank Polski.

Grossman G.M., Helpman E. (1991), Quality ladders in the theory of growth, *Review of Economic Studies*, 58(1), 43–61.

Growiec J. (2008), *Productivity differences across OECD countries, 1970–2000: the World Technology Frontier revisited*, IBS Working Papers, 1/2008, Instytut Badań Strukturalnych.

Fischer S., Sahay R., Vegh C. (1998a), *From transition to market; evidence and growth prospects*, IMF Working Papers, 98/52, International Monetary Fund.

Fischer S., Sahay R., Vegh C. (1998b), *How far is Eastern Europe from Brussels?*, IMF Working Papers, 98/53, International Monetary Fund.

Forgo B., Javcak A. (2015), *Economic convergence of Central and Eastern European EU member states over the last decade (2004–2014)*, European Economy Discussion Paper, 001, July.

Howitt P. (2000), Endogenous growth and cross-country income differences, *American Economic Review*, 90(4), 829–846.

Iradian G. (2007), *Rapid growth in transition economies. Growth-accounting approach*, IMF Working Papers, 07/164, International Monetary Fund.

Katz L.F., Murphy K.M. (1992), Changes in relative wages, 1963–1987: supply and demand factors, *The Quarterly Journal of Economics*, 107(1), 35–78.

Kolasa M., Strzelecki P. (2007), Zmiany jakości wykorzystywanych zasobów pracy w Polsce, *Gospodarka Narodowa*, 11–12/2007, 35–53.

Konopczak K. (2013), Konwergencja gospodarek państw Europy Środkowo-Wschodniej względem strefy euro – test wspólnego trendu i wspólnego cyklu, *Bank i Kredyt*, 44(4), 353–374.

Lucas R.E. Jr. (1990), Why doesn't capital flow from rich to poor countries?, *American Economic Review*, 80, 92–96.

Nehru V., Dhareshwar A.M. (1993), A new database on physical capital stock: sources, methodology and results, *Revista de analisis economico*, 8(1), 37–59.

Nelson R.R., Phelps E.S. (1966), *Investment in humans, technological diffusion and economic growth*, Cowles Foundation Discussion Papers, 189, Cowles Foundation for Research in Economics, Yale University.

OECD (2015), *Lifting investment for higher sustainable growth*, OECD Economic Outlook, Chapter 3, 2015/1.
Ottaviano G.P., Peri G. (2008), *Immigration and national wages: clarifying the theory and the empirics*, CEPR Discussion Papers, 6916.
Prochniak M., Witkowski B. (2013), Real beta-convergence of transition countries, *Eastern European Economics*, 51(3), 6–26.
Romer P.M. (1990), Endogenous technological change, *Journal of Political Economy*, 98(5), S71-102.
Sachs J. (1994), *Poland's jump to the market economy*, vol. 1, The MIT Press.
Solow R.M. (1956), A contribution to the theory of economic growth, *Quarterly Journal of Economic*s, 70(1), 65–94.

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Appendix

Table 1
Relative GDP, capital and TFP and capital per efficiency unit, and steady state value of capital per efficiency unit for the period 1995–2013 (1995 = 1)

	Poland	**Hungary**	**Czechia**	**Germany**
GDP (% of German)	32	40	39	100
Capital (% of German)	18	31	37	100
TFP (% of German)	55	59	54	100
Capital per efficiency unit	2.46	3.83	5.16	5.56
Steady state capital per efficiency unit (1995–2013)	2.90	5.83	8.25	4.75
Capital-output ratio	1.83	2.46	3.00	3.15

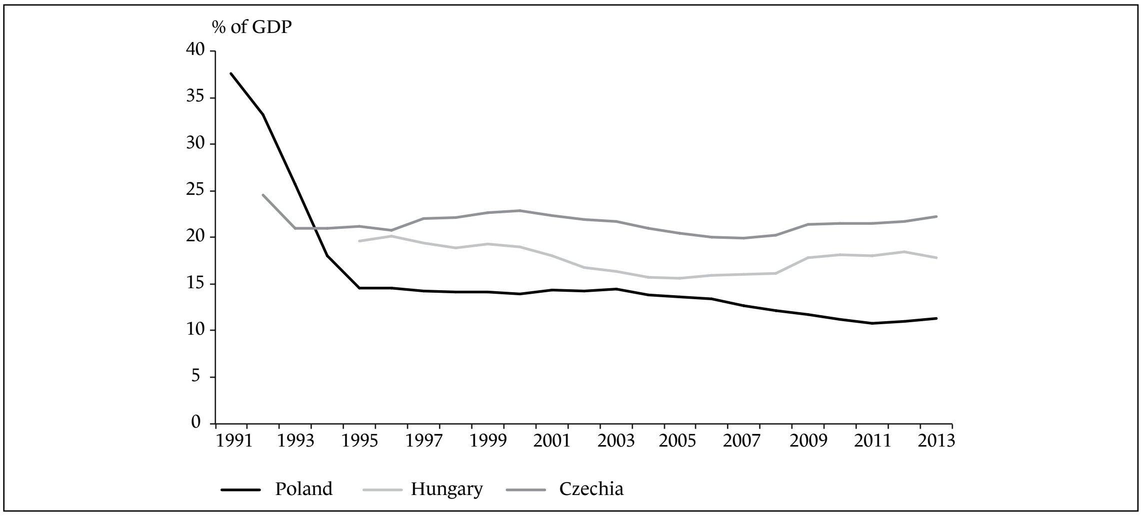
Table 2
Relative GDP, capital and TFP and capital per efficiency unit (2007 = 1)

	Poland	**Hungary**	**Czechia**	**Germany**
GDP (% of German)	45	48	49	100
Capital (% of German)	24	35	44	100
TFP (% of German)	73	68	64	100
Capital per efficiency unit	2.07	3.38	4.64	5.41
Capital-output ratio	1.63	2.26	2.80	3.10

Table 3
Relative GDP, capital and TFP and capital per efficiency unit (2013 = 1)

	Poland	**Hungary**	**Czechia**	**Germany**
GDP (% of German)	55	50	50	100
Capital (% of German)	33	42	51	100
TFP (% of German)	79	67	62	100
Capital per efficiency unit	2.57	4.14	5.60	5.48
Capital output ratio	1.88	2.59	3.17	3.13

Figure 1
Consumption of capital (as a fraction of GDP) for Poland, Hungary and Czechia since 1991



Source: stats.OECD.

Figure 2
The sensitivity of capital index to the initial level of capital in Poland

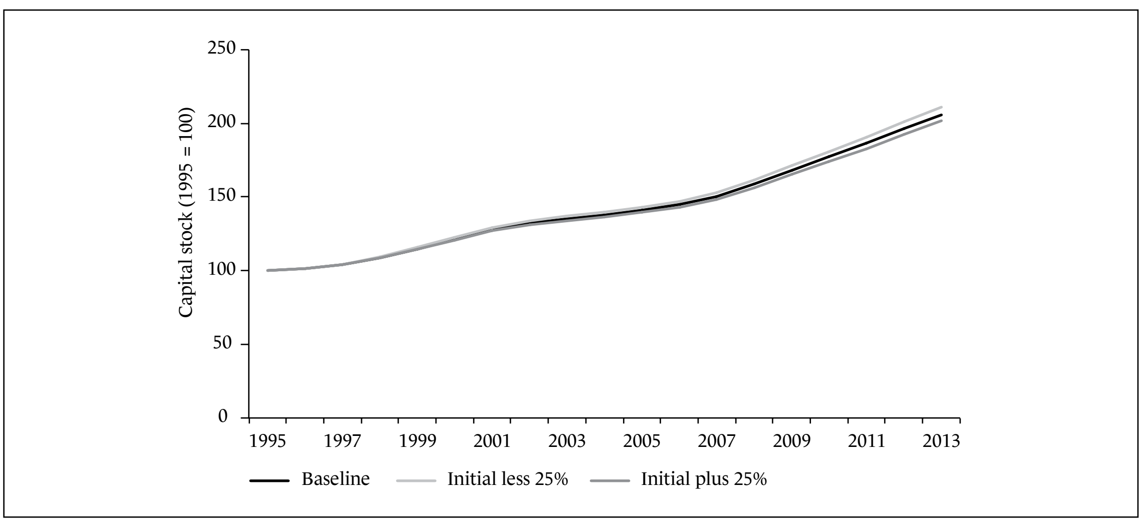


Figure 3
The sensitivity of capital index to the different assumptions on depreciation in Poland between 1995 and 2013

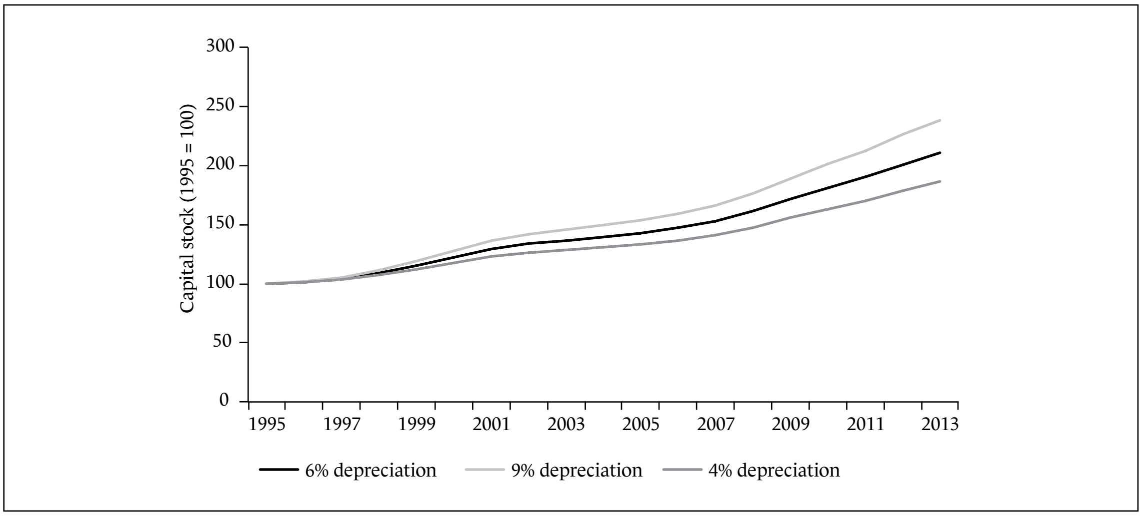


Figure 4
Comparison of OECD, WIOD and own capital indexes for Poland, Hungary and Czechia

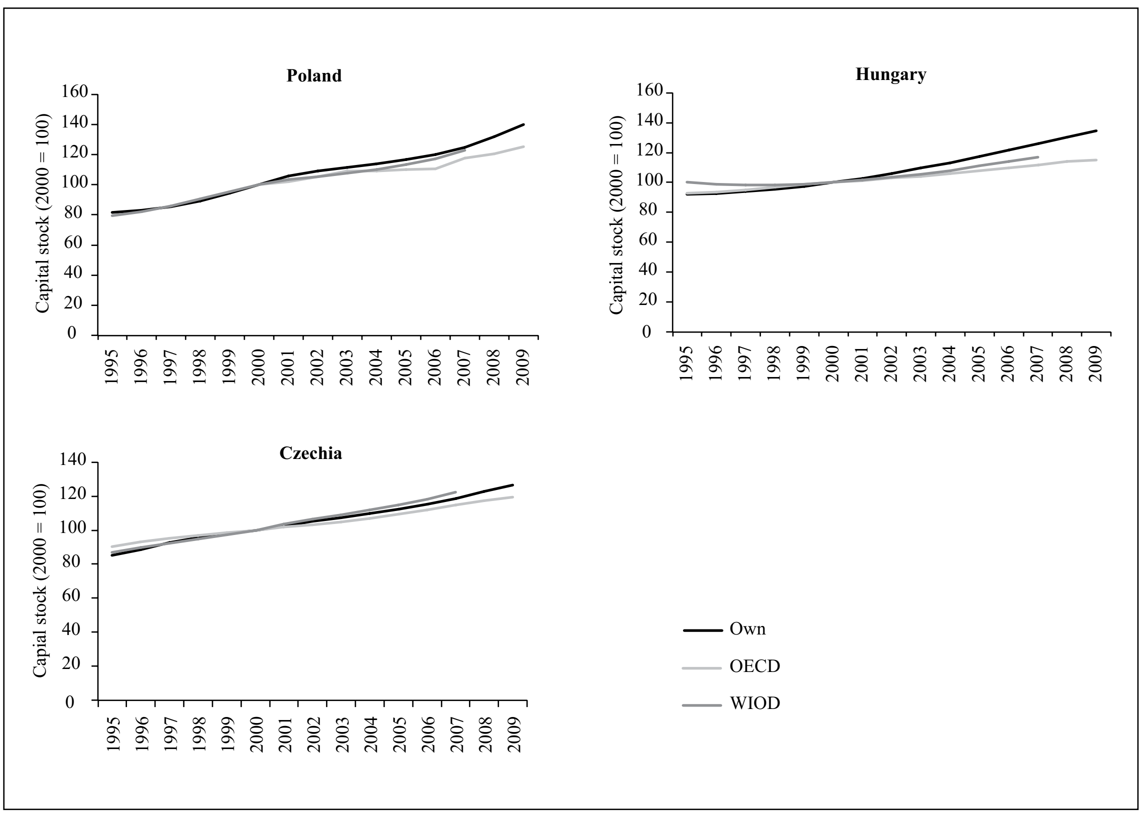
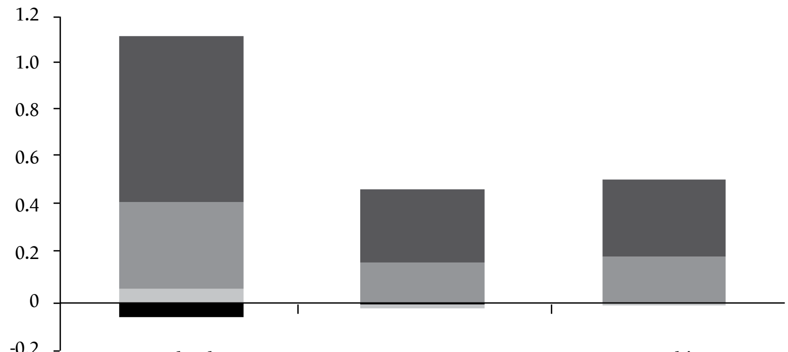
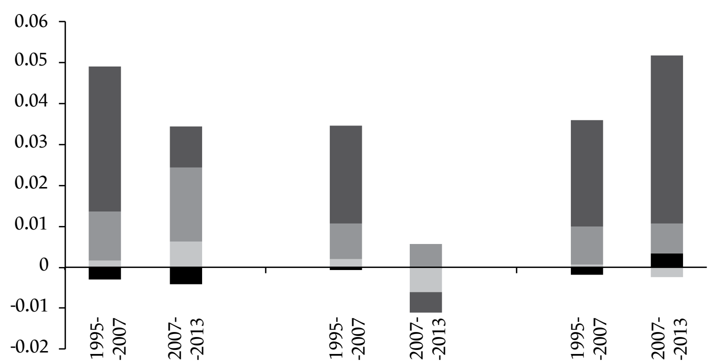


Figure 5
The contribution of TFP, GDP and labour input growth to the total GDP growth between 1995 and 2013 for Poland, Hungary and Czechia



	Poland	Hungary	Czechia
TFP	69%	30%	32%
Capital	37%	17%	19%
Number of persons engaged	6%	-1%	-1%
Hours per person engaged	-6%	-1%	0%

Figure 6
The contribution of TFP, GDP and labour input growth to the average annual GDP growth before and after 2007 for Poland, Hungary and Czechia



	Poland		Hungary		Czechia	
	1995-2007	2007-2013	1995-2007	2007-2013	1995-2007	2007-2013
TFP	3.6%	1.0%	2.4%	-0.5%	2.6%	4.1%
Capital	1.2%	1.8%	0.9%	0.6%	0.9%	0.7%
Number of persons engaged	0.2%	0.6%	0.2%	-0.6%	0.1%	-0.2%
Hours per person engaged	-0.3%	-0.4%	-0.1%	-0.0%	-0.2%	-0.3%

Figure 7

The average annual contributions of TFP, GDP and labour input growths to closing the gap between Polish, Hungarian and Czech, and German GDP

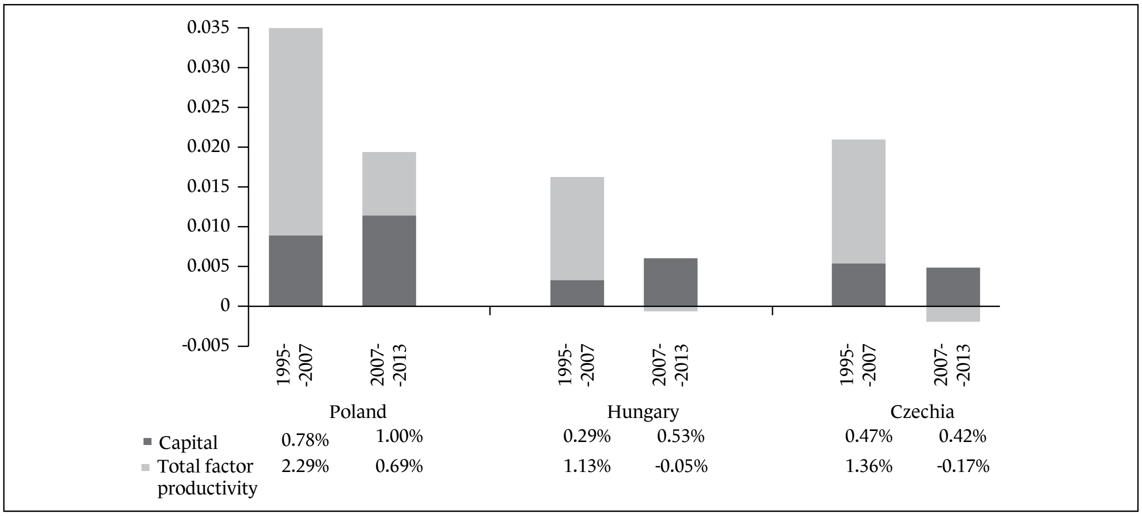


Figure 8

The evolution of capital per efficiency unit between 1995 and 2013 for Poland, Hungary and Czechia

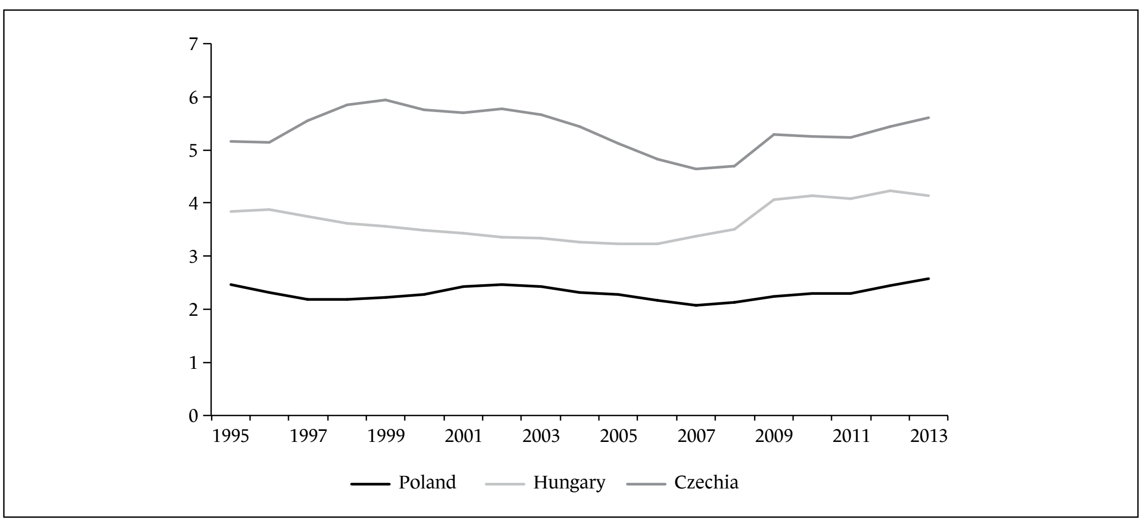
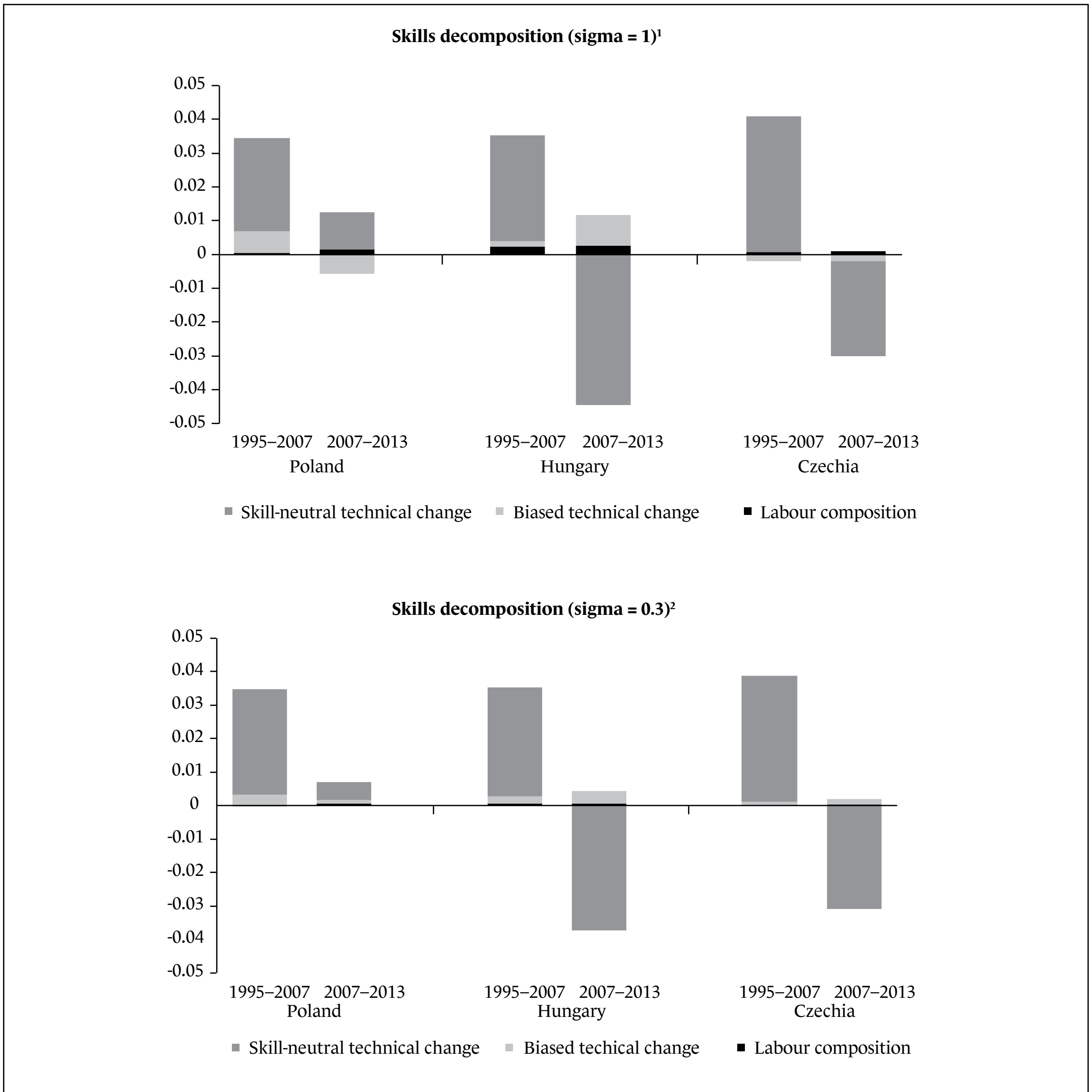


Figure 9

Decomposition of growth of residual for favourable technological change, labour composition (expression (7)) and skill-neutral productivity improvement



[1] The decomposition is done assuming that the high-skilled and low-skilled workers are perfect substitutes, i.e. the value of ($\sigma = 1$).

[2] The decomposition is done assuming that the high-skilled and low-skilled workers are imperfect substitutes, with the value of ($\sigma = 0.3$).