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Bas van Leeuwen, University of Warwick, Utrecht University, Free University Amsterdam

Peter Földvari, University of Debrecen, Utrecht University

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Bas van Leeuwen, University of Warwick, Utrecht University, Free University Amsterdam

Peter Földvari, University of Debrecen, Utrecht University

Abstract

Central and Eastern Europe is a region with widely divergent development paths. Up to WWII, these countries experienced comparable growth patterns. Yet, whereas Austria and West Germany remained part of the capitalist West and underwent periods of rapid growth, other countries, under state-socialist regimes, experienced on average far lower growth rates. The lack of data, however, often limits the possibilities of a detailed, quantitative analysis. In this paper, we use a new dataset on physical and human capital in seven Eastern and Central European countries for the period 1920-2006 to calculate the effect on economic growth. We analyse the effect of including the quality of education in human capital. This allows us to perform a growth accounting analysis with the several production factors for Central Europe between 1920 and the present. The difference in growth path across countries is partly explained by differences in efficiency.

Keywords: Eastern Europe, human capital, physical capital, growth accounting, efficiency, long run growth

JEL Codes: E22, J24, N14, N34, O47

Corresponding author: Bas van Leeuwen: bas.vanleeuwen1@googlemail.com

1. Introduction

The transition from centrally planned to market economies in Eastern Europe in the 1990s is one of the rare episodes in history that can serve as natural experiment. There are very few other historical examples of such sudden and massive regime changes in economic systems. This even inspired Fukuyama (1992) to call it the "end of history" and herald the victory of Western liberalism. From an economic perspective, it was also clear that socialism had a profound impact on economic growth. The relative per capita GDP of Eastern European countries expressed in international dollar at 1990 prices ranged between 20.2-43.3 % of the US in 1938. After the decades of state-socialism, their relative position was even worse, within the interval of 17.9-40.1% (Good and Ma, 1999). And not only did these countries fail to converge to the West, but intraregional differences, even though they decreased somewhat, remained quite significant: the coefficient of variation of per capita income among seven Eastern European socialist countries in 1938 was not much higher (0.296) than in 1989 (0.232). Austria and West Germany, on the other hand, managed to converge to the USA in terms of per capita GDP reaching 75-83% of its per capita income level by 1989, even though their initial position in 1938 was not much better than that of Czechoslovakia or Hungary.

But how can this difference in growth performance be explained? A comparison of the role of the factors of production in economic growth in Central Europe may be one possible way to account for the differences. Up to World War II all countries in the region had comparable levels of human- and physical capital and per capita GDP – significantly lower than North-Western Europe, but higher than the Near East or Russia. The similarities ended in the post-war years, when Austria and (Western) Germany remained part of the 'capitalist' half of the continent, whereas major institutional changes (such as central planning, and state-led redistribution) were introduced in Eastern Europe. This had consequences for human- and physical capital formation as well. One of the rationales of the centrally planned economies was to invest heavily in physical capital, but apparently this did not lead to a dramatic catching up in terms of economic growth. Indeed, while the growth in education and physical capital over the period 1930-1990 were almost equal (and hence the relative levels of education and physical capital in Central Europe in 1990 were comparable), per capita GDP in 1990 was substantially higher in Germany and Austria (Maddison, 2003; Van Leeuwen and Földvári, 2011).[1]

If capital, and more specifically human capital, is indeed a main factor driving long-run economic performance (as incorporated into some new growth theories, see Lucas, 1988 and Romer, 1990), this suggests a considerable decrease in productive efficiency of human capital accumulation in Eastern Europe during socialism (i.e. Simkus and Andorka, 1982; Easterly and Fisher, 1995). The objective of this paper is therefore to analyse the accumulation and efficiency of both human – and physical capital in economic growth in Central Europe before, during, and after socialism. The next section will discuss the pattern of economic development while Section 3 and 4, and 5 discuss physical-and human capital respectively. In Section 6, this information is combined in a growth accounting analysis. We end with a brief conclusion.

2. Central European patterns of economic development

Maddison (2003) provides data on per capita income, where we add information on GDP in West-and East Germany separately based on the ratios of GDP in Mitchell (2007) (see Table 1). These data show that economic growth in Central Europe was considerable. Looking at the data reveals that even though the region experienced periods of significant growth, in relative terms, intra-regional differences increased spectacularly. Clearly, Austria and Germany were

[1] Even more revealing is a comparison with Southern Europe: prior to WW2 per capita physical capital and education attainment were almost equal just as was GDP per capita. In the 1970s however Southern Europe clearly outperformed the state-socialist countries of Europe (Lains, 2003; Maddison, 2003; Altug, Filiztekin, and Pamuk, 2008; Prados de la Escosura and Rosés, 2009; Prados de la Escosura and Rosés, 2010).

ahead of the other Central European countries. However, the difference in the pre-War period between Germany and Austria on the one hand, and the Hungary and Czechoslovakia, the more developed Eastern European countries, on the other was small, only around 30% in terms of per capita income. After the war, however, the gap increased so that in the 1990s the difference was around 60%.

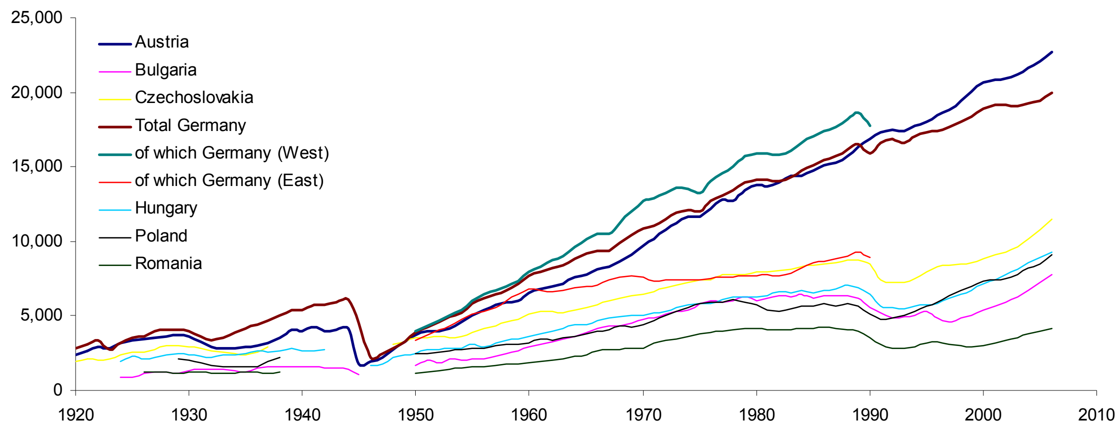
Table 1. *Per capita GDP (1990 GK dollars, decadal averages)*

	Austria	Bulgaria	Czechoslovakia	of which		Total Germany	of which		Hungary	Poland	Romania
				Czechia	Slovakia		Germany (West)	Germany (East)			
1920-1930	3,159	1,109	2,448			3,437			2,170	2,117	1,219
1930-1940	3,221	1,443	2,662			4,206			2,473	1,775	1,191
1940-1950	3,228	1,428	3,174			4,411			2,292		816
1950-1960	4,845	2,144	3,956			5,517	5,688	4,863	2,957	2,758	1,506
1960-1970	7,694	3,756	5,603			8,936	9,811	7,057	4,393	3,755	2,353
1970-1980	11,640	5,546	7,246			12,267	13,868	7,503	5,714	5,479	3,644
1980-1990	14,753	6,281	8,329			15,044	16,931	8,348	6,648	5,617	4,101
1990-2000	18,167	5,033	7,981	8,397	7,178	17,198	17,789	8,957	5,987	5,662	3,068
2000-2010	21,435	6,424	9,897	10,174	9,372	19,291			8,182	7,974	3,566

Source: Maddison (2009); Mitchell (2007).

The same can also be seen in Figure 1. Here we plotted per capita GDP in Central Europe. We can see that up to the late 1950s per capita income was almost equal in the Western and the more developed socialist countries. Bulgaria, Poland, and Romania, the slightly poorer Central European countries, were, however, not far behind. Yet, during the socialist period, per capita income in Austria and (West) Germany increased far stronger than in the socialist countries. There was thus a divergence in per capita income between the "western" and socialist countries. It is also interesting to see that, within the socialist countries, a convergence in per capita income took place. Bulgaria, no doubt one of the poorest Eastern European countries during the interbellum, converged during socialism to the Hungarian level. Eastern Germany, on the other hand, which had a relatively high per capita income in the 1960s, made the convergence the other way around. Apparently, the richer and poorer socialist countries managed to achieve some convergence in terms of per capita income. After the Transition in the early 1990s, this pattern changed. Apparently, especially the poorer countries (both in human-and physical capital as in per capita income), Romania and Bulgaria, started to diverge in per terms of per capita income again.

Fig. 1. *Per capita GDP in Central Europe, 1920-2007 (1990 GK int. $)*



The obvious reasons why this development took place can be found in the factors of production, physical- and human capital which are discussed in next three sections.

3. Physical capital development

A strong emphasize on physical capital formation is generally seen as characteristic for state-socialist economies. Allen (2003) even argued that in the Soviet Union, because of massive capital investments, per capita income in the 1950s was higher than it would have been without socialism. Indeed, it is possible that Eastern European countries benefited in the short-run from heavy investments in physical capital (Flakierski, 1975; Mihályi, 1988), but whether it is the case in the long-run is difficult to decide without more detailed macroeconomic data.

Unfortunately, with some exceptions (e.g. Hoffmann, 1965; Flakierski, 1975; Gregory, 1975; Pula, 2003; Kamps, 2006), little is known about the physical capital stock in Central

Europe. An exception is the Comecon database (wiiw Comecon Database, obtained 2009). This dataset includes the physical capital stock for Bulgaria, GDR, Hungary, Poland, and Romania between ca. 1944 and 1980. Unfortunately, this is largely based on, sometimes unclear, contemporary definitions of the stock of physical capital; a definition that sometimes changes over time. Therefore, we cannot rely on this data and rather estimate physical capital stock using alternative sources. The data used is the gross fixed capital formation from the World Development Indicators of the World Bank (2009). These are brought back in time, using the investment data from Mitchell (2007), Tschakaloff (1946), the KSH (1969, 1974, 1979, 1980a, 1980b, 1981), and Eckstein (1955). All data were converted in gross capital formation equivalents in order to create a comparable dataset.

We follow the literature in employing a perpetual inventory method in which the following identity is made use of:

$$K_t = (1-\delta)K_{t-1} + I_t \quad (1.)$$

where K is the stock of physical capital, δ is depreciation, and I is the gross fixed capital investment. In order to arrive to stock estimates without needing to take benchmark form another work, we assumed, following Groote *et al*. (1996) for machinery, a linear depreciation of 20 years for the period 1967-2006.[2] For all countries, this leads to a capital-output ratio (K/Y) of between 2 for Austria and Germany and 1.5 for most former socialist countries around 2000. For the period for which we could not sum the stock directly, we calculated the geometric depreciation rate in combination with equation (1).

There are two breaks in the series: the first is during World War II and the first years of reconstruction, while the second is during the years of transition, when the physical capital stock in post-socialist countries had lost some of its value or had been completely withdrawn

[2] $K_t = \sum_{i=0}^{20}\left(1-\frac{i}{20}\right)I_{t-i}$ with 20 years chosen this is equivalent with roughly 8.8% geometric depreciation per annum.

from production. There are different estimates on the magnitude of capital loss during transition years. We follow Pula (2003, p. 9) in using a Cobb-Douglas type production function, assuming 60% share of labour incomes and 0% TFP growth to estimate the most probably size of the drop in capital stock. We start with assuming a production function similar to Mankiw, Romer and Weil (1992):

$$Y_t = A_t K_t^{\alpha} H_t^{\beta} L_t^{1-\alpha-\beta} \quad (2)$$

If we assume that the TFP remained constant, and α=β=1/3, we can estimate the ratio of physical capital stock between any two years as follows:

$$\frac{K_t}{K_0} = \left(\frac{Y_t}{Y_0}\right)^{\frac{1}{\alpha}} \left(\frac{A_t}{A_0}\right)^{-\frac{1}{\alpha}} \left(\frac{L_t}{L_0}\right)^{\frac{\alpha+\beta-1}{\alpha}} \left(\frac{H_t}{H_0}\right)^{-\frac{\beta}{\alpha}} \quad (3)$$

Since we know the necessary data (on the human capital series please see section 5), using the above equation method, with no TFP change assumed, we can estimate the probable magnitude of the capital loss during the years of the transition 1989-1992.

We apply the same method to estimate the stock of physical capital around 1939. We use 1950 as reference year, and since there is 11 year difference we assume a TFP growth of ca. 10%. In all cases, we apply here a lower rate of depreciation than after 1950. This is in accordance with the estimate of Prados de la Escosura and Rosés (2010, table 2) who find that average depreciation is around 2% smaller in the first half of the twentieth century. This results on average in a K/Y ratio of around 0.9 around 1930 for the former socialist countries. For Austria and Germany, countries the ratio is slightly higher with around 1.1. For comparison, Schulze (2005) estimates that the capital output ratio for Austria around 1913 to be around 2 and those of Hungary around 1.8. This large gap with our estimates can partly be contributed to the effect of war, and the following unstable period paired with hyperinflation. Partly, it is also caused by the situation that Schulze uses 28 years asset life for machinery only, hence, almost 50% higher than our average asset life assumption. Taking these two factors into consideration, our estimates seem plausible.

Since we want to calculate per worker capital, we calculated the labour force by ILO (2008) and Mitchell (2007). The in-between years were interpolated using the population data by Maddison (2003). The result is given in Table 2, with per worker physical capital stock reported in Table 3. The per worker physical capital stock grew on average 3.3% in Eastern Europe versus 4.1% annually in Austria and Germany between 1935 and 1985. This means that between the inter-war period and the 1990s, the ratio of per worker physical capital in Eastern Europe and Austria and Germany declined slightly, notwithstanding a clear increase in this ratio in the 1960s and 1970s. During the transition, with the massive capital depletion, this ratio decreased even further, only to increase again since the late 1990s.

Table 2**.** *Labour force (*1000)*

	Austria	Bulgaria	Czechoslovakia	of which Czech Republic	Slovakia	Total Germany	of which Germany (West)	Germany (East)	Hungary	Poland	Romania
1920-1930	2,973	2,974	6,535			30,106			3,654	12,363	8,573
1930-1940	2,961	3,718	7,121			31,741			3,997	13,971	9,632
1940-1950	3,356	4,314	6,806			32,386			4,228	12,987	9,873
1950-1960	3,139	4,289	6,225			35,864	24,996	8,254	4,556	13,495	10,275
1960-1970	3,158	4,408	6,736			37,494	27,861	8,081	4,925	15,506	10,472
1970-1980	3,104	4,592	7,606			36,046	27,068	8,159	5,028	17,446	10,585
1980-1990	3,368	4,628	8,243	5,489	2,754	36,701	25,954	7,819	4,854	18,097	10,621
1990-2000	3,794	3,758	7,747	5,178	2,569	39,938	26,665	7,665	4,315	17,602	11,460
2000-2005	4,118	3,366	7,830	5,149	2,681	41,112			4,284	17,356	10,181

It is obvious that physical capital accumulation played an important role in the increasing gap in per capita income between the former socialist and western countries. However, it is exactly in the 1960s and 1970s, the only period that the East experienced faster

Table 3. *Physical capital per worker (1990 GK dollars)*

	Austria	Bulgaria	Czechoslovakia	Total Germany	of which Germany (West)	Germany (East)	Hungary	Poland	Romania
1920-1930	8,337	1,653	3,679	5,466			3,258		
1930-1940	9,398	2,160	5,991	9,004			5,015	7,100	
1950-1960	11,858	4,849	7,043	10,567	13,821	4,060	3,163	6,206	
1960-1970	28,040	7,747	12,398	31,353	37,923	14,719	6,367	11,415	
1970-1980	54,374	13,960	22,167	57,089	65,928	33,495	14,004	20,821	10,968
1980-1990	68,999	17,798	29,516	66,304	79,128	53,961	23,895	29,283	17,030
1990-2000	76,979	17,846	23,119	48,485			20,307	22,992	9,540
2000-2005	86,777	17,503	27,840	51,689			30,213	24,908	

growth of capital than the Western world that we can see that per capita income started to diverge. Therefore, it can certainly not explain the (lack of) economic development. This leaves human capital accumulation as the alternative explanation.

4. Average years of education

Many studies equate human capital with "average years of education". There are several studies that calculate this variable for Eastern European countries (De la Fuente and Doménech, 2000; Barro and Lee, 2003; Cohen and Soto, 2007; Földvári and Van Leeuwen, 2009). The best known dataset is that of Barro and Lee (2003). However, the reliability of their data is often questioned. For example, Van Leeuwen and Földvári (2008) point out that where Barro and Lee find a divergence in average years after 1985 with the USA, the more reliable data of Cohen and Soto indicate a convergence.

Cohen and Soto (2007) essentially based their estimates on a set of directly comparable census data. Their set of benchmark data are therefore generally considered superior to those of Barro and Lee. However, census data are generally only available for every 10 years. That is why Barro and Lee used a perpetual inventory method to create data points for the in-between years as well, hence doubling their number of observations. Unfortunately, the calculation of those in-between years has been questioned as well.

Using the benchmarks from Cohen and Soto (2007), Statistical Office of the Slovak Republic (2006), Český statistický úřad (2009), Glówny Urzad Statystyczny (Polska) (1994), and National Statistical Institute Bulgaria (2009) in combination with enrolments and age cohorts from Mitchell (2007) and the U.S. Census Bureau (2009), we apply the method proposed by Földvári and Van Leeuwen (2009) to calculate the in-between years. In that paper they used the attainment census method that is generally considered to give the best results. Since data in censuses are generally only available every 10th year, they calculated the in between years based on modified version of the perpetual inventory method by Barro and Lee (2003) based on enrolment statistics.

The modification was needed since the unbiasedness of the Barro and Lee estimates has been questioned by several authors. As Portela *et al* (2004) argue, the main source of bias in the Barro and Lee series is that they implicitly assume the mortality rate to be independent of the level of education, which results in a downward bias when they forecast from a census year and an overestimation in case of backcasting. Földvári and Van Leeuwen (2009), however, base their method on the assumption that the two types of biases can offset each other. Hence, we estimate the average years of education series between census years as an average of the backward and forward estimates.

Unfortunately, the benchmark data not in all cases run back to 1920. Therefore, we used a different method for the years for which we did not have benchmarks. We calculated enrolment per level of education. Next, we calculated age specific mortality, based on the data of Mitchell (2007). Summing this up for all people between the ages of 15 and 65, results in an estimate of average years of education in the population. Obviously, this results in an underestimate of average years of education, since people with more education generally have a higher life expectancy, which is also one of the main criticisms about the Barro and Lee dataset. Therefore, we linked these data to our estimates based on direct census observations.

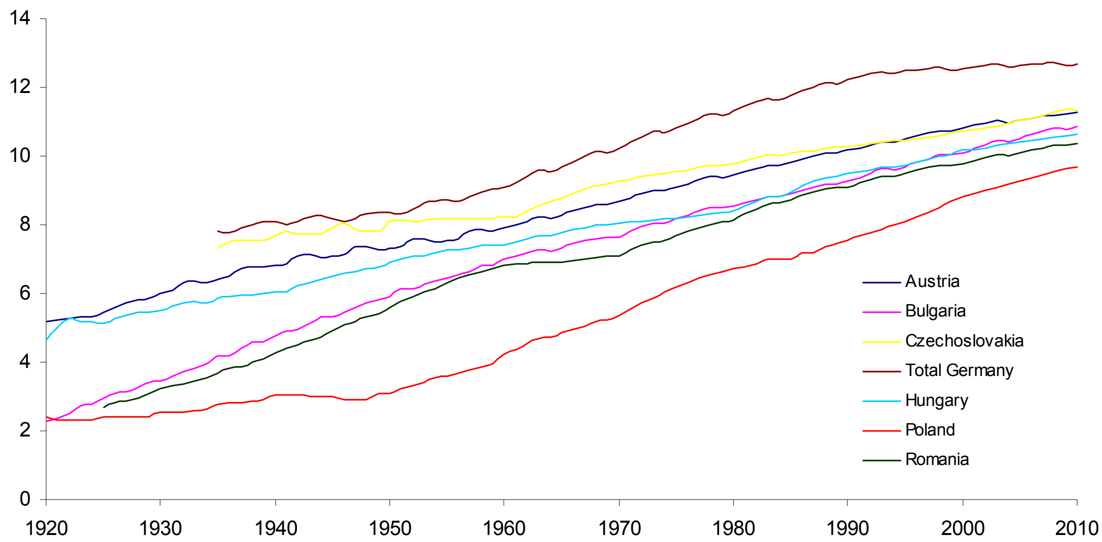
Table 5. *Average years of education (decadal averages)*

	Austria	Bulgaria	Czechoslovakia	of which		Total Germany	of which		Hungary	Poland	Romania
				Czechia	Slovakia		Germany (West)	Germany (East)			
1920-1930	5.5	2.8							5.2	2.4	2.9
1930-1940	6.4	4.0	7.5			7.9			5.8	2.7	3.6
1940-1950	7.1	5.3	7.8			8.2			6.4	3.0	4.8
1950-1960	7.6	6.4	8.2	8.1	8.2	8.7			7.2	3.6	6.2
1960-1970	8.3	7.3	8.7	8.4	7.9	9.7	9.7	9.8	7.7	4.8	6.9
1970-1980	9.1	8.1	9.5	9.5	8.7	10.8	10.6	11.3	8.2	6.1	7.6
1980-1990	9.8	8.9	10.1	9.9	9.5	11.8	11.6	12.4	8.9	7.0	8.7
1990-2000	10.5	9.7	10.5	10.5	10.4	12.4	12.2	12.6	9.7	8.1	9.5
2000-2010	11.0	10.5	11.0	11.0	10.9	12.6			10.4	9.2	10.1

Source: Foldvari and Van Leeuwen 2011; this text

The results from Table 5 are also plotted in Figure 2. As can be seen, although average years of education in Austria and Germany is consistently higher than Poland, Bulgaria, and Romania, the difference with the more developed Czechoslovakia and Hungary is negligible while the gap with the other countries seems to be closing. This is quite an important conclusion since in the new growth theories (Lucas, 1988; Romer, 1990) human capital is the main source of long-run growth. If the gap in "average years of education" was closing, how is it possible that per capita income increased much stronger in Austria and Germany than in the state-socialist countries of East and Central Europe? Purely looking at educational attainment data, we cannot find an explanation for the divergent path of the economies of the Central and Eastern Europe.

Fig. 2. *"Average years of education" in Central Europe, 1920-2007*



5. Human capital formation

5.1 Volume versus value

It is repeatedly stressed that human capital is usually measured in a very different way than physical capital (e.g. Judson, 2002). The popular indicator "average years of education" is at best indicative of the volume of human capital. It is as if one measured physical capital by counting the number of machines without keeping account with the heterogeneity of capital goods. Indeed, Van Leeuwen and Földvári (2008) show that the difference in terms of per capita human capital between Eastern and Western countries may be very different depending on which indicator is used. When one uses a cost- or income based measure to arrive at a monetary value of human capital stock the difference between the USA and post-socialist countries is much bigger than when only educational attainment is used.[3] Obviously the productivity of a worker depends strongly on his/her environment in the widest sense including the institutional background, and also the productivity of his/her colleagues. So the

[3] For a summary of human capital measurement methods see Wössman (2003).

observed difference in what is suggested by educational attainment and the value of human capital stock is mostly attributable to serious differences in the productivity and consequently, the price of human capital.

It is therefore important to estimate the value of human capital since it reflects not only the volume but also the price of human capital. This idea can be formalized as follows: We start with a standard formula in which the individual i's human capital is defined as the product of the volume (quantity) and the unit price:

$$h_i = p_i^h q_i^h \quad (4)$$

where q is a volume measure of human capital, like the amount of time spent with education for example (years of education), while p denotes the unit the price. The latter depends on the definition of human capital: it can be the discounted value total expected future incomes flows (prospective methods), or it can be the total costs (retrospective methods) divided by the volume. There are three reasons why omitting the price/using only volume measures will bias empirical results.

The first problem with quantity measures is the aggregation. The sole fact that the measurement unit is the same for all individuals does not mean that the individual volumes can be added. We see this clearly when it is about products: we cannot add potato to orange, even though they are both measured by weight. The same applies to physical capital: no one would ever think of adding up the number of machines and use it as a physical capital measure; nevertheless, this is exactly what is done by average years of education, which is purely the sum of all individual q's divided by the number of individuals:

$$S_t = \frac{1}{n}\sum_{i=1}^{n} q_{i,t} \quad (5)$$

This is obviously wrong from a statistical point of view, except if we have reason to believe that labor is homogenous. If this is not case, aggregating individual human capital can happen only by adding up the values. The total stock of human capital is year t is therefore:

$$H_t = \sum_{i=1}^{n} p_{i,t}^h q_{i,t}^h \quad (6)$$

and the per capita level is:

$$\bar{H}_t = h_t = \frac{1}{n}\sum_{i=1}^{n} p_{i,t}^h q_{i,t}^h = E(p_{i,t}^h \cdot q_{i,t}^h) \quad (7)$$

The second problem is that the volume and value (p and q) in the previous expression are not separable, except if the price and the quantity are not correlated. But there is more than enough empirical evidence suggesting that higher the quantity of human capital the smaller additional gain is (diminishing returns). Also, if one sticks to a cost based definition of human capital, it is obvious that the additional costs of learning depends on the volume (level of education already attained). So:

$$h_t = \frac{1}{n}\sum_{i=1}^{n} p_{i,t}^h q_{i,t}^h = E(p_{i,t}^h \cdot q_{i,t}^h) \neq E(p_{i,t}^h) \cdot E(q_{i,t}^h) \quad (8)$$

This has the practical consequence that one cannot solve the problem by using an empirical specification as follows:

$$\ln y_t = \beta_0 + \beta_1 \ln k_t + \beta_2 \ln S_t + \beta_3 \ln z_t + e_t \quad (9)$$

where *S* is the average years of education, and z denotes some average measure (proxy) of the price of human capital (like average wages or average expenditure on education), because this specification suffers from an omitted variable bias. One can however circumvent the problem by introducing non-linearity in the regression by interaction terms or assuming a functional relationship between the price and volume of human capital that in case of linear function leads to some quadratic function of the volume.

Thirdly, as discussed above, if one uses average years of education in growth regressions as the proxy of human capital, one faces a possibly serious omitted variable bias, which can be an explanation why most empirical studies find that average years of education yields an insignificant coefficient, usually close to zero, when physical capital stock is included.[4] To show this formally, let us start by assuming that the real model is the following (we assume a Cobb-Douglas production function, and the lowercase letters denote per labor unit variables):

$$\ln y_t = \gamma_0 + \gamma_1 \ln k_t + \gamma_2 \ln h_t + u_t \quad (10)$$

If we capture the relationship between the volume and unit price of human capital by an interaction term, we can rewrite the model as follows (note that we restricted the coefficients of the price and quantity to be equal, but this is not necessary to prove the presence of omitted variable bias):

$$\ln y_t = \gamma_0 + \gamma_1 \ln k_t + \gamma_2 \ln z_t + \gamma_2 \ln S_t + \gamma_3 \ln S_t \cdot \ln z_t + u_t \quad (11)$$

We can simplify this as

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\gamma} + \mathbf{W}\boldsymbol{\gamma}_2 + \mathbf{C}\boldsymbol{\gamma}_3 + \mathbf{u} \quad (12)$$

with

$$\mathbf{X} = \left(i_T, \ln k_t, \ln S_t\right),\ \mathbf{Y}_t = \left(\ln y_t\right),\ \mathbf{W} = \left(\ln z_t\right),\ \mathbf{C} = \left(\ln S_t \cdot \ln z_t\right),\ \gamma_1 > 0, \gamma_2 > 0, \gamma_3 < 0 \quad (13)$$

If we, instead of including prices and interaction term, only include average years of education (the volume), we estimate the following equation:

$$\ln y_t = \eta_0 + \eta_1 \ln k_t + \eta_2 \ln S_t + v_t \quad (14)$$

Or simplified:

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\eta} + \mathbf{v} \quad (15)$$

[4] See for example Benhabib and Spiegel (1994); Krueger and Lindahl (2001).

With

$$\boldsymbol{\eta} = \left(\eta_1, \eta_2\right) \quad (16)$$

Consequently, with an OLS estimator the coefficient vector is going to be:

$$\boldsymbol{\eta} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'(\mathbf{X}\boldsymbol{\gamma} + \mathbf{W}\gamma_2 + \mathbf{C}\gamma_3 + \mathbf{v}) = \boldsymbol{\gamma} + (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}\gamma_2 + (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{C}\gamma_3 + (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{v} \quad (17)$$

and the expectation is (under the assumption of exogenous regressors):

$$E(\boldsymbol{\eta}) = \boldsymbol{\gamma} + (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}\gamma_2 + (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{C}\gamma_3 \quad (18)’$$

that is, if the price of human capital is correlated with the physical capital stock or/and with its quantity, the estimates from the model with average years of education (or a comparable volume measure) leads to biased parameter estimates. If we assume that a higher physical capital stock leads to an increase in the unit price of human capital, the physical capital coefficient is going to be overestimated, while the coefficient of the average years of education should be downward biased, theoretically can even be negative. In addition, even without deriving the standard error for the coefficients η, it is obvious that the standard errors are also affected and cannot be trusted anymore.

Hence omitted variable bias is a likely candidate to explain why growth regression employing average years of education or a similar volume proxy lead to strange results. This offers an explanation also why the average years of education starts to yield a positive, significant coefficient once physical capital is removed: the coefficient will then reflect the interrelatedness of physical capital stock and average years of schooling resulting in an upward bias. This is however again a misspecified model: even at micro level (Mincer type equations for example) it is questionable why one should implicitly assume, that the individual wages are dependent on schooling, experience, ability, etc, but not on the value of capital goods the individual is employed together with.

5.2 Estimating a stock of human capital

Above discussion indicates that we can expect more reliable results if we measure human capital at its value. In calculating the stock of human capital for Central Europe, we follow the method proposed by Földvári and Van Leeuwen (2011 forthcoming). They calculate the stock of human capital using a prospective method. In those methods, human capital is treated in parallel with investments: the price of an asset, like a bond or stock, will tend to equal the present value of all expected future flows of income from it. Since, when one invests in human capital one expects a higher wage; the present value of the individual human capital can be seen as the present value of the future expected wages, corrected for the individual chance of survival.

Földvári and Van Leeuwen (2011 forthcoming) defines the value of human capital as the sum of all discounted expected future wage flows (we assume continuous time for convenience and use real wages):

$$h_{i,x} = \int_{t=0}^{65-x} E\left(w_{i,t}\right) e^{-qt} dt \quad (19)$$

where x and $E(w_{i,x})$ is age and the expected real wage of individual *i* respectively, and *q* is the discount factor. The formula above assumes that the individual remains in the labour force until his age 65. Since we are interested in the human capital stock of the average individual, the formula can be simplified:

$$\overline{h} = \int_{t=0}^{65-\overline{x}} E\left(\overline{w}_t\right) e^{-qt} dt \; (20)$$

Where $\overline{x}$ denotes the average age in the population. If the average individual expects that his/her real wage is going to grow at a constant rate *g*, the formula further simplifies:

$$\overline{h} = \int_{t=0}^{65-\overline{x}} \overline{w} e^{(g-q)t} dt = \frac{\overline{w}}{g-q}\left(e^{(g-q)(65-\overline{x})} - 1\right) (21)$$

With assumption about *g-q*, and the average age and wage of the population, we can express the average (per capita) stock of human capital in monetary units. We assume in this paper that *q-p*=0.02, that is people expect that their utility resulting from higher wages will increase with time (this in line with Dagum and Slottje (2001) whose method can be considered as a micro equivalent of the method used in this paper).

The alternative human capital measure, that has become a standard in the literature has been suggested and first used by Hall and Jones (1999) and Pritchett (2001). In their method, the per capita human capital stock is defined as follows:

$$h = e^{r_t S_t} \quad (22)$$

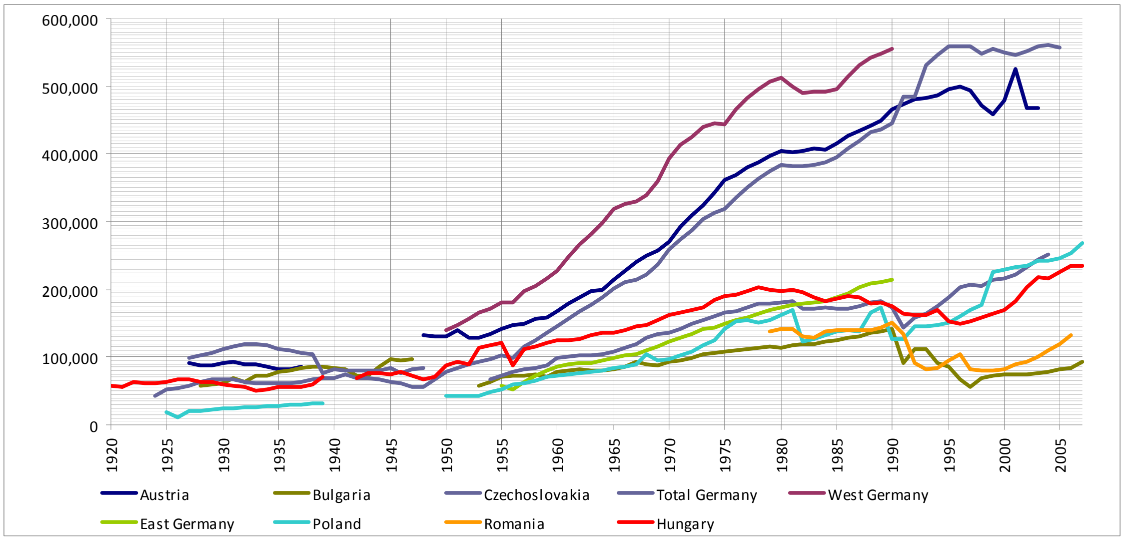
where r denotes the rate of returns to education, and S is the average years of education. Hence both the quality and the quantity of human capital are captured by (22). The change of this value therefore reflects changes in the value of human capital and can be employed in a growth accounting. However, when either formal schooling is 0, or when there are no returns, the human capital value will be zero. For that reason, this method results only in an index of the value of human capital, instead of expressing its in terms of a monetary value. A more serious concern is that this measure does not fully capture changes in the value of human capital. We can see this easily when we establish a relationship between (22) and our income based human capital measure in (21). Since the average wage can be expressed as the product of the wage of an unschooled individual times the effect of schooling on wages as follows: $\overline{w} = w_u e^{rS}$ equation (20) can easily be rewritten as: $\overline{h} = \int_{t=0}^{65-\overline{x}} w_u e^{rS} e^{(g-q)t} dt$. It is straightforward that if we assume that the unschooled wages remain constant (no productivity growth in the long-run), and the discount factor and the expected growth of real wages are equal (g-q=0), and r and S are constant, we revert to equation (22). That is, the human capital measure in (22) is equivalent with the prospective method suggested in this paper only under some very strict assumptions. Most importantly, the equivalence is true only if all productivity improvements are limited to schooled individuals, since equation (22) fails to capture changes in the unskilled wages (this shortcoming is explicitly mentioned by Pritchett (2001)). Therefore, we apply the method in equation (21) on the data on population between age 15 and 65 and average wages from Mitchell (2007) and the ILO October Enquiries (Various issues) and the ILO (Laborsta), we obtain our series of per worker human capital as reported in Table 6. Both Table 6 and in Figure 3 reflect a clear upward trend, not without breaks though. In the socialist countries, after 1975, the per capita human capital stock seems to stagnate which continues until the end of transition. After 1995 we see a sharp increase in per worker human capital in those countries.

Table 6. *Human capital/worker (1990 GK dollars)*

	Austria	Bulgaria	Czechoslovakia	Total Germany	of which Germany (West)	Germany (East)	Hungary	Poland	Romania
1920-1930	88,709	58,869	102,965	56,598			62,395	18,395	
1930-1940	87,274	76,113	106,786	65,037			57,475	28,179	
1950-1960	141,243	68,872	78,907	101,942	176,175	65,079	105,849	53,080	
1960-1970	212,062	83,983	111,520	191,697	299,189	98,571	136,797	84,042	
1970-1980	343,372	105,543	160,619	317,869	451,193	146,732	183,643	130,437	138,137
1980-1990	419,171	124,955	176,107	401,016	511,751	189,782	188,916	146,800	138,182
1990-2000	480,681	90,067	182,894	527,208	556,155	215,094	160,883	157,525	98,249
2000-2005	485,662	76,569	233,175	553,817			202,365	238,052	98,769

More spectacularly, we see a strong divergence between the socialist countries and Germany and Austria. Since we noticed that this was not caused by average years of education, this implies a strong relative reduction of the value of each unit of human capital

Fig. 3. *Per worker stock of human capital in Central Europe 1920-2007 with prospective method in 1990 GK dollars*



during the socialist period. But besides this divergence, we can see a convergence among the Eastern European countries up to 1989. Up to that time, the poorer countries in terms of human capital, Bulgaria, and Poland, grew much faster than the richer ones, such as Czechoslovakia and Hungary. This pattern changed after transition. There are clearly three groups of countries to be distinguished. First, Germany and Austria, second, the wealthier post-socialist countries: Hungary, Czechoslovakia, and Poland (the latter seems to have successfully caught up), and finally, the poorest countries i.e. Bulgaria and Romania.

In other words, socialism did cause a convergence within Eastern Europe and a divergence in terms of human capital with Western countries. After Transition, the countries seem to return to their "normal" paths of development: Poland, Hungary and Czechoslovakia seem to catch up, while the initially poorer countries Bulgaria and Romania, which were also less well endowed in factors of production, started to lag behind. Hence, the lack of human capital may be an explanation for slower per capita growth. Yet, this needs to be formally tested in a growth accounting framework in the next section.

6. Growth accounting and efficiency in Central Europe

6.1 Growth accounting

Now that we have annual estimates of physical-and human capital for Central Europe, before, during, and after socialism, it is possible to employ them in a growth accounting analysis. In most cases it is assumed that the factor shares in aggregate income remain constant, which is in accordance with unit elasticity of substitution (a Cobb-Douglas type production function). We follow the specification of Mankiw, Romer and Weil (1992) in which physical capital, raw labour, and human capital are each allocated with a factor share of 1/3. We can rewrite equation (2) as:

$$\Delta \ln A_t = \Delta \ln Y_t - \alpha \Delta \ln K_t - \beta \Delta \ln H_t - (1 - \alpha - \beta) \Delta \ln L_t \quad (23)$$

, where $\alpha = \beta = \left(1/3\right)$. The results are reported in Table 7.

Two interesting observation can be made based on Table 7. First, with the exception of the period 1981-95 human capital accumulation was an important factor in economic growth in Central Europe for all countries. The role TFP growth, which is often referred to as an indicator of technology and to a certain degree institutions as well (see Hall and Jones 1999) is strongly reduced by the inclusion of human capital.

Second, if we exclude outliers, the contribution of human capital to GDP growth remains constant for all countries and periods at roughly 33%. Interestingly, in the socialist and western countries alike, we see that the share of physical capital in growth declines from

Table 7. *Growth accounting 1924-2005, average annual growth rates*

Country	Period	GDP growth rate	Capital stock growth rate	Labour growth rate	Human capital growth rate	TFP growth with hc effect deducted	TFP growth without hc effect deducted
Austria	1924-1940	0.28%	1.57%	3.95%	3.92%	-2.87%	-1.56%
	1950-1989	4.74%	6.58%	0.17%	3.26%	1.40%	2.49%
	1994-2005	2.16%	2.63%	0.82%	1.82%	0.40%	1.01%
Germany	1924-1940	4.07%	10.82%	0.63%	4.00%	-1.08%	0.25%
	1950-1989	4.2%	7.7%	0.3%	4.85%	-0.08%	1.54%
	1994-2005	1.44%	0.96%	0.35%	0.73%	0.76%	1.00%
Bulgaria	1924-1940	4.23%	3.14%	2.65%	7.12%	-0.08%	2.30%
	1950-1989	4.14%	4.45%	0.01%	2.52%	1.81%	2.65%
	1994-2005	1.94%	-0.91%	-1.29%	-3.80%	3.94%	2.67%
Czechoslovakia	1924-1940	1.13%	5.18%	0.63%	1.42%	-1.28%	-0.81%
	1950-1989	3.2%	5.4%	0.9%	3.94%	-0.23%	1.09%
	1994-2005	2.89%	3.25%	0.26%	4.41%	0.24%	1.72%
Hungary	1924-1940	3.64%	6.38%	0.92%	2.26%	0.46%	1.21%
	1950-1989	2.81%	7.28%	0.23%	2.43%	-0.50%	0.31%
	1994-2005	3.84%	6.97%	-0.15%	2.85%	0.62%	1.57%
Poland	1924-1940						
	1950-1989	3.45%	5.89%	0.91%	4.85%	-0.53%	1.09%
	1994-2005	4.53%	1.22%	-0.15%	4.56%	2.65%	4.18%
Romania	1924-1940						
	1950-1989						
	1994-2005	2.76%	4.49%	-1.29%	2.44%	0.80%	1.62%

Note: in the last column we assume 1/3 share for physical capital, 1/3 share for labour incomes and 1/3 for human capital.

roughly 80% during the pre-war period to 55% and 45% during the 1950-1990 and the 1994-2005 periods respectively. The share of TFP growth in GDP growth, however, increases over time for both the socialist and Western countries. Yet, since the growth of both physical capital and human capital is lower for the former socialist countries, so is GDP growth.

6.2 Technical efficiency

Clearly, institutional efficiency, especially concerning markets, during the socialist period was less than either before or after. After all, we concluded that, although the share of physical and human capital in GDP growth was roughly equal in all countries, still economic growth in the former socialist countries lagged behind. In other words, the economy of these countries must have been less efficient in employing physical and/or human capital. This argument can, however, more directly be assessed by calculating the efficiency of these economies.

Efficiency can be measured in a more direct way by applying a Stochastic Frontier Analysis (SFA). The SFA is based on the assumption that the regression residual of an empirical production function can be divided into two parts: a strictly positive one (denoted now as u), which is the loss of output through the less efficient use of resources (X), and a traditional error term ε.

$$\ln Y_{it} = \sum_{j=1}^{k} \beta_j \ln X_{ijt} + \varepsilon_{it} - u_i \quad (24)$$

or

$$\ln Y_{it} = \sum_{j=1}^{k} \beta_j \ln X_{ijt} + \varepsilon_{it} + TE_i \quad (25)$$

The Technical Efficiency (TE) is understood therefore as a multiplier ($0<TE<1$) of the function of the production factors. If TE is close to one, the factors are used efficiently, while a lower TE is indicative of inefficiencies. The SFA has been developed as a cross-sectional method, but recently it is also used on panel data.

We can estimate technical efficiency both as being time invariant and time variant (see Table 8). The main advantage of the time variant approach is that it allows an analysis of efficiency over time. However, because it captures all sources of changing efficiency, it also captures TFP growth. In other words, it should be understood as a measure of technical efficiency in the widest sense, including not only differences in institutions, but also the effect of technological development. The time invariant version makes it possible that we estimate efficiency based on the assumption that it is fundamentally specific to a country, and does not change easily. In that case, we can use a linear time trend in the regression to capture the effect of productivity changes.

The results of the regression are given in below table. Interestingly, if we apply this to the different countries, we find in Table 9 that technical efficiency was smaller in the former socialist countries. Where Austria and Germany have a technical efficiency of roughly 97%, the more developed socialist countries Hungary and Czechoslovakia are round 80%, and the poorest socialist countries are round 70%.

Table 8. *Time variant and time invariant Stochastic Frontier Model*

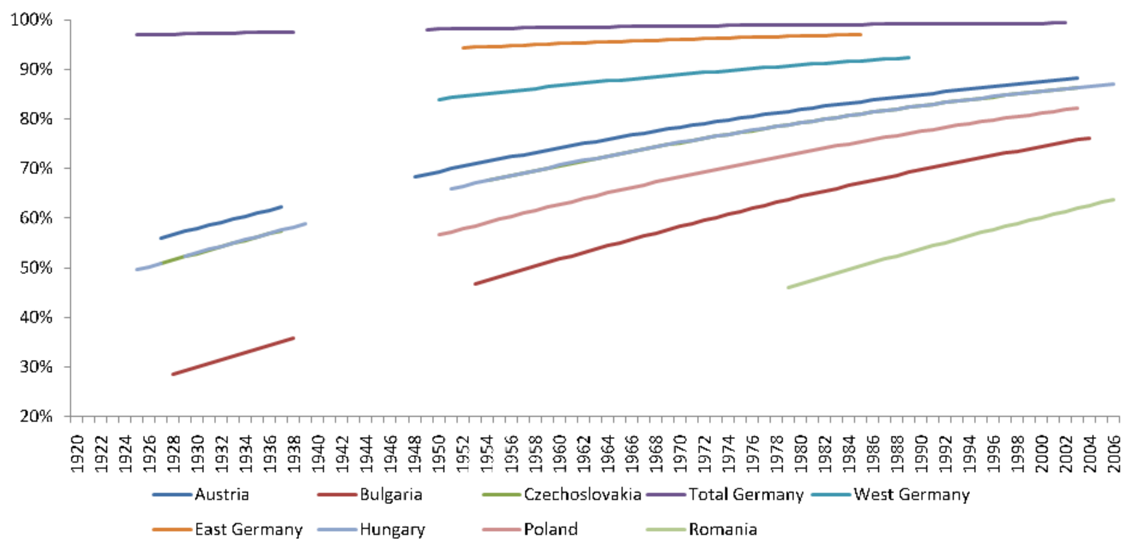
	Time invariant inefficiency	Time variant inefficiency
Constant	2.214 (2.47)	-1.727 (-4.85)
lnK	0.249 (13.9)	0.260 (15.5)
lnH	0.141 (5.28)	0.376 (16.2)
lnL	0.384 (3.67)	0.289 (12.5)
Trend	0.012 (18.5)	-
N	487	487

Table 9. *Technical efficiency parameters from the time invariant SFA specification*

Country	Technical efficiency (%)
Austria	97.7%
Bulgaria	65.8%
Czechoslovakia	81.1%
Total Germany	97.6%
West Germany	98.5%
East Germany	94.6%
Hungary	78.4%
Poland	70.0%
Romania	74.7%

The time variant efficiency/technology development is given in Figure 4. It is clear that efficiency in Eastern Europe is converging to the western level. Partly, this can be attributed to the situation that in Eastern Europe the effect of physical capital in growth slowly gave way in favour of human capital. This signifies an increase in technical development (after all, human capital is used to apply technologies in the productive process), which would be reflected in the efficiency parameter as well.

Fig. 4. *Technical efficiency in Central Europe form the time variant Stochastic Frontier Analysis specification (percentage)*



7. Conclusion

In this paper we had two objectives. First, we estimated the physical and human capital stocks for Central Europe, for the period 1924-2006. We found that physical capital growth was less in the former socialist countries, although it did not explain growth difference between the former socialist countries and Austria and Germany. The same applied to average years of education, as an indicator of human capital. Where per capita GDP diverged strongly during the 1960s and 1970s, average years of education actually showed a convergence.

We argued that "average years of education" is indicative of the volume of human capital while both physical capital and GDP are in monetary units. Indeed, it is to be expected that the same volume of human capital is less worth in value during the socialist period than before or after. We find that, expressed in monetary value, the human capital stock starts to decline after 1975, to pick up again after the transition. That the value of human capital stock decreased during the last two decades of Socialism, we attribute to the much less efficient allocation mechanisms when compared to market economies.

The second objective of this paper is to apply human and physical capital in growth models. Using a standard growth accounting method, we find that the relative contribution of human-and physical capital to economic growth in Western and Socialist countries developed similarly over time. However, since, the growth levels of human- and physical capital were lower in the former socialist countries, so was the growth of per capita GDP. Applying a Stochastic Frontier Analysis, we find another confirmation that technical efficiency was much smaller in Socialist countries than in Austria and West Germany. We find a convergence in this respect however.

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