Capital accumulation and growth in Central Europe, 1920-2006

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1. Introduction

The transition in Eastern Europe in the 1990s has triggered many studies into the sources of economic growth. Indeed, there are very few other historical examples of such sudden and massive regime changes in economic system. This even caused Fukuyama (1992) to call it the "end of history" and the victory of Western liberalism. From an economic perspective, it was also clear that socialism had a profound impact on economic growth. Where, before the dawn of socialism, the gap in per capita GDP between Western Europe and the later socialist countries was 45%, a percentage that was sustained till the mid-socialist period, this percentage decreased to around 30% around 1990.

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 serve as a natural experiment. Up to World War II all countries had comparable levels of human- and physical capital and per capita GDP – 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, state 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 broad capital, but apparently this did not lead to a dramatic catching up in terms of economic growth. Indeed, while the growth in

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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; Földvári and Van Leeuwen 2009).[3]

If capital, and more specifically human capital, is indeed a main factor driving long-run economic performance (Lucas 1989; 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 role of both types of 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 and regression 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). These data show that economic growth in Central Europe has been spectacular. Clearly, Austria and Germany were 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

[3] Even more conspicuous is a comparison with Southern Europe. Here per capita physical capital and education were almost equal just as GDP. However, in the mid-socialist period per capita income started to grow much faster in Southern Europe compared to Eastern Europe (Lains 2003; Maddison 2003; Altug, Filiztekin, and Pamuk 2008; Prados de la Escosura and Rosés 2008; Prados de la Escosura and Rosés 2009).

Table 1

Per capita GDP (1990 GK dollars, decadal averages)

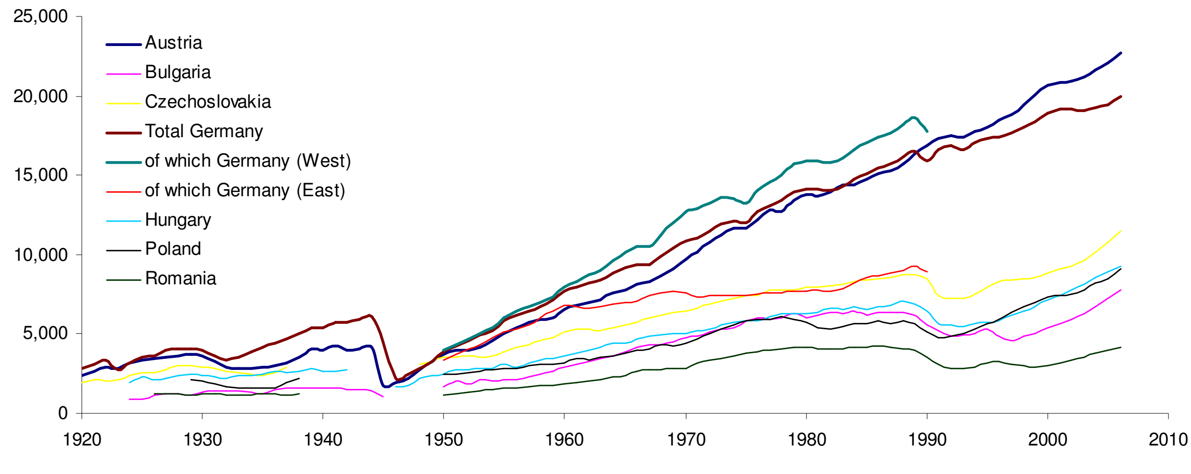
	Austria	Bulgaria	Czechoslovakia	of which Czechia	of which Slovakia	Total Germany	of which Germany (West)	of which Germany (East)	Hungary	Poland	Romania
1920-1930	3,159	1,109	2,448			3,437			2,170	2,117	1,219
1930-1940	3,221	1,443	2,662			4,206			2,473	1,775	1,191
1940-1950	3,228	1,428	3,174			4,411			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).

around 30%. After the war, the gap increased spectacularly so that in the 1990s the difference was around 60%.

The same can also be seen in Figure 1. Here we plotted per capita GDP Central Europe. We can see that up to the late 1950s per capita income was almost equal in the Western and

Figure 1
Per capita GDP in Central Europe, 1920-2007



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 poorer interwar Eastern European countries, 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 per capita income, although on a lower level than in the capitalist countries. 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 divergence again.

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 two sections.

3. Physical capital development

Increasing physical capital formation is generally seen as characteristic for socialist economies. Allen (2003) for the Soviet Union even argued that, because of massive capital investments, per capita income in the 1950s was higher than it would have been without socialism. Indeed, it may be that eastern European countries benefited in the short-run from strong investments in physical capital (Flakierski 1975; Mihályi 1988).

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. Therefore, we create a dataset with physical capital measures. 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) and 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.[4] 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.

It seems unlikely that the physical capital stock for any of those countries could have been significantly lower or higher than our estimates. We know that the share of capital incomes (we call this α) must have been around 1/3-1/2 of the total income, if we assume both a Cobb-Douglas type production function, and that capital is paid its marginal product, it is straightforward that the rate of returns to capital should equal $\alpha\frac{Y}{K}$. Depending on our estimate of α, therefore the rate of returns should have been 20-30%. With a K/Y ratio of 1.3, the payback period would be around 2.6-3.9 years. Such high rate of returns should have set off a very high capital inflow into the country, even with all additional risks involved, increasing the K/Y ratio quickly. On the other hand, if we assumed a ratio of 2.5, we get a payback period of 8.3-12.5 years, which results in implausibly low rate of returns.

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

This type of cross-check exercise has some consequence for capital stock estimates in general: if one sticks to the traditional estimate of share of capital incomes being around 1/3, than the K/Y ratio cannot be much lower than 0.8-1. In all other cases (except for exogenous shocks like war) having a too low K/Y ratio would imply an unrealistically high profit rate (above 33%).

For the period for which we could not sum the stock directly, we calculated the geometric depreciation rate in combination with equation (1). The depreciation fluctuated around 8%, which is close to the finding of Pula (2003) who uses a rate of depreciation of 2% for buildings and 9.2% for machinery for Hungary in the 1980s.

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 from production. There are different estimates on the magnitude of capital loss during transition years. The IMF estimated a 35 percent drop in capital stock for Hungary in 1991, calculated as a sum of a 20 percent loss due to the collapse of CMEA trade and an additional 15 percent due to the so-called "disorganization" effect (IMF (1999)). This view is challenged by Pula (2003, 9), who, based on a Cobb-Douglas type production function, assuming 60% share of labour incomes and 0% TFP growth, estimates that the observed 15% drop in aggregate income must have been caused by a one-time drop of 25% in physical capital in the early 1990s. Similarly to Pula we use a level accounting (or development accounting) with no change in TFP to estimate the magnitude of capital loss. 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, which is altogether 54% for Hungary. This is more than other estimates, but one should bear in mind that we assumed that this drop occurred over four years and not during a single year as by IMF (1999) and Pula (2003). If we restricted the capital loss to 1991 only, we would arrive at 25% similarly to Pula. On average, the drop in capita stock in the former socialist countries between 1989-1992 is 33.5%.

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 (2008, 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 feasible.

Since we want to calculate per worker capital, we calculated the labour force by ILO (2008) and Mitchell (2007). The inbetween years were interpolated using the population taken from Maddison (2003). The result is given in Table 2, with per worker physical capital stock

Table 2

Labour force (*1000)

	Austria	Bulgaria	Czechoslovakia	of which Czechia	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

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	

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.

It is clear that capital played an important role in the increasing gap in per capita income between the former socialist and western countries. However, exactly in the 1960s and 1970s, the only period that knew faster growth of capital than in the Western world, we can see that per capita income starts diverging. Therefore, it can certainly not explain the (lack of) economic development. This leaves human capital as an 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 there 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 datapoints for the inbetween years as well, hence doubling their number of observations. Unfortunately, the calculation of those inbetween years have 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 inbetween 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 inbetween 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

Table 5

Average years of education (decadal averages)

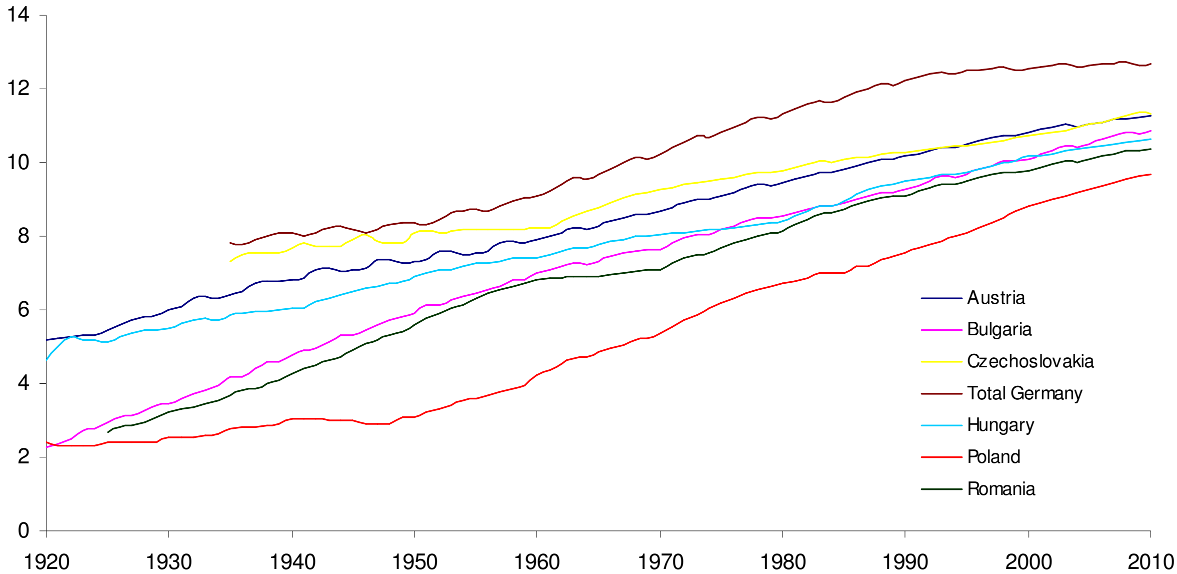
	Austria	Bulgaria	Czechoslovakia	of which Czechia	Slovakia	Total Germany	of which Germany (West)	Germany (East)	Hungary	Poland	Romania
1920-1930	5.5	2.8							5.2	2.4	2.9
1930-1940	6.4	4.0	7.5			7.9			5.8	2.7	3.6
1940-1950	7.1	5.3	7.8			8.2			6.4	3.0	4.8
1950-1960	7.6	6.4	8.2	8.1	8.2	8.7			7.2	3.6	6.2
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

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. In Földvári and Van Leeuwen (2009) we base our method on the assumption that the two type of bias 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.

The results from Table 5 are also plotted in Figure 2. As can be seen, although Austria and Germany are consistently higher than Poland, Bulgaria, and Romania, the difference

Figure 2
"Average years of education" in Central Europe, 1920-2007



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" is closing, how then can we explain that per capita income increased much stronger in Austria and Germany than in the other countries? The more since, as we have seen in the previous section, physical capital is also unable to provide an answer.

5. Human capital formation

It is repeatedly stressed that average years of education is not measured as physical capital (e.g. Judson 2002). Indeed, “average years of education” is at best indicative of the volume of human capital. It is as if you measure physical capital by counting the number of machines without keeping account that some machines are much more valuable than others. Indeed, Van Leeuwen and Földvári (2008) show that the difference in per capita human capital between Eastern and Western countries increases when one values it, either at its cost, or at the prospective income it is supposed to generate.

This finding is not surprising a real world example may suffice. The Ikarus bus manufacturer was a company set up in Hungary in 1949 by the fusion of some smaller vehicle producing companies. In the 1950s and 1960s, their new front engine models also draw attention of countries outside of Eastern Europe. By 1962 it delivered 8,000 buses abroad and its new ‘200’ series won a second place at the Nizza Bus Exposition and the Expo in Monaco in 1970 and 1971. Even though the company had some innovative new types in the eighties, still, in order to preserve sales (and the certain export income), the factory remained to produce and market the old 200 series, thereby slowly losing its technological advantage. So, while the engineers at the Ikarus bus company were probably at least as good as their Western colleagues, the company finally could not compete with the other large bus producers and lost its leading position by the end of the 80s. After some attempts to save the company, it was finally liquidated in 2007. Ikarus is a typical example how institutional differences may affect the productivity of labour and the value of human capital. The knowledge and innovativeness of the Ikarus engineers were paired by a short sighted product/marketing strategy finally causing their efforts to go in vain. Even though they spent a lot of years at university, and accumulated a lot of experience (in the terminology of this paper: they had a large volume of human capital), its value was finally lower than it would have been in a market economy.

It is therefore important to estimate human capital according to its value. In calculating the stock of human capital for Central Europe, we follow the method proposed by Földvári and Van Leeuwen (2009b). They calculate the stock of human capital using a prospective method. In those methods, human capital is understood 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 (2009b) start by defining human capital as the sum of all discounted expected future wage flows (we assume continuous time for convenience and use real wages):

$$h_{i,x} = \int_{t=0}^{65-x} E\left(w_{i,t}\right) e^{-qt} dt \quad (4)$$

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

$$\overline{h} = \int_{t=0}^{65-\overline{x}} E\left(\overline{w}_t\right) e^{-qt} dt \; (5)$$

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

$$\overline{h} = \int_{t=0}^{65-\overline{x}} \overline{w} e^{(g-q)t} dt = \frac{\overline{w}}{g-q}\left(e^{(g-q)(65-\overline{x})} - 1\right) (6)$$

Now, if we have some assumptions regarding *g-q*, with 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 there utility resulting from higher wages will increase with time.

This method is chosen over the standard Mincerian human capital as calculated by Hall and Jones (1999) and Pritchett (2001), which is more common in the literature. In that method, the per capita human capital stock is defined as follows:

$$h = e^{r_t S_t} \quad (7)$$

where r denotes the rate of returns to education, and S is the average years of education. That is both the quality and the quantity of human capital is captured in (7). 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 an absolute value. More seriously, this measure does not fully capture human capital. We can see that easily when we establish a relationship with our income based human capital measure. 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 (5) 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 (7). That is, the Mincerian human capital is equivalent with the prospective method suggested by us only under some very strict assumptions, most importantly, it assumes that there is only skill biased growth because, as acknowledged by Pritchett (2001), the measure in equation (7) fails to capture changes in the unskilled wages.

Therefore, applying (6) 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

Human capital/worker (1990 GK dollars)

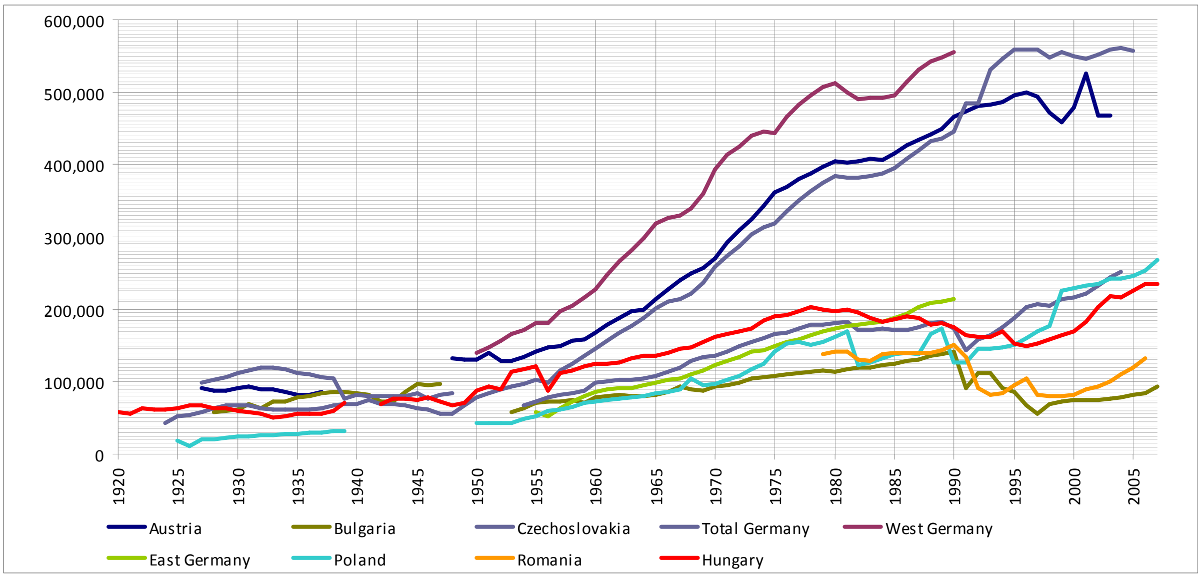
	Austria	Bulgaria	Czechoslovakia	Total Germany	of which Germany (West)	Germany (East)	Hungary	Poland	Romania
1920-1930	88,709	58,869	102,965	56,598			62,395	18,395	
1930-1940	87,274	76,113	106,786	65,037			57,475	28,179	
1950-1960	141,243	68,872	78,907	101,942	176,175	65,079	105,849	53,080	
1960-1970	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

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.

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 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

Figure 3

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



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, the western countries, Germany and Austria. Second, the richer Eastern European countries, Hungary, Czechoslovakia, and Poland (the latter seems to have successfully caught up). And finally, the poorer Eastern European countries, Bulgaria and Romania.

In other words, socialism did cause a convergence within Eastern Europe, but 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 ad 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 and regression framework in the next section.

4. Growth accounting and regression analysis

4.1 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:

$$\Delta \ln A_t = \Delta \ln Y_t - \alpha \Delta \ln K_t - \beta \Delta \ln H_t - (1 - \alpha - \beta) \Delta \ln L_t \quad (8)$$

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

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 with neglecting hc
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.

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 share of human capital in GDP growth remains constant for all countries and periods at roughly 33%. Interestingly, in both the socialist and Western countries, we see the share of physical capital in growth decline from 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.

4.2 Regression analysis

Above analysis has one drawback: since it is already assumed that human capital plays a role in the production process, it is guaranteed that one has some results. The rest is usually a question of narrative. It is much more difficult to have human capital included in some growth regressions, and see that the human capital variable ultimately behaves as expected. Most studies find either a positive or negative effect of education on growth, but it is rarely significant (e.g. Benhabib and Spiegel 1994). The lack of success resulted in two different kind of reactions. Pritchett (2001) in his famous article basically accepts the lack of macroeconomic relationship between growth and education and tries to find an economic-social answer why education does not turn out to be a key of economic success. Krueger and Lindahl (2001), similarly to Cohen and Soto (2007), claim that data and measurement error is mainly responsible for the insignificant or even negative coefficients.

Our point of view is closer to this latter strand of the literature, with the major difference that while they still rely on educational attainment or closely related data, we believe that the strange empirical results are due to the wrong indicators. Human capital should be expressed in terms of monetary units, similarly to physical capital stock and not proxied by an indirectly related educational indicator. In order to prove this point, we estimate a simple, Cobb-Douglas type production function with our measure of human capital employed.

Table 8

Results from FE regression analysis

	1920-1942	1950-1975	1975-	1975-
constant	4.634 (3.46)	6.586 (8.87)	-3.415 (-3.22)	-3.464 (-2.97)
lnk	0.253 (3.77)	0.124 (2.57)	0.323 (5.09)	0.312 (4.01)
lnh	0.164 (1.55)	0.022 (0.26)	0.378 (4.14)	0.396 (4.99)
trend	-0.004 (-1.13)	0.030 (7.59)	0.007 (5.25)	0.006 (2.83)
D^{soc}	-	-	-	-0.044 (-1.25)
D^{trans}	-	-	-	-0.082 (-1.85)
R^2	0.704	0.554	0.828	0.852
N	69	195	226	226

Note: Dependent variable is the log of GDP per worker. t-statistics in parentheses

We find that all factors of production yield the expected coefficients in Table 8. It is interesting to note that human capital and physical capital is especially small during the socialist period, which is no surprise since we estimate a fixed effects model. Hence, all country specific institutional factors are netted out, which will be especially large during the socialist period. That these can be significant during socialism can be seen in both the pre-and

Table 9

Results from pooled OLS regression analysis

	1920-1942	1950-1975	1975-	1975-
constant	4.723 (4.66)	2.007 (5.01)	-0.791 (-3.77)	-0.252 (-0.86)
lnk	0.764 (20.13)	0.394 (20.04)	0.482 (11.71)	0.480 (12.35)
lnh	-0.203 (-2.28)	0.314 (7.80)	0.413 (9.00)	0.392 (8.80)
trend	-0.028 (-5.72)	-0..002 (-1.47)	0.007 (5.93)	0.004 (3.44)
D^{soc}	-	-	-	-0.086 (-3.53)
D^{trans}	-	-	-	-0.071 (-1.71)
R^2	0.886	0.843	0.931	0.934
N	68	183	244	244

Note: Dependent variable is the log of GDP per worker. t-statistics in parentheses

post socialist period where physical and human capital shares are significantly higher. Indeed, we also calculated a Pooled OLS in Table 9. This model has the assumption that the country specific effects are not correlated with the regressors (which is obviously not true). Here we can see that the Pooled OLS leads to higher coefficients, especially during the socialist period.

For the 1950-1975 period h is significantly higher, while for the post-1975 period the results are not significantly different. This suggests that the individual (country) specific effects, including different levels of institutions, were positively correlated with the level of the factors of production to 1975, while after 1975 this link seems to fade.

Clearly, institutional efficiency during the socialist period was less than during the pre- or post socialist period. This can also be deduced from the growth accounting exercise. After all, we conclude that, although the share of physical and human capital in GDP growth is roughly equal in all countries, still GDP growth in the former socialist countries lags behind.

In other words, the economy of these countries must be less efficient in creating physical and/or human capital. This thesis 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.

$$\ln Y_{it} = \sum_{j=1}^{k} \beta_j \ln X_{ijt} + \varepsilon_{it} - u_i \text{ (9.)}$$

or

$$\ln Y_{it} = \sum_{j=1}^{k} \beta_j \ln X_{ijt} + \varepsilon_{it} + TE_i \text{ (10.)}$$

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 calculate efficiency both as being time invariant and time variant. 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

Table 10

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

the different countries, we find, no surprise, in table 11 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

Table 11

Technical efficiency parameters from the time invariant SFA specification

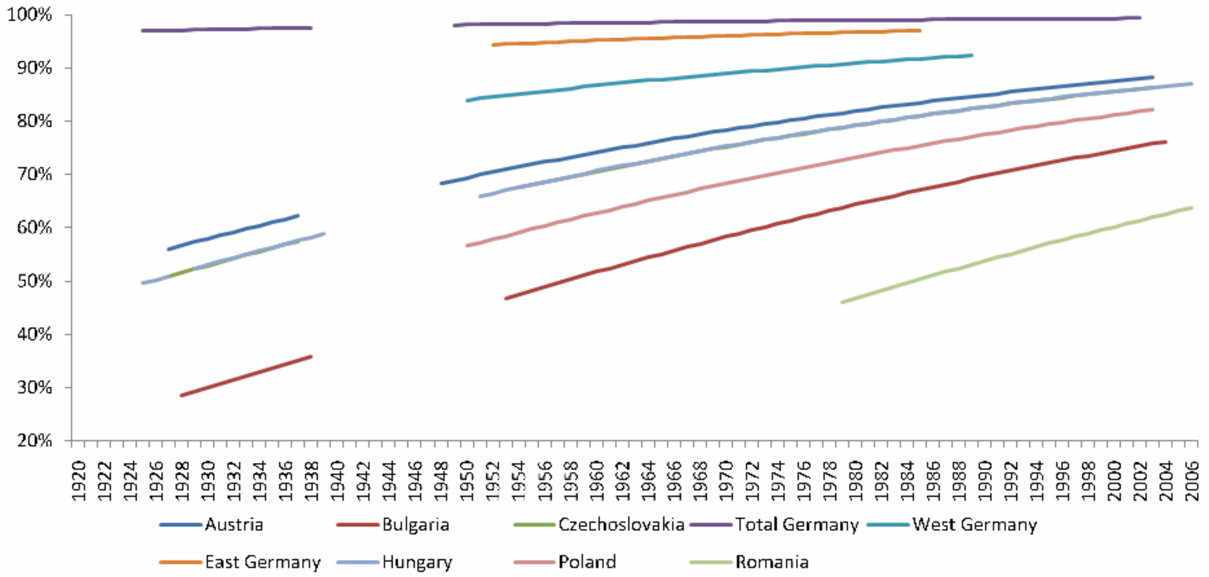
Country	Technical efficiency (%)
Austria	97.7%
Bulgaria	65.8%
Czechoslovakia	81.1%
Total Germany	97.6%
West Germany	98.5%
East Germany	94.6%
Hungary	78.4%
Poland	70.0%
Romania	74.7%

are round 80%, and the poorest socialist countries are round 70%.

The time variant efficiency/technology development is given in below figure. It is clear that efficiency in Eastern Europe is converging to the western level. Partly, this can be

Figure 4

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



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.

5. 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. Indeed, 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 economy.

The second objective of this paper is to apply human and physical capital in growth models. Using a standard Mankiw, Romer, and Weil (1992) growth accounting model, we find that the shares of human-and physical capital in Western and Socialist countries developed in about the same way over time. However, since, the growth levels of human- and physical capital were lower in the former socialist countries, so was the growth of GDP there.

Letting go the growth accounting assumption that human capital must affect economic growth, we also find that the prospective measure of human capital yields a positive and significant coefficient in regression analysis, while the country specific effects are specifically large during the socialist period. Also we find that growth efficiency is much smaller in Socialist countries than in the Western countries.

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