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Economic Growth and Income Convergence in Transition: Evidence from Central Europe

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Abstract

The paper examines the evolution of income per capita for a sample of high-income transition countries in the period 1991-2007. The analysis focuses on the dynamics of income per capita convergence throughout the period. We review patterns of income dispersion in Central Europe in a historical perspective and examine the dynamics of convergence over time. We present the model of beta and sigma convergence in augmented Solow model with human capital accumulation. Our evidence suggests that high-income transition countries experienced a period of robust convergence as the income per capita differential, relative to the U.S level, diminished substantially over time. The increase in the stock of human capital contributed substantially to the speed of real convergence.

Keywords: Economic growth; Output convergence; Post-socialist transition; Solow model; Panel-data estimation methodology

Introduction

Real convergence in income per capita distribution had been one of the most intensively studied issues in growth literature. Even though transition countries have been examined heavily in the growth literature, the vast majority of studies analyzed the mechanics of output decline in the post-socialist transition. Although the transition from planned economy to decentralized market mechanism sparked a considerable discussion on the theoretical approach to the evolution of institutional reforms, little had been discussed of the nature of growth in transition countries. Starting from a low income per capita level after years of cumulative output decline naturally implies higher marginal productivity of capital and higher growth rate in the steady state. Earlier study by [1] has raised concerns over the nature of growth in transition economies, studying the example of low growth of total factor productivity in Slovenia in late 1990s. In fact, last two decades have been characterized by price liberalization and macroeconomic stabilization as key requirements to sustain nominal convergence. The study of real convergence in Central Europe had not been examined in detail mainly due to the lack of macroeconomic data on GDP per capita and short time span when testing convergence hypothesis would be ambiguous.

The purpose of this paper is to test conditional convergence hypothesis in the sample of central European countries in 1991-2007 period. Central European countries share common political, historical and institutional similarities arising from decades of Habsburg rule. Moreover, the region experienced similar economic and political fate after the end of WW2 by adoption the socialist economic model. Nevertheless, despite common institutional, political and economic background, the per capita income distribution in the region has emerged unevenly. Whereas Slovenia, Estonia, Poland, Czech Republic and Slovakia forged ahead to the EU15 income level, Hungary and Croatia failed to keep the catch-up face and experienced considerably slower growth. The onset of economic and financial crisis changed the politico-economic map of Central Europe considerably since Hungary slipped from high-income to upper-middle income status at the World Bank and Croatia's per capita income fell back to the pre-transition level. Given a wide degree of heterogeneity across transition countries, especially in terms of income per capita variation, the paper builds on the panel of 7 high-income transition countries to test the conditional convergence hypothesis, using human capital accumulation and fertility rates as determinants of conditional convergence. We use the data on real GDP per capita, investment-to-GDP ratio, income per capita as a percentage of the U.S level, educational attainment and fertility rate in the period 1991-2007 and test the convergence hypothesis in our panel. The inclusion of human capital and fertility rate into growth specification provide an estimate of the impact of educational attainment, defined as average total years of schooling, on the speed of convergence in our sample. In addition, we provide a detailed account of the specification error analysis, utilizing Breusch-Pagan LM Test for random effects and Hausman's Specification Test.

The paper proceeds as follows. In Section II, we briefly review patterns of income dispersion in Central Europe during Habsburg period and in the period of 1970-1990. In particular, we provide the estimate of the unconditional β-convergence for both periods. In Section III, we review the literature relevant to the topic studied. In Section IV, we present a simple theoretical framework of growth and convergence, building on key assumptions and adjustment mechanism through which the process of convergence takes place. In this section, we provide an overview of augmenting Solow-Swan model with human capital component as well as some crucial aspects of the assumed fertility dynamics. In Section V, we present the data. In Section VI, we develop the underlying model specification. In Section VIII, we discuss our results. Section VIII concludes.

Patterns of Income Dispersion in Central Europe

The study of long-run dynamics of economic growth in Central Europe offers little account of the evidence of the conditional convergence. Although the topic of the convergence in Central and Eastern Europe had been discussed extensively [2-4] the patterns of income dispersion have been little known in the systematic study of convergence hypothesis in Central Europe before 1989 when planned

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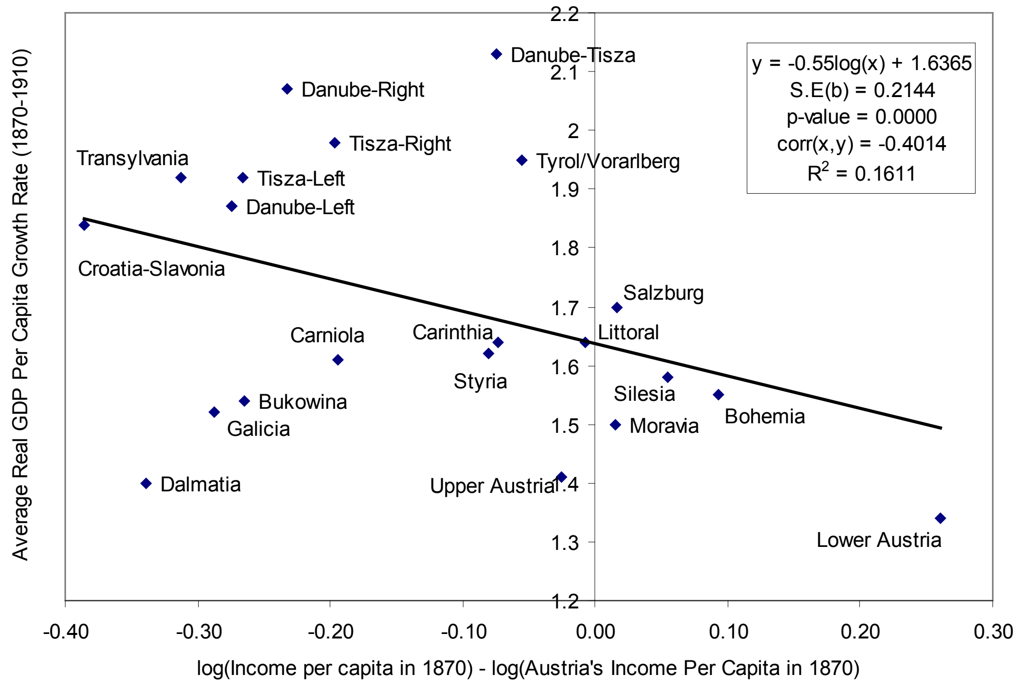
economies of East-Central Europe experienced the initial stage of transition to market economies.

A study by [5] presents a comprehensive and pioneering approach to estimating income per capita for Habsburg territories and its successor states based on Crafts-type structural equation approach using proxies to derive the level of per capita GDP. The estimates of income per capita in and average annual growth rates in the period 1870-1910 enable the testing of convergence hypothesis based on the aggregate data for each territory within the Habsburg Empire. In the particular period, the experience from the Habsburg Empire is a natural experiment in testing conditional convergence hypothesis. Within the empire, cross-country dispersion of income per capita was considerable and persistent. In Figure 1, we used Good's estimates of income per capita for Habsburg provinces for 1870 and average annual growth rate of GDP per capita in the period 1870-1910. On the horizontal axis, we plotted log-differential in income per capita in 1870 between each province and Imperial Austria, as a measure of baseline cross-country income differential. On the vertical axis, we plotted average annual growth rate of real GDP per capita for the period 1870-1910. The estimate suggests that the unconditional convergence hypothesis for Habsburg Empire is not rejected in the specific period. Even though the rate of the real convergence was persistent, significant differences in baseline income per capita had not disappeared after all since peripheral regions eventually failed to catch-up the Austrian level of income per capita. In addition, high-income regions in Czech lands and Austria still experienced robust rates of growth during the particular period. Our estimates suggest that baseline log-differential in income per capita explains about 16 percent of the growth variance for the period 1870-1910. The estimated convergence coefficient from Figure 1 implies that provinces with lower initial income per capita, on average, experienced higher growth rate. The estimated coefficient suggests the rate of unconditional convergence of about 5% per annum. Estimating conditional convergence hypothesis is crucial to the understanding of the evolution of income per capita differentials over time in Central Europe. However, further analytical framework is required with the relevant empirical analysis on growth process to test conditional convergence hypothesis.

In Figure 2, we demonstrated the per capita income disparities in Central Europe in 1970-1990 periods. In particular, we utilize the data from International Macroeconomic Data Set (Economic Research Service, 2012) on real GDP per capita at 2005 constant prices and average growth in the particular period. Our estimates for the period suggest that Central European countries, ranging from Ukraine to Austria, experienced a significant degree of divergence in income per capita in the period 1970-1990. The estimate reflects the macroeconomic setback of slow growth of socialist economies from 1970 onwards. Although the estimate does not provide the direct empirical support for conditional divergence, the unconditional divergence explains almost 38 percent of the growth variance. In fact, high-income countries such as Austria and Czech Republic sustained higher rate of growth compared to Poland, Hungary, Bulgaria, Romania and Ukraine. Slovenia, which in 1970 emerged as the second wealthiest part of former Habsburg Empire enjoyed considerably lower growth rate over the period.

The beta convergence is based on the assessment of average growth rate against the income level in the initial period. A more appropriate tool to study the dispersion of per capita income is the sigma convergence which measures the changing pattern of distribution in per capita income across a particular sample or sub-sample of countries. Young et al. [6] used county-level data for the United States to study the dispersion of per capita income and rejected sigma convergence hypothesis within the U.S. states. For a sample of OECD countries in the period 1970-1995, sigma convergence hypothesis. In Figure 3, the estimated sigma convergence for the sample of Central



Source: Good [5], own estimate

Figure 1: Unconditional β-Convergence in Habsburg Empire.

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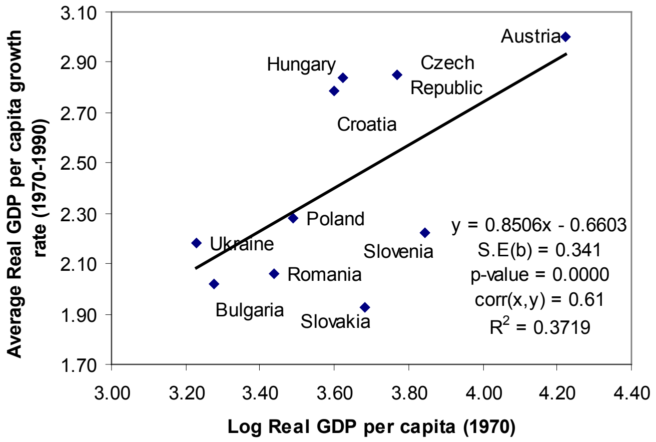


Source: [7]

Figure 2: Unconditional β-Divergence in Central Europe (1970-1990).

European transition countries[1] is presented. For the period 1970-1989, the data on reconstructed per capita GDP is used from Economic Research Service [7] whereas for the period 1990-2010, the data on per capita GDP from Summers et al. [8] is used to estimate the dispersion of per capita income in the respective period. The evidence suggests a contrasting pattern of sigma convergence over time. In pre-1990 period, the Central European transition countries experienced a mild but persistent sigma divergence which intensified until the onset of early 1990s. In the post-1990 period, a gradual and irreversible sigma convergence is observed. The evidence amply suggests that the during the transition, income per capita disparities in Central European sub-sample declined, leading to the convergence of per capita income.

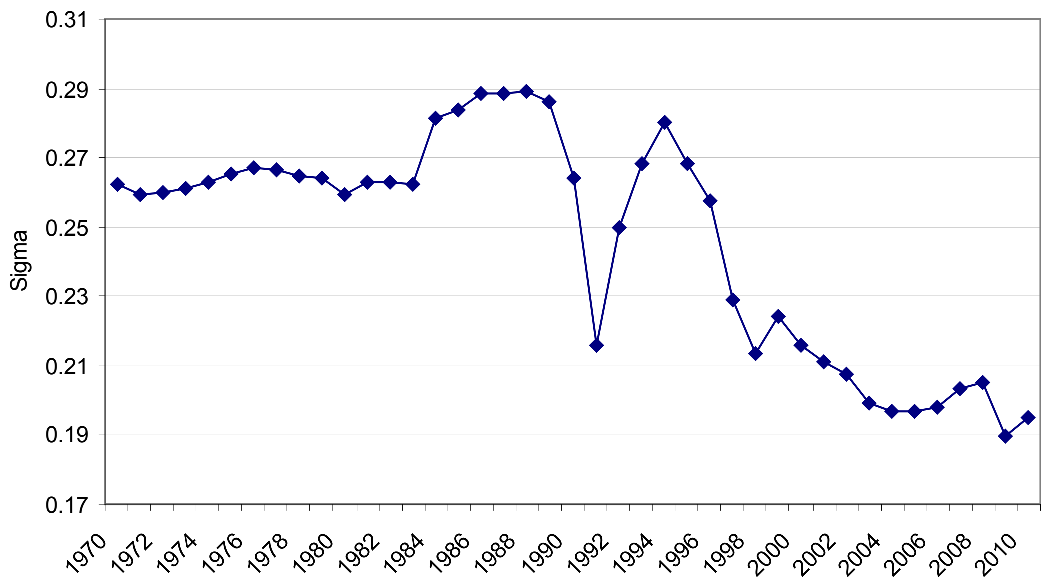
The comparison of Habsburg period, 1970-1990 period and post-1990 period reveals a reversible pattern of income dispersion. While unconditional convergence hypothesis was not rejected in Habsburg state, the pre-1990 period was marked by significant unconditional divergence which reflected considerable differences in the institutional frameworks. In the onset of post-1990 period, cross-country income inequality in Central European transition sub-sample decreased as suggested by sigma convergence. The relationship does not imply conditional convergence since structural controls are omitted from the estimation framework but the estimate suggests a remarkable reversion of the convergence pattern over time from the Habsburg period onward.

Review of Literature

Earlier studies of income per capita convergence have departed from testing the basic Solow-Swan neoclassical model of growth [9] which predicts subsequent convergence in income per capita along the increase in the stock of capital per worker. However, one of the most notorious characteristics of the Solow-Swan growth model is the exogenous treatment of technology as a public good. Mankiw et al. [10] derived the augmented Solow-Swan model in which the authors endogenized human capital accumulation which comprises significant explanatory power in accounting for differentials in long-run income per capita dispersion. Hence, the augmented Solow-Swan model would predict higher speed of cross-country convergence between countries with similar human capital characteristics.

Early contribution to the study of convergence by Baumol [11] had documented a rapid speed of convergence of productivity and income per capita for 16 industrialized countries based on Maddison's income per capita estimates between 1870 and 1979. Regressing average annual productivity growth rate on the natural log of productivity level in 1870, a rapid speed of convergence was confirmed even when log difference in income per capita between the two periods was regressed on the natural log of initial productivity level. De Long [12] criticized Baumol's findings on the basis of sample selection bias and measurement error inherent in the independent variable. Discrepancy in selection bias

[1]The sample consists of Croatia, Czech Republic, Estonia, Hungary, Poland, Slovak Republic and Slovenia.



Source: Own estimation based on Economic Research Service [7] and Summers et.al. [8]

Figure 3: Sigma Divergence and Convergence in Central Europe, 1970-2010.

arises from dynamics of growth rates prior to the period when the rate of convergence was estimated. Countries which eventually failed to catch-up high-income countries prior to 1870 were not taken into account of Madison's original data which casts doubt in the validity of convergence hypothesis in the long-run. In addition, De Long reports some curious examples of countries such as Argentina and Spain which enjoyed high productivity level in 1870 but were not included into the original sample. Such inconsistencies render the significance of cross-country aggregate convergence in productivity growth in the long run, biasing the coefficient on the speed of convergence.

Aghion et al. [13] studied the impact of financial development on the speed of convergence in a multi-country Schumpeterian growth model in which they ran cross-country growth regressions by considering a set of institutional, geographic and institutional variables. The findings suggest that rapid convergence is subject to the critical level of financial development. Once the critical level is sustained, convergence to the world technology frontier occurs whereas other countries are marked by strictly lower growth rates. In addition, Ventura [14] suggested that it is possible to explain the patterns of conditional convergence by combining weak-form factor price equalization theorem of international trade with Ramsey growth model.

Lee et al. [15] studied the heterogeneity of growth effects on the speed of convergence in dynamic panels, identifying the inconsistency of imperfect homogenous composition of the on estimated parameters as the crucial obstacles in estimating the convergence coefficient. Error variance, inherent in the measurement of the initial differences of income per capita, is the classical source of imperfect estimates of the convergence coefficient which usually underestimate or overestimate the speed of the adjustment of income per capita to the frontier. Hence, Basu and Weil [16] pioneered a theoretical framework in which the speed of convergence is rapid conditional on the appropriate technology diffusion.

An interesting finding was presented by McQuinn and Whelan [17] where the authors studied the empirical behavior of capital-output ratio to estimate the speed of the convergence dynamics through the adjustment mechanism. The estimates suggest 7 percent convergence rate per annum which is considerably higher than reported in earlier studies of output per worker convergence. The study provided an example of the positive impact of capital deepening on the rate of growth of output per worker.

On the other hand, Eicher and Turnovsky [18] studied convergence characteristics in two-sector non-scale growth model featuring population growth and endogenous technological change. The findings seem to suggest that crucial inputs may exhibit markedly different convergence patterns, differing strikingly in their speed of convergence. Furthermore, Jones [19] reexamined the pattern of convergence employing the advances from recent literature to predict the subsequent distribution of income per capita in the future, suggesting that the United States is likely to lose the leading rank in output per worker.

Cross-country dynamics of output per worker had been well-covered by the literature. In fact, cross-country empirical evidence on the sources of ultimate growth has proven essential to the understanding of convergence or divergence across nations. Therefore, Barro and Sala IM [20] established the neoclassical growth model featuring baseline income per capita and a set of institutional, demographic and schooling variables for a sample of 48 states in the U.S. for the period 1840-1963. The evidence suggests a rapid and persistent speed of convergence of output per worker in the particular period. In another paper Barro and Sala IM [21], the authors developed a model with endogenous growth to test whether the implications of the neoclassical growth model hold in the long run when technology is not assumed exogenous as in the original Solow-Swan model. The model implies that in the long run the growth rate of the world economy is driven by discoveries of technological leaders whereas follower countries converge to the frontier of leaders over time. The selection of technological leaders depends on the enforcement of intellectual property rights where poor quality of the intellectual property rights can supply leaders with insufficient incentives to innovate and followers with no excessive incentive to copy. The similar finding had been established by Cohen [22] who tested the convergence hypothesis, emphasizing poor endowment in knowledge as the ultimate failure to catch-up.

Tamura [23] developed endogenous growth model to study convergence of per capita income with identical preferences of agents and identical access to technology as to examine differences in the level of human capital accumulation. The latter provides the spillover effect where below-average agents sustain higher rate of return on human capital investment than above-average agents. The model implied faster growth and, hence, income convergence in developed world and within the U.S. O'Neill [24] reinforced the finding by the evidence suggesting that convergence in the level of education leads to the reduction in cross-country income per capita dispersion.

The literature on the speed of income convergence in transition countries is rare given relatively short period when convergence hypothesis could be tested. Kutan and Yigit [25] estimated the speed of convergence for new EU member states in a panel for the period 1995-2006. The findings suggest that human capital contributed the largest share to the productivity growth rate whereas income per capita purported considerable adjustment to EU15 levels and, therefore, a significant catch-up to the frontier. Hence, Campos and Coricelli [3] provided a systematic establishment of the stylized facts of transition, surveying theoretical literature and discussing the explanations for initial output decline. While Berglöf and Bolton [26] studied the convergence of financial architecture in transition countries, little had been discussed about the speed of income per capita convergence on the basis of the underlying theory and empirical evidence. Quah [27] presented a model of growth with imperfect capital mobility across countries as to characterize the dynamics of income distribution where the convergence hypothesis had not been rejected but the evidence suggested little empirical account of cross-country convergence and, at the same time, polarization of countries into convergence clubs defined by the similarity of structural characteristics. In later paper [27], the evidence further suggested twin-peaks in cross-sectional income per capita distribution as a distinct pattern of convergence.

Convergence and Growth: Simple Framework

Basic assumptions

Consider the economy with infinite horizon populated by a continuum of firms c denoted $c \in \{0,1\}$ with the mass normalized to unit in discrete time. The economy is characterized by Cobb-Douglass aggregate production function with constant returns to scale:

$$\frac{Y}{L} = F\left[K(t), L(t), A(t)\right] \quad (1)$$

Where Y/L output per worker is, K(t) denotes total stock of capital, L(t) denotes total labour supply and A(t) denotes baseline level

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of technology such as infrastructure and the quality of public goods. In each period, the output of the representative firm is constrained by constant unit cost of labour and capital. Hence, the assumption of profit maximization implies:

$$\max_{L(t),K(t)} F\left[K(t),L(t),A(t)\right]-w(t)L(t)-r(t)K(t) \tag{2}$$

Where W(t) and K(t) represent constant unit cost of labour and capital. As a forward-looking agent, the firm seeks to increase the future stock of capital through Aftalion-Clark accelerator effect:

$$I(t)=\mu v\sum_{i=1}^{\infty}(1-\mu)^{i}\left(Y_{t-i}-Y_{t-i-1}\right) \tag{3}$$

Where μ measures the speed of the adjustment of current stock of capital to the steady-state level in *t* periods while I(t) represents net investment. We assume capital depreciates constantly at rate δ. The law of motion implies the evolution of the stock of capital at time *t+1*:,

$$K(t+1)=(1-\delta)K(t)+I(t) \tag{4}$$

We assume savings-investment identity S(t)=I(t) and linear savings function $S(t)=sY(t)$ to set the existence of macroeconomic equilibrium. The savings curve is downward sloping since, as L'Hôpital rule suggests, $\lim_{K\to\infty}\left[s\cdot f_K(K)\right]=0$ and $\lim_{K\to\infty}\left[s\cdot f_K(K)\right]=0$ implies that $\lim_{K\to\infty}\left[\frac{s\cdot f_K(K)}{K}\right]=0$.

The aggregate production function in (1) satisfies the Inada conditions to ensure the existence of steady-state inner equilibrium:

$$\begin{aligned}&\lim_{K\to\infty}F_K(K,L,A)=0 \qquad \lim_{L\to\infty}F_L(K,L,A)=0\\&\lim_{K\to 0}F_K(K,L,A)=\infty \qquad \lim_{L\to 0}F_L(K,L,A)=\infty\end{aligned} \tag{5}$$

From the fundamental Solow-Swan equation we derive the growth rate of the total stock of capital:

$$\gamma_K=\frac{\dot{K}}{K}=\frac{s\cdot f(K)}{K}-(n+\delta) \tag{6}$$

Where n is the exogenous rate of population growth at time and δ is the depreciation rate as denoted in (4). Hence, the growth rate of output per worker, denoted $\gamma_{Y/L}$, would be characterized as:

$$\gamma_{Y/L}=F_K(K)\cdot\frac{K}{F(K)}=\left[\frac{K\cdot F_K(K)}{F(K)}\right]\cdot\left(\frac{\dot{K}}{K}\right) \tag{7}$$

where $\dot{K}$ represents the rate of change of total capital stock in discrete time. Equation (7) implies that total stock of capital per worker would grow at the rate equal to:

$$\left(\frac{K}{L}\right)=s\cdot F(K)-\delta K \tag{8}$$

Differencing and rearranging (7) yields the rate of growth of total stock of capital expressed in linear differential equation:

$$\dot{K}=\frac{d(K/L)}{dt}=\frac{\dot{K}}{L}-nk \tag{9}$$

A. Human capital

In the spirit of Mankiw et al. (1992) [10], the introduction of human capital, denoted $H(t)$, into the aggregate Solow-Swan [28] function would modify the Solow-Swan production function in (1) into:

$$\frac{Y}{L}=F\left[K(t),H(t),AL(t)\right] \tag{10}$$

Under the assumption of constant returns to scale, (10) would be transformed into:

$$\frac{Y}{L}(t)=K^{\beta}(t)\cdot H^{\alpha}(t)\left[A(t)L(t)\right]^{1-\alpha-\beta} \tag{11}$$

The dynamics of capital accumulation is described as:

$$\begin{aligned}K(t+1)&=s_KY_t-\delta_KK(t)\\H(t+1)&=s_HY_t-\delta_HH(t)\end{aligned} \tag{12}$$

where s and δ represent savings rate and depreciation rate for both physical and human capital. In the long run, the growth of total factor productivity is driven by technological change and the rate of population growth. Dividing human capital and physical capital variables by technological progress and labor supply gives steady-state values for human and physical capital per effective unit of labor:

$$K^*=\left(\frac{s_K}{\delta_K+n+\gamma_A}\right)^{\frac{1-\beta}{1-\alpha-\beta}}\left(\frac{s_H}{\delta_H+n+\gamma_A}\right)^{\frac{\beta}{1-\alpha-\beta}} \tag{13}$$

$$H^*=\left(\frac{s_K}{\delta_K+n+\gamma_A}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{s_H}{\delta_H+n+\gamma_A}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} \tag{14}$$

B. Fertility

Consider Lucas [29]-type dynamic human capital production function.

$$H_{t+1}=H_t\lambda(v_t) \tag{15}$$

where $\lambda(v_t)$ represents the amount of child-raising. The resource constraint of the representative household is:

$$c\le H(1-(v+k)n) \tag{16}$$

The budget set (16) would lead to Bellman equation of the representative household:

$$F(H)=\max_{c,n,v}W(c,n,g(h\lambda(v))) \tag{17}$$

Where *c*, *n* and *u* stand for household consumption, number of children and the fraction of time devoted to household production. Following Becker et al. [30] from of human capital growth, we derive the final form of human capital investment decision based on the changing number of children:

$$\lambda(v)=Cv^{\varepsilon} \tag{18}$$

Where *C* represents baseline cross-country differential in fertility and ε represents the child-raising allocation parameter. Equation (18) suggests that an increase in ε would lead to greater amount of child-raising per child and lower equilibrium fertility rate as per capita income increases. The transition to low-fertility equilibrium also implies greater return on human capital investment. Equation (15) implies that greater investment in human capital increases the opportunity cost of child quantity which leads to lower fertility rate and greater amount of child-raising which also increases the child-raising allocation parameter in Equation (18).

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Data and Sample

Our sample consists of seven advanced transition countries with relative GDP per capita above the average. In our sample, we included Croatia, Czech Republic, Estonia, Hungary, Poland, Slovakia and Slovenia. Compared to other transition countries such as Romania and Ukraine, our sample does not suffer from considerable variation in schooling rate, fertility rate or investment-to-GDP ratio. The choice of countries in the Central European sub-sample is based on the pre-1990 comparative levels of per capita income. The selected countries enjoyed relatively similar per capita incomes in both Habsburg period and the socialist period. Similarities in income levels also imply similarities in the characteristics of the production factors and key determinants in the growth process. As an exclusion criterion, this allows us to identify the key determinants of income convergence or divergence over time by focusing on countries with relatively similar income levels which diverged considerably over time as shown in Figure 3. Income convergence across a sample of Central European countries is studied in 1991-2007 period since the main objective of this paper is to reconstruct the dynamics of income dispersion and its determinants in the transition period which started in early 1990s.

The data on Real GDP per capita growth rate, investment-to-GDP ratio, Real GDP per capita relative to the U.S and Baseline GDP per capita are from Summers et al. [8] dataset. We use the data for transition countries for the period 1991-2007 in which we pooled 119 observations in total. We defined schooling rate as total years of schooling at the median of age distribution and obtained the relevant data from international dataset on educational attainment Barro and Lee [31]. The key implication from Equations (13) and (14) is that the steady-state output dynamics is determined by physical and human capital investment. For the stock of physical capital, we use the cross-country time-series on investment-GDP ratio in the estimation period similar to Mankiw et al. [10]. As a proxy for human capital investment, median average years of schooling variable are used directly in cross-country growth regression. Both investment-GDP ratio and average years of schooling effectively reflect the intensity of physical and human capital accumulation and its effect on the steady-state output in the growth process. The inclusion of fertility rate in the underlying cross-country growth regression is based on the Becker et al. [30] argument which essentially captures the implication that declining fertility rate increases the rate of return on human capital directly by deploying quantity-quality switch from high-fertility to low-fertility equilibrium. Greater human capital intensity leads to a changing steady-state with higher rates of return and growing stock of human capital. Invoking Lucas-type utility function from equation (22), lower fertility raises child-rearing allocation parameter directly and leads to subsequent increase in human capital stock and indirectly to rising household consumption. The departure into low-fertility equilibrium necessarily implies rising return human capital investment and average years of schooling. In addition, the transition to low-fertility equilibrium also reflects the effect of demographic transition. Therefore, the estimation strategy should not preclude the control for changing pattern of fertility rates to account for the structural effect of demographic transition. The data on fertility rates were obtained from UN's 2010 World Population Prospects. Table 1 provides basic descriptive statistics for our sample.

Model Specification

The basic fixed-effects empirical relationship that takes place is:

$$g_{j,t} = \phi + \delta \ln y_{j,t=0} + \lambda \ln \left[y_{j,t} - y_{US,t} \right] + \mathbf{X}'_{j,t}\beta + \alpha_j + u_{j,t} \tag{19}$$

where $g_{j,t}$ represents real GDP per capita growth rate of j-th country at time t, $y_{j,t=0}$ is baseline real GDP per capita, $y_{j,t}-y_{US,t}$ is the income per capita differential relative to the U.S level. $X_{j,t}$ is the vector of growth determinants from Mankiw et al. [10] which includes investment-to-GDP ratio and average years of schooling as a proxy for the stock of human capital. In addition, the vector also contains the fertility rate and β is the set of coefficients for growth determinants. The term α_j captures country-specific fixed effects and $u_{j,t}$ is the disturbance term. Our primary interest lies in the δ coefficient which measures the speed of conditional convergence across countries in our sample. A positive and statistically significant coefficient indicates that countries with lower initial income level in our sample such as Estonia sustained higher rate of per capita income growth and converged to the frontier of countries with higher initial income level such as Czech Republic and Slovenia. The coefficient λ measures the speed of closing the per worker income gap relative to the United States over time. A positive coefficient would denote that closing the gap in the level of labor productivity behind the U.S is associated with higher rate of per capita income growth.

The specification of the empirical relationship (19) allows the estimation of robust fixed-effects coefficients. The consideration of country-fixed effects allows us to capture the effect of cross-country heterogeneity on the distribution of growth rates over time (Table 1).

Results

In Table 2, we report the estimated cross-country convergence equation (19). As noted above, we applied fixed-effects estimation framework and provided three different specifications of (19). In column (1) we tested the convergence hypothesis conditional on the income per capita differential relative to the U.S level and investment-to-GDP ratio. The presence of conditional convergence would imply $\delta < 0$. The estimates suggest that high-income transition countries experienced a relatively high speed of income per capita convergence in the period 1991-2007 periods. The estimate suggests the implied speed of conditional convergence of 8.64 percent per annum. The estimate is significant at 1% significance level. The estimated coefficient λ implies that the increase of the income per capita relative to the U.S. level by 1 percent would, holding all other factors constant, increase the rate of GDP per capita growth by 0.33 percentage point. Therefore, the closing of the relative gap behind the U.S. level of income per capita would boost the rate of growth significantly. In column (1) In Table 2, we also include investment-to-GDP ratio which proved contradictory since greater capital deepening would boost divergence from the mean real GDP per capita respectively.

Variable	N	Mean	Std. Dev.	Min	Max
Real GDP Per Capita Growth Rate	119	2.993	5.745	-19.33	11.13
Ln (GDP per capita relative to the US)	119	3.58	0.24	3.06	4.15
Ln (Baseline GDP per capita)	119	9.26	0.21	9.13	9.65
Log (Investment as % of GDP)	119	1.403	0.087	1.18	1.61
Average Years of Schooling	119	9.842	1.598	6.94	12.61
Fertility Rate	119	1.330	0.123	1.09	1.69

Source: author's estimates

Table 1: Descriptive Statistics.

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Dependent variable is real GDP per capita growth rate			
	(1) Fixed Effects	(2) Fixed-Effects	(3) Fixed-Effects
Constant Term	-52.422*** (13.561)	-49.837*** (13.818)	-54.872*** (13.193)
$\ln y_{t,j=0}$	-0.0864*** (0.0092)	-0.0873*** (0.0093)	-0.0689*** (0.0102)
$\ln y_{t,j}-\ln y_{US,t}$	0.3273*** (0.0688)	0.3408*** (0.0702)	0.1621* (0.0833)
Ln Investment/GDP Ratio	0.0467 (0.0481)	0.0490 (0.0481)	0.0778* (0.0464)
Total Fertility Rate		-0.0372 (0.0381)	-0.0668* (0.0371)
Average Years of Schooling			0.0324*** (0.0091)
No. of observations	119	119	119
Within R^2	0.5147	0.5190	0.5706
Between R^2	0.0112	0.0126	0.0008
Overall R^2	0.3071	0.2830	0.2177
Prob>F	0.0000	0.0000	0.0000
Note: Conventional standard errors denoted in the parentheses. Significance levels denoted by asterisks: *** (1%) **(5%) *(10%)			

Source: author's own estimates

Table 2: Conditional Convergence.

In column (2) we added the fertility rate. Higher fertility rate would be accompanied by higher rate of growth but only as long as demographic transition would not take a full-fledged start. But the state of demographic transition depends on the initial level of income per capita per se. Our estimates suggest that transition countries with higher fertility rate tend to experience lower real GDP per capita growth rate. Although the finding is in line with the prediction by Becker et al. [30], it fails to make a significant contribution to the explanation of the convergence relationship. However, the inclusion of fertility rate into regression equation improves the conditional convergence coefficient by 1.04 percent while also improving the fit of the regression equation.

In column (3) we also included schooling variable to estimate the equilibrium impact of human capital accumulation on the rate of economic growth. The estimates of the regression coefficients suggest the log-difference in GDP per capita relative to the U.S and baseline real GDP per capita in 1991 exert a significant influence on the adjustment and speed of convergence. Contrary to columns (1) and (2), investment-to-GDP ratio (I/Y) is positive and statistically significant at the 10% level. The estimate suggests that the nature of growth in transition countries for the 1991-2007 periods had been earmarked by capital deepening rather than by innovation or R&D. In addition, the coefficient on fertility rate is higher in magnitude than reported in column (2) as well as statistically significant (10% level). Moreover, the estimated coefficient on average years of total schooling suggests that human capital accumulation is a significant determinant of the convergence relationship. Increasing average years of total schooling by additional year would increase the growth rate of real GDP per capita by 0.0324 percentage points. The estimate is statistically significant at the 1% level, suggesting a remarkably strong influence of the human capital accumulation on the rate of economic growth. However, the inclusion of the schooling variable into the regression specification slightly reduces the speed of the conditional convergence coefficient by 10.57 percent. Despite the change in the magnitude of the coefficient, the empirics of the conditional convergence suggest that the hypothesis of conditional convergence cannot be rejected.

We also provide the specification analysis since bias arising from improper choice of the functional form of the model can significantly reduce the explanatory power of the conditional convergence specification. In particular, we estimated (23) with fixed-effects and random-effects sample estimator and used Hausman [32] and Breusch and Pagan [33] specification test to select the appropriate estimator. When equation (23) is estimated by random-effects, the coefficient on income per capita and baseline real GDP per capita is correct and statistically significant. However, the fit of the regression equation is considerably worse since the coefficients on fertility rate and schooling are statistically insignificant, the magnitude of the coefficient being extremely small which should suggest that fertility rate and schooling exert no effect on the speed of convergence. Albeit random-effects models allow the inclusion of time-invariant variables in the regression equation, the robustness of the estimated coefficients is ambiguous. Even when strict exogeneity is assumed, random-effects model can suffer from unobserved heterogeneity within the panel, biasing the estimated coefficients. We tested the choice of the estimation framework with Breusch-Pagan LM test and Hausman's specification test (Table 3 and 4). We report error diagnostics in the appendix

LM test suggests that underlying panel data do not suffer from random-effects that could compromise the robustness of the regression coefficients. The null hypothesis is not rejected in each specification since chi-square values are far above the critical level. Therefore, the choice of fixed-effects is the preferred specification of our model. We tested the choice of the estimation framework in Hausman's specification test. The major drawback of random-effects model is the inconsistency arising from the correlation between the independent variables and random effects. Estimated asymptotic covariance matrices for fixed-effects and random-effects coefficient variances have very low chi-square values, again reinforcing the fixed-effects model as the preferred specification of the regression equation.

Conclusion

Even though the study of conditional convergence had been itself controversial in transition countries, the evidence overwhelmingly suggests that in the 1991-2007 period, high-income transition countries (Czech Republic, Croatia, Estonia, Hungary, Poland, Slovakia and Slovenia) experienced significant conditional convergence The estimated β suggests the annual rate of convergence of about 8 percent. Furthermore, the speed of conditional convergence diminishes to about 7 percent when we included schooling variable as a proxy for human capital accumulation. Our results indicate that the original Solow-Swan model failed to predict the subsequent convergence in high-income transition countries while the conditional convergence in the augmented Solow model was confirmed. After regressing average per capita GDP growth rate on baseline real GDP per capita in income per capita differential relative to the U.S, we conclude that countries

	(1)	(2)	(3)
$\sqrt{Var\left(g_{j,t}\right)}$	5.745	5.746	5.746
$\sqrt{Var\left(\varepsilon_{j}\right)}$	4.107	4.108	3.899
$\sqrt{Var\left(\varepsilon_{j,t}\right)}$	0.000	0.000	0.836
Prob>χ^2	0.5174	0.6636	0.4074

Source: author's own estimate

Table 3: Breusch-Pagan LM Test for Random Effects.

(1)			
	Coefficients		Asymptotic Covariance $Var\left[\mathbf{b}_{fixed}-\beta_{random}\right]^{-1}$
	$\mathbf{b}_{fixed}$	β_{random}	
log $(Y/L)_{t=0}$	-0.0864	-0.0884	
log $\left[(Y/L)_j-(Y/L)_{US}\right]$	0.3273	0.0806	0.058
log (I/Y)	0.0467	0.0399	0.007
Prob> χ^2	0.0000		
(2)			
	Coefficients		Asymptotic Covariance $Var\left[\mathbf{b}_{fixed}-\beta_{random}\right]^{-1}$
	$\mathbf{b}_{fixed}$	β_{random}	
log $(Y/L)_{t=0}$	-0.0873	-0.0874	
log $\left[(Y/L)_j-(Y/L)_{US}\right]$	0.3408	0.0936	0.5796
log (I/Y)	0.0490	0.0397	0.0075
Total Fertility Rate	-0.0373	0.0331	0.0138
Prob> χ^2	0.0000		
(3)			
	Coefficients		Asymptotic Covariance $Var\left[\mathbf{b}_{fixed}-\beta_{random}\right]^{-1}$
	$\mathbf{b}_{fixed}$	β_{random}	
log $(Y/L)_{t=0}$	-0.0689	-0.0839	0.0025
log $\left[(Y/L)_j-(Y/L)_{US}\right]$	0.1619	0.1105	0.0694
log (I/Y)	0.0778	0.031	
Total Fertility Rate	-0.6681	0.1090	0.1
Average Years of Schooling	0.0324	0.0053	0.0084
Prob> χ^2	0.0000		

Source: author's own estimate

Table 4: Hausman specification test.

with low baseline income per capita subsequently sustained a robust catching-up to the U.S level of income per capita although the difference in per capita income and living standards remains substantial. Hence, the estimates suggest that one additional year of total schooling would boost the rate of real GDP per capita growth by about 3 percent on average, holding all other factors constant. In addition, our model predicted that a decline in total fertility rate alongside the stock of human capital would boost growth and cross-country convergence process as the empirical evidence presented in this paper suggests. Future research on the dynamics of convergence in transition should further consider more detailed effects of demographic transition and human capital accumulation as the main structural determinants of income per capita convergence across countries.

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