Productivity and income convergence in transition: theory and 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 evolution of convergence and divergence in a distinct perspective. We present the model of beta convergence by augmenting the basic Solow-Swan model with human capital accumulation and total fertility rate. 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. In addition, the increase in the stock of human capital contributed substantially to the speed of real convergence.

JEL Classification Codes: C23, N13, O47, P20

Keywords: economic growth, output convergence, post-socialist transition, Solow model, panel-data estimation methodology

I. 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 studied heavily in the literature on growth, the vast majority of studies analyzed output decline and institutional setup in the post-socialist transition. Although the transition from planned economy to market setup sparked a considerable discussion on the theoretical approach to the evolution of systemic and institutional reforms, little had been said 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 rate of investment and intensive growth in early years of transition. Earlier study by Mrkaic (2002) has raised concerns over the nature of growth in transition economies, studying the example of low growth of total factor productivity in Slovenia. In fact, last two decades have been earmarked by the efforts to pursue price liberalization and macroeconomic stabilization as key requirements to sustain nominal convergence. The study of real convergence in Central Europe had not been conducted 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 the paper is to test conditional convergence hypothesis in the sample of central European countries in 1991-2007 period. 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 in the aforementioned period. We test the hypothesis of conditional convergence, using human capital accumulation and fertility rates as the measures determining conditional convergence. We assembled 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 run panel-data regressions to test the convergence hypothesis. The inclusion of human capital and fertility rate into regression equation would 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 empirical evidence from fixed-effects estimation framework and the interpretation of the results obtained from the empirical analysis. In Section VI, we present some concluding remarks and draw relevant conclusions thereafter. In Section VII, we provide the list of references. In the Appendix, we enlist the analysis of the econometric specification, in particular Breusch-Pagan LM test and Hausman specification test, of the model built throughout the course of the paper.

II. 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 (Estrin, Urga & Lazarova, 1997; Corricelli & Campos, 2003; Polanec, 2004), the patterns of income dispersion have been little known in the systematic study of convergence hypothesis in Central Europe before 1989 when planned economies of East-Central Europe experienced the initial stage of transition to market economies.

A study by Good (1994) presents a comprehensive and pioneering approach to estimating income per capita for Habsburg territories and its successor states. 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. During the particular period, the experience from the Habsburg Empire serves as the natural experiment in the formulation and testing of conditional convergence hypothesis. Within the empire, cross-country dispersion of income per capita was unambiguous. 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 the 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 estimates suggest that during the aforementioned period, the convergence hypothesis for Habsburg Empire was not rejected. 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 with the lowest average annual growth rates within the Habsburg Empire. 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 variance of the average growth rate during the studied period. 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 would be unambiguously crucial to the understanding of the evolution of income per capita differentials over time in Central Europe but the effort would require the relevant data on human capital accumulation and other control variables that determine the rate of conditional convergence.

[Figure 1 near here]

In Figure 2, we demonstrated the dynamics of income per capita dispersion in Central Europe in 1970-1990 period. In particular, we utilize the data from *International Macroeconomic Data Set* on real GDP per capita in 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 fact, regression away from the mean income per capita reflects the macroeconomic setback of slow growth of communist economies from 1969 onwards. Although the estimate does not provide the empirical account of the conditional divergence, the measure of unconditional divergence points contains the elements of high explanatory power since almost 38 percent of the growth variance is explained by baseline differences in 1970 level of real GDP per capita. 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 comparison of Habsburg period and 1970-1990 period reveals a reversible pattern of income dispersion. While unconditional convergence hypothesis was not rejected in Habsburg state, the period prior to the onset of post-socialist transition was marked by significant unconditional divergence which reflected considerable differences in the institutional frameworks. Again, the relationship does not imply conditional convergence since human capital accumulation, fertility rate and other proxies have remained intact in the estimation framework but the estimate suggests a remarkable reversion of the convergence pattern and a significant digression from the mean income per capita in the particular period.

[Figure 2 near here]

III. Review of Literature

Earlier studies of income per capita convergence have departed from testing the basic Solow-Swan neoclassical model of growth (Solow, 1956) which predicts subsequent convergence in income per capita alongside the increases in 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 and the characteristic of the cross-country differential in baseline income per capita. Mankiw, Romer & Weil (1992) 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 (1986) 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 initial productivity level. De Long (1988) criticized Baumol's findings on the basis of sample selection bias and measurement error inherent in the independent variable. Discrepancy in selection bias 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 Maddison's original data which casts persistent degree of skepticism in the existence of convergence patterns 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 which purports largely illusionary belief in the existence of inverse relationship between baseline cross-country income per capita differentials and average productivity growth over the long run as well as the inconsistencies biasing the coefficient on the speed of convergence.

Aghion, Howitt & Mayer-Foulkas (2005) studied the impact of financial development on the speed of convergence in a multicountry 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 particular level is exceeded, convergence to the growth rate of world technology frontier occurs whereas other countries are marked by strictly lower growth rates. In addition, Ventura (1997) suggests 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, Pesaran & Smith (1998) studied the heterogeneity of growth effects on the speed of convergence in dynamic panels, identifying the inconsistency of the sample estimator and imperfect composition of the homogeneity on estimated parameters as the crucial hindrances in estimating the convergence coefficient. Error variance, inherent in the measurement of the initial differences of income per capita, is the typical 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 & Weil (1998) 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 & Whelan (2007) 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 a rare example of the positive impact of capital deepening on the rate of growth of output per worker.

On the other hand, Eicher & Turnovsky (1999) 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 (1997) 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 & Sala-i-Martin (1992) established the neoclassical model of growth 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 & Sala-i-Martin, 1997), 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 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 (1996) who tested the convergence hypothesis, emphasizing poor endowment in knowledge as the ultimate failure to catch-up.

Tamura (1991) 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 (1995) 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 & Vigit (2009) estimated the speed of convergence in a panel data 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 & Coricelli (2002) provided a systematic establishment of the stylized facts of transition, surveying theoretical literature and discussing the explanations for initial output decline. While Berglöf & Bolton 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 (1997) 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 evidence 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 (Quah, 1997), the evidence furthermore suggested twin-peaks in cross-sectional income per capita distribution as a distinct pattern of convergence.

IV. 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:

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

Where Y/L is output per worker, $K(t)$ denotes total stock of capital, $L(t)$ denotes total labour supply and $A(t)$ denotes baseline level 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, $\lim_{K\to 0}\left[s\cdot f_K(K)\right]=\infty$ 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 equilibria:

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

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 charaterized as:

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

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:

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

Human Capital

In the spirit of Mankiw, Romer & Weil (1992), the introduction of human capital, denoted $H\left(t\right)$, into the aggregate production function would modify the Solow-Swan production function in (1) into:

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

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

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

The dynamics of capital accumulation is described as:

$$\begin{aligned} K\left(t+1\right) &= s_K Y_t - \delta_K K\left(t\right) \\ H\left(t+1\right) &= s_H Y_t - \delta_H H\left(t\right) \end{aligned} \tag{12}$$

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 labour supply gives steady-state values for human and physical capital per effective unit of labour:

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

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

Fertility

Consider Lucas-type dynamic human capital production function.

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

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

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

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

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

where *c*, *n* and *u* stand for household consumption, number of children and the fraction of time devoted to household production. Following Becker-Murphy-Tamura (1992) form of human capital growth, we derive the final form of human capital

$$\lambda(v) = Cv^{\varepsilon} \tag{22}$$

where *C* represents baseline cross-country differential in fertility and ε represents the child-raising allocation parameter . Equation (22) 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.

V. Empirical results

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

$$g_{j,t} = Cons + \delta \log\left(\frac{Y}{L}\right)_{j,t=0} + \lambda \log\left[\left(\frac{Y}{L}\right)_{j,t} - \left(\frac{Y}{L}\right)_{US,t}\right] + \mathbf{X}'_{j,t}\beta + \alpha_j + u_{j,t} \tag{23}$$

where $g_{j,t}$ represents real GDP per capita growth rate of j-th country at time *t*, $\frac{Y}{L}$ is baseline real GDP per capita, $\left(\frac{Y}{L}\right)_{j,t} - \left(\frac{Y}{L}\right)_{US,t}$ is the income per capita differential relative to the U.S level. $\mathbf{X}'_{j,t}\beta$ is the vector of control variables such as investment-to-GDP ratio $\left(\frac{I}{Y}\right)$, fertility rate and average years of schooling as a proxy for the stock of human capital, α_j captures country-specific fixed effects and $u_{j,t}$ is the disturbance term.

The specification of the empirical relationship (23) allows the estimation of robust fixed-effects coefficients. The functional form of the model is linearly-logarithmic (lin-log) since negative growth rates during the period of cumulative output decline could not be logged unless the explanatory power of the regression coefficients and quality of the specification would be compromised.

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 regression coefficients and possibly lead to the wrong sign of each coefficient. In particular, we estimated (23) with fixed-effects, between-effects and random-effects. The coefficients of the estimated regression equation by between-effects were highly insignificant. The explanatory power of the between-effects regression equation is poor, therefore incapable of yielding the appropriate conclusions.

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. 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.

VI. Methodology and Data

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 extreme variation in schooling rate, fertility rate or investment-to-GDP ratio. In particular, we decided to include high-income transition countries into our sample mainly because the probability of measurement bias in national income accounts, schooling rate and fertility rate is somehow mitigated.

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-Heston* 2011 dataset. The data for transition countries are available for the period 1991-2007 in which we pooled the total of 119 observations. We defined schooling rate as total years of schooling and obtained the relevant data from Barro-Lee 2010 international dataset on educational attainment. The data on fertility rates were obtained from UN's 2010 *World Population Prospects*. Table 1 provides basic descriptive statistics for our sample.

[Table 1 near here]

VII. Estimation Results

In table 2, we report the estimated convergence equation (23). As noted above, we applied fixed-effects estimation framework and provided three different specifications of (23). In specification (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 period. 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 specification (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.

In specification 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, Murphy & Tamura (1992), 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.

[Table 2 near here]

In specification 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 specification (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 period 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 specification (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.

VIII. 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 conditional on either investment-to-GDP ratio and fertility rate. 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 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 a decline in total fertility rate alongside the increases in per capita income which the empirical evidence suggests. Future research on the dynamics of convergence in transition should seriously consider the role of demographic transition and improved measurement of human capital as the determinant of income per capita convergence.

IX. Notes and references

Acemoglu, D., 2008. *Introduction to Modern Economic Growth*. New Jersey: Princeton University Press.

Aghion, P., Howitt, P. and Mayer-Foulkes, D., 2005. The Effect of Financial Development on Convergence: Theory and Evidence. *Quarterly Journal of Economics*, 120(1), 173-222.

Barro, R. J. and Sala-i-Martin, X., 1992. Convergence. *Journal of Political Economy*, 100(2), 223-251.

Barro, R. J. and Sala-i-Martin, X., 1997. Technological Diffusion, Convergence and Growth. *Journal of Economic Growth*, 2(1), 1-26.

Barro, R. J. and Sala-i-Martin, X., 1998. *Economic Growth*. Cambridge, MA: MIT Press.

Barro, R. J. and Lee, J. W., 2010. A New Dataset of Educational Attainment in the World, 1950-2010. *NBER Working Paper No. 15902*.

Basu, S. and Weil, D. N., 1998. Appropriate Technology and Growth. *Quarterly Journal of Economics*, 113(4), 1025-1054.

Baumol, W. J., 1986. Productivity Growth, Convergence and Welfare: What the Long-Run Data Show. *American Economic Review*, 76(5), 1072-1085.

Becker, G. S., Murphy, K. M. and Tamura, R., 1990. Human Capital, Fertility and Economic Growth. *Journal of Political Economy*, 98(5), 12-37.

Berglöf, E. and Bolton, P., 2002. The Great Divide and Beyond: Financial Architecture in Transition. *Journal of Economic Perspectives*, 16(1), 77-100.

Breusch, T. S. and Pagan, A. R., 1979. The LM Test and its Applications to Model Specification in Econometrics. *Review of Economic Studies* 47(1), 239-254.

Cohen, D., 1996. Tests of the Convergence Hypothesis: Some Further Results. *Journal of Economic Growth*, 1(3), 351-361.

Coricelli, F. and Campos, N. F., 2002. Growth in Transition: What We Know, What We Don't Know and What We Should. *Journal of Economic Literature*, 40(3), 793-836.

De Long, J. B., 1988. Productivity Growth, Convergence and Welfare: Comment, *American Economic Review*, 78(5), 1138-1154.

Eichner, T. S. and Turnovsky, S. J., 1999. Convergence in a Two-Sector Nonscale Model of Growth. *Journal of Economic Growth*, 4(4), 413-428.

Estrin, S., Urga, G. and Lazarova, S., 2001. Testing for Ongoing Convergence in Transition Economies, 1970 to 1998. *Journal of Comparative Economics*, 29(4), 677-691.

Good, D. F., 1994. The Economic Lag of Central and Eastern Europe: Income Estimates for Habsburg Successor States, 1870-1910. *Journal of Economic History*, 54(4), 869-891.

Hausman, J., 1978. Specification Tests in Econometrics. *Econometrica*, 46(6), 1251-1271.

Islam, N., 2005. Growth Empirics: A Panel-Data Approach. *Quarterly Journal of Economics*, 110(4), 1127-1170.

Jones, C. I., 1997. Convergence Revisited. *Journal of Economic Growth*, 2(2), 131-153.

Kutan, A. M. and Yigit, T. M., 2009. European Integration, Productivity Growth and Real Convergence: Evidence from the New Member States. *Economic Systems*, 33(2), 127-137.

Lee, K., Pesaran, H. M. and Smith, R., 1998. Growth Empirics: A Panel-Data Approach - A Comment. *Quarterly Journal of Economics*, 113(1), 319-323.

Lucas, R. E. (2004). *Lectures on Economic Growth*. Cambridge, MA: Harvard University Press.

Mankiw, N. G., Romer, D. and Weil, D. N., 1992. A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics*, 107(2), 407-437.

McQuinn, K. and Whelan, K., 2007. Conditional Convergence and the Dynamics of Capital-Output Ratio. *Journal of Economic Growth*, 12(2), 159-184.

Mrkaic, M., 2002. The Growth of Total Factor Productivity in Slovenia, *Post-Communist Economies*, 14(4), 445-454.

O'Neill, D., 1995. Education and Income Growth: Implications for Cross-Country Inequality. *Journal of Political Economy*, 103(6), 1289-1301.

Polanec, S., 2004. Convergence at Last?: Evidence from Transition Countries. *Eastern European Economics*, 42(4), 55-80.

Quah, D. T., 1996. Convergence Empirics Across Economies with (Some) Capital Mobility. *Journal of Economic Growth*, 1(1), 95-124.

Quah, D. T., 1997. Empirics for Growth and Distribution: Stratification, Polarization and Convergence Clubs. *Journal of Economic Growth*, 2(1), 27-59.

Solow, R. M., 1956. A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics*, 70(1), 65-94.

Solow, R. M., 1957. Technical Change and Aggregate Production Function. *Review of Economics and Statistics*, 39(3), 312-320.

Summers, R. and Heston, A., 1991. The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988. *Quarterly Journal of Economics*, 106(2), 327-68.

Tamura, R., 1991. Income Convergence in an Endogenous Growth Model. *Journal of Political Economy*, 99(3), 522-540.

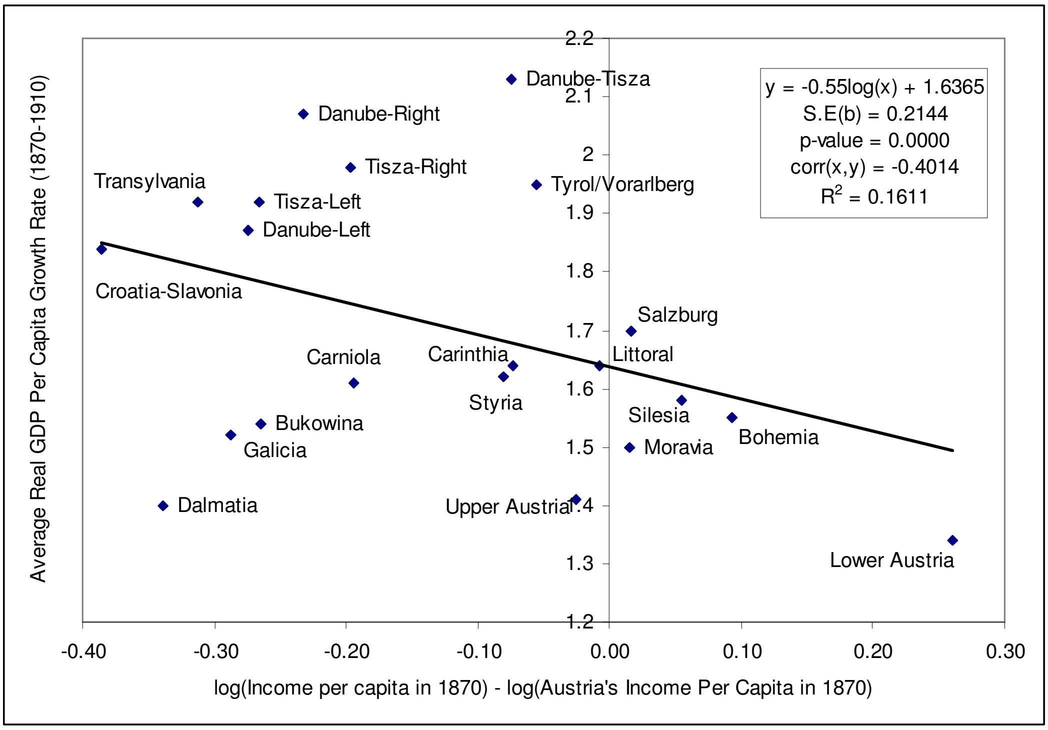
United Nations, 2009. Department of Economic and Social Affairs, Population Division, *World Population Prospects: The 2008 Revision*.

U.S. Department of Agriculture, 2010. International Macroeconomic Data Set, Economic Research Service.

Ventura, J., 1997. Growth and Interdependence. *Quarterly Journal of Economics*, 112(1), 57-84.

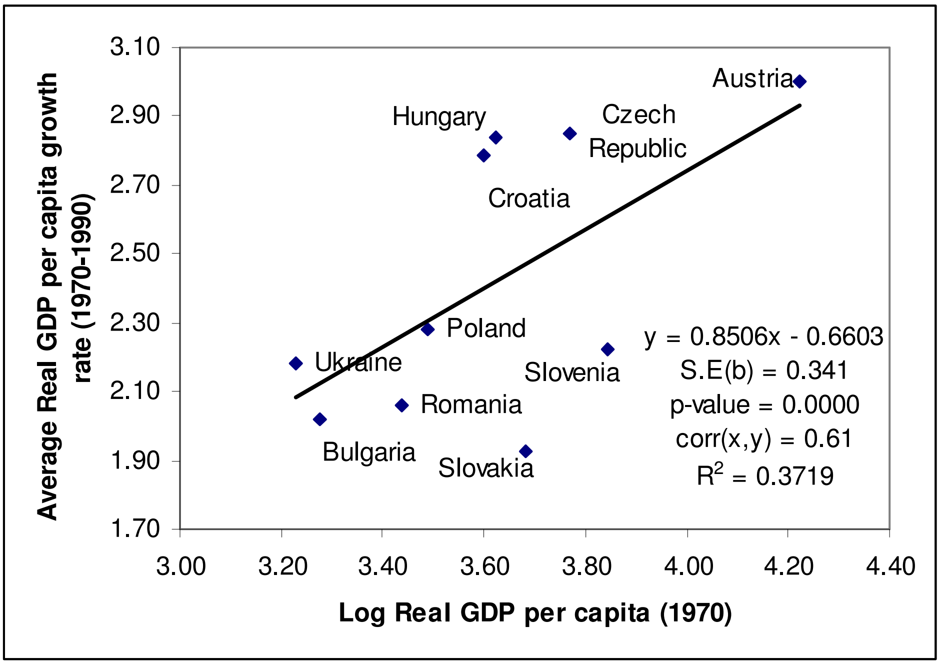
Appendix

Figure 1: Unconditional β-Convergence in Habsburg Empire



Source: Good (1994), own estimate

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



Source: International Macroeconomic Data Set (2010)

Table 1: Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max
Real GDP Per Capita Growth Rate	119	2.993	5.745	-19.33	11.13
Log (GDP per capita relative to the US)	119	1.519	0.112	1.3	1.79
Log (Baseline GDP per capita)	119	0.102	0.412		2.02
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 2: Conditional Convergence

Dependent variable is real GDP per capita growth rate			
	(1) **Fixed Effects**	**(2)** **Fixed-Effects**	**(3)** **Fixed-Effects**
Constant	-52.422***	-49.837***	-54.872***
	(13.561)	(13.818)	(13.193)
$\log\left(Y/L\right)_{t=0}$	-0.0864***	-0.0873***	-0.0689***
	(0.0092)	(0.0093)	(0.0102)
$\log\left[\left(Y/L\right)_j - \left(Y/L\right)_{US}\right]$	0.3273***	0.3408***	0.1621*
	(0.0688)	(0.0702)	(0.0833)
$\log\left(I/Y\right)$	0.0467	0.0490	0.0778*
	(0.0481)	(0.0481)	(0.0464)
Total Fertility Rate		-0.0372	-0.0668*
		(0.0381)	(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: Standard errors denoted in the parentheses. Significance levels marked by *** (1%) **(5%) *(10%)

Source: author's own estimates

Table 3: Breusch-Pagan LM Test for Random Effects

	(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 4: Hausman specification test

(1)

	Coefficients		Asymptotic Covariance
	$\mathbf{b}_{fixed}$	β_{random}	$Var\left[\mathbf{b}_{fixed}-\beta_{random}\right]^{-1}$
$\log\left(Y/L\right)_{t=0}$	-0.0864	-0.0884	
$\log\left[\left(Y/L\right)_{j}-\left(Y/L\right)_{US}\right]$	0.3273	0.0806	0.058
$\log\left(I/Y\right)$	0.0467	0.0399	0.007
Prob> χ^2			0.0000

(2)

	Coefficients		Asymptotic Covariance
	$\mathbf{b}_{fixed}$	β_{random}	$Var\left[\mathbf{b}_{fixed}-\beta_{random}\right]^{-1}$
$\log\left(Y/L\right)_{t=0}$	-0.0873	-0.0874	
$\log\left[\left(Y/L\right)_{j}-\left(Y/L\right)_{US}\right]$	0.3408	0.0936	0.5796
$\log\left(I/Y\right)$	0.0490	0.0397	0.0075
Total Fertility Rate	-0.0373	0.0331	0.0138
Prob> χ^2			0.0000

(3)

	Coefficients		Asymptotic Covariance
	$\mathbf{b}_{fixed}$	β_{random}	$Var\left[\mathbf{b}_{fixed}-\beta_{random}\right]^{-1}$
$\log\left(Y/L\right)_{t=0}$	-0.0689	-0.0839	0.0025
$\log\left[\left(Y/L\right)_{j}-\left(Y/L\right)_{US}\right]$	0.1619	0.1105	0.0694
$\log\left(I/Y\right)$	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