Education, Health and the Dynamics of Cross-Country Productivity Differences

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Abstract

In this paper, we study the dynamics of the total factor productivity (TFP) and the impact of education and health on the growth rate of TFP (GRTFP) in a sample of 97 countries for the period 1960-2005. We estimate TFP by using the augmented Solow model in which health capital is a factor of production. We find that both health and education have a positive and significant effect on GRTFP. The results support the Nelson-Phelps (1966) hypothesis that education plays an important role in technology diffusion. However, results also suggest that in designing policies which facilitate technology diffusion, we need to broaden the concept of human capital to include health.

Keywords: Augmented Solow Growth Model, Productivity, TFP Growth, Education, Health

JEL Code: F43; E23; N10; N30; O47

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1 Introduction

Recent studies suggest that cross-country per-capita income differentials are largely accounted for by the differences in the total factor productivity (TFP) rather than by the differences in the use of factors of production (e.g. Islam 1995, Hall and Jones 1999, Kumar and Kober 2012). The estimated differences in the TFP levels have been found to be persistent and large (e.g. Islam 2003, Liberto et al. 2011). These large differences in TFP raise many important questions such as why are there such differences in the cross-country TFP; why do not low TFP countries adopt new and advanced technologies to catch up with high TFP countries; and what are the determinants of the catch-up process? In this paper, we examine these questions. In particular, we analyze the effects of human capital, both education and health, on the process of change in the TFP across countries and over time.

Nelson and Phelps (1966) were first to argue that the adoption and the effective use of new technology depend not only on the availability, but also on the capability of countries to adopt and effectively use these technologies. They suggest that education plays a crucial role in determining the capability of countries to adopt new technologies that allows developing countries to catch up with advanced countries. There is a growing empirical literature which examines the Nelson-Phelps hypothesis. This literature finds that education has a positive and significant impact on the growth rate of TFP (Benhabib and Spiegel 1994, Aiyar and Feyrer 2002, Liberto et al. 2011).

However, none of these studies examine the effect of health capital on the growth rate of TFP (GRTFP). As a crucial aspect of human capital, health capital can affect GRTFP both directly and indirectly through its impact on the incentive of firms to adopt new technologies. The incentive of firms to adopt new technologies in part depends on the availability of workers and their capacity to work. There is a large literature which examines the link between health, undernutrition and the capacity of work in the poor countries (e.g. Dasgupta and Ray 1990, Ray 1993). This literature suggests that healthier workers have larger capacity to work and are thus more productive. Workers with better physical condition are less likely to be absent from work. Lavovsky (2001) estimates that the burden of disease in the developing countries measured in terms of disability-adjusted life years (DALYs) lost per-million people is about twice of that in the developed countries.

Moreover, healthy workers are likely to be more willing to acquire education and skills because of an increase in return from education. Also there is a large number of studies which suggest that healthier children have better cognitive abilities (Morley and Lucas 1997, UN 2004, Watanabe et. al. 2005). Disease environment can also affect the development of institutions.

Acemoglu et. al. (2001) argue that higher mortality rate of European settlers in tropical countries induced them to develop exploitative institutions in these countries.

Examining the role of health capital is also important to clarify the effect of education on the TFP growth. Empirical evidence suggests that both education and health are significantly and positively correlated. Omitting health capital in the regression model may lead to the omitted variable bias and the overestimation of the effect of education on the TFP growth.

A number of empirical studies show that the effect of education on per-capita income (e.g. Knowles and Owen 1995, McDonald and Roberts 2002) and TFP (Kumar and Kober 2012) becomes insignificant, once health capital is included in the regression model in a cross-country setting. The weak relation found between the per-capita income and education has led to the debate, whether education affects per-capita income directly as a factor of production or indirectly through its effects on TFP and TFP growth (Nelson and Phelps 1966, Lucas 1990).

To analyze the effects of education and health on the TFP dynamics, we first estimate the TFP of individual countries adopting the panel data approach developed by Islam (1995, 2003). Cross-country TFP is estimated as the country-fixed effect similar to many existing studies (e.g., Islam 1995 2003, Liberto et al., 2011; Kumar and Kober 2012). We estimate the augmented Solow model which includes health capital as a factor of production using the data for the period 1960-2005.

For studying the TFP dynamics, the full sample is split into two sub-periods, the initial period, 1960-85, and the subsequent period, 1985-05. The period 1985-05 witnessed the IT revolution which affected different countries differently with the advanced countries being the main beneficiary (Jorgenson 2005). We estimate cross-country TFP for these two sub-periods and calculate the annual growth rate in TFP (GRTFP) by using these estimates. The period 1985-2005 covers the IT revolution phase.

In the second stage, we examine the effects of health and education on GRTFP. The main findings of this paper are as follows. First, health capital has a significant positive effect on GRTFP. This result is robust to alternative indicators of health capital such as life-expectancy, infant mortality rate, and the incidence of undernourishment. Moreover, education has a positive and significant effect on GRTFP. The results suggest that education has an independent effect on GRTFP and confirms the hypothesis of Nelson and Phelps (1966).

Most of the literature and policy discussions have focussed on the role played by education in facilitating the transfer, adoption, and utilization of technologies and productivity enhancing measures. The results suggest that health capital plays a crucial role in increasing the TFP growth. In designing policies to increase the TFP growth, one needs to broaden the concept of human capital to include health.

The rest of this paper is organized as follows: In section 2, we describe the methodology used to estimate TFP and GRTFP. Section 3 discusses the estimation method, data, and the estimation results of the augmented Solow model. Section 4 provides a preliminary analysis of the TFP dynamics between the sub-periods 1960-1985 and 1985-2005. Section 5 discusses the determinants of GRTFP. Section 6 provides the analysis of the estimated results. Section 7 concludes.

2 Methodology

2.1 The Augmented Solow Model

Let the production function be

$$Y_{it} = [A_{it}L_{it}]^{1-\alpha-\beta}K_{it}^{\alpha}H_{it}^{\beta} \tag{1}$$

where Y is output, A is technology, L, K, and H are labor, physical and health capital respectively, α and β are the elasticities of output with respect to physical and health capital respectively, and the subscripts denote country (i) and time (t).[1] Letting lower case letters with ˆ denoting variables per "effective" labor unit (e.g. $\hat{y}_{it} = \frac{Y_{it}}{A_{it}L_{it}}$) the production function can be written in the intensive form as

$$\hat{y}_{it} = \hat{k}_{it}^{\alpha}\hat{h}_{it}^{\beta}. \tag{2}$$

Assume that labor force in country i grows at the country specific rate, n_i, and the technology frontier advances at the common rate, g, across all countries and that the physical and human capital stocks depreciate at the rate, δ. Thus, $L_{it} = L_{i0}\exp^{n_i t}$ and $A_{it} = A_{i0}\exp^{gt}$, where 0 indicates the initial period.

Let $\hat{k}_i^*$ and $\hat{h}_i^*$ denote the steady state level of physical and health capital *per-effective labor unit* respectively in country i. Also let s_i^K denote the

[1] We do not include education as a factor of production. In the growth regression, none of the indicators of education turn out to be significant. These results are similar to previous studies, which show that education has insignificant effect on real per-capita income either when fixed-effects (e.g. Islam 1995, Liberto et. al. 2011) or health indicators (Knowles and Owen 1995) or both (e.g. McDonald and Roberts 2002) are included in the growth regression. Also sample size falls as the data for education for the entire period 1960-2005 is available for a smaller number of countries.

investment rate for the physical capital respectively in country i. Then, one can derive (see Mankiw et. al. 1992 and Islam 1995)

$$\ln y_{it_2} = \frac{(1-\exp^{-\lambda\tau})\alpha}{1-\alpha}\ln s^K_{i\tau} - \frac{(1-\exp^{-\lambda\tau})\alpha}{1-\alpha}\ln(n_{i\tau}+g+\delta)+$$

$$\frac{(1-\exp^{-\lambda\tau})\beta}{1-\alpha}\ln h^*_{i\tau}+\exp^{-\lambda\tau}\ln y_{it_1}+g(t_2-\exp^{\lambda\tau}t_1)+(1-\exp^{-\lambda\tau})\ln A_{i0} \quad (3)$$

where $\lambda=(1-\alpha-\beta)(n+g+\delta)$ is the rate of convergence. y_{it_1} and y_{it_2} refer to per-worker real income in periods t_1 and t_2 respectively. $s^K_{i\tau}$, $h^*_{i\tau}$, and $n_{i\tau}$ refer to the average savings rate, health capital, and the labor force growth rate respectively over the period $\tau=t_2-t_1$ in country i.

Equation (3) represents a dynamic panel data model with $(1-\exp^{-\lambda\tau})\ln A_{i0}$ as the time-invariant fixed country-effect term. It can be written in the following conventional form of panel data literature:

$$y_{i,t}=\gamma y_{i,t-1}+\sum_{j=1}^{3}\phi_j x^j_{it}+\eta_t+\mu_i+v_{it} \quad (4)$$

with

$$y_{i,t}=\ln y_{it_2};\ y_{i,t-1}=\ln y_{it_1};\ x^1_{it}=\ln s^K_{i\tau};\ x^2_{it}=\ln(n_{i\tau}+g+\delta);$$

$$x^3_{it}=\ln h^*_{i\tau};\ \eta_t=g(t_2-\exp^{\lambda\tau}t_1)\ \&\ \mu_i=(1-\exp^{-\lambda\tau})\ln A_{i0} \quad (5)$$

where v_{it} is the idiosyncratic error term with mean zero. In the first step, we use (4) and (5) to derive estimates of α, β, and the productivity level, A_{i0}. A_{i0} can be recovered from the following relation

$$\ln A_{i0}=\frac{\mu_i}{1-\exp^{-\lambda\tau}}. \quad (6)$$

Note that given the assumption that g is constant across countries and time period, the TFP level, A_{it}, across countries at time t differ only to the extent that the initial productivity level A_{i0} differ. Also the relative changes in the TFP level across countries over time will be due to differential changes in A_{i0}. In our theoretical framework, the dynamics of the TFP and the technology diffusion can be analyzed by estimating A_{i0} for several time-periods as in Islam (2003) and Liberto et. al. (2011).

Similar to Liberto et. al. (2011), we estimate (5) for two periods 1960-85 and 1985-05. Let A_{i1960} and A_{i1985} indicate the initial TFP levels during 1960-85 and 1985-05 respectively. In the second step, we analyze determinants of the growth rate of TFP (GRTFP). For this analysis, we estimate the following regression:

$$\mathrm{GRTFP_i} \equiv \frac{\ln A_{i1985} - \ln A_{i1960}}{25} = \Xi X + u_i \tag{7}$$

where Ξ is the vector of coefficients , X is the matrix of explanatory variables including a constant term, the initial TFP level ($\ln A_{i1960}$) and the indicators education and health, and u_i is the idiosyncratic term with mean zero.

Under the assumption that the current TFP heterogeneity is at its stationary value, the coefficient of the explanatory variables other than the constant should be zero. However, if there is a technology catch-up process then we expect the countries with the initial TFP level lower than their stationary value to have higher GRTFP. Thus, the coefficient of the initial TFP level should be negative and significant. Also, if higher human capital leads to a faster catch up rate, then the coefficients of the indicators of human capital should be positive and significant.

3 Estimation Method and Data for the Augmented Solow Model

3.1 Estimation Method

We first use the Breusch-Pagan (BP) test to assess the need for the country fixed effects with null, $H_0 : Var(\mu_i) = 0 \;\forall\; i$. If the BP test rejects the null, then we test whether fixed or random effects model is more appropriate using the Hausman (H) test. In the case, the H test rejects the null hypothesis that both fixed effects and random effects estimates of the model are consistent, we use fixed effects model.

In the case of fixed effects model, we use the Arellano and Bond (1991) generalized method of moment method (AB method) to estimate parameters of (4). This method is widely used to estimate dynamic panel models with relatively short number of time-periods. For the comparison purpose we also estimate (4) using least squares dummy variable (LSDV) method. However, in the presence of lagged dependent variable LSDV estimator is not consistent.[2]

[2]We do not use the system- GMM suggested by Blundell and Bond (1998) as it assumes that the growth rate of per-capita income, Δy_{it} is independent of the fixed effect, μ_i.

In the AB method, first differencing is used to eliminate fixed country effects. First differencing produces an equation that is estimable using instrument variables. This method uses a matrix of instruments to produce a consistent estimator. The lagged dependent variable in first difference is instrumented using level values of dependent variable lagged two or more periods, level values of predetermined variables lagged one period and more and differences of strictly exogenous variable.

The AB estimator has been shown to perform well in cross country panels (Judson and Owen 1999). Arellano and Bond (1991) suggest that the Sargan test of over-identifying restrictions be applied to test that the model is identified. Also, the error term in the first difference may not have an autocorrelation of order two. If this is violated, then the AB estimator is not consistent.

The AB estimator does not directly estimate country effects, μ_i. The estimated country effects are obtained as follows:

$$\hat{\mu}_i = \overline{y}_{i,T} - \hat{\gamma}\overline{y}_{i,T-1} - \sum_{j=1}^{3} \hat{\phi}_j \overline{x}_i^j - \overline{\hat{\eta}} \tag{8}$$

where

$$\overline{y}_{i,T} = \frac{1}{T}\sum_{t=1}^{T} y_{it},\ \overline{y}_{i,T-1} = \frac{1}{T}\sum_{t=1}^{T-1} y_{it},\ \overline{x}_i^j = \frac{1}{T}\sum_{t=1}^{T} x_{it}^j,\ \overline{\hat{\eta}} = \frac{1}{T}\sum_{t=1}^{T} \eta_t$$

with $\hat{\eta}_t$ being the estimates of the time effects. Using the estimates of μ_i, the implied values of $\ln A_{i0}$ can be recovered from equation (6).

3.2 Data

The full sample includes 97 countries for which data is available consistently from 1960 to 2005. Small countries with populations less than one million in the terminal year are excluded, because their real GDP is more likely to be affected by specific factors.

The main sources of our data are the Penn World Table (PWT) version 7 and the World Development Indicators. Real GDP per worker and saving rate are directly collected from PWT. We divide real GDP per capita by real

However, if there is catch-up process then this assumption is likely to be invalid as the income growth rate is likely to depend on the TFP growth rate. The other commonly used estimator is suggested by Kiviet (1995), which corrects for the bias in the LSDV estimates. However, this assumes that the regressors are strictly exogenous.

GDP per worker in order to compute the labor force participation rate. Then using the population data and the labor force participation rate, we compute labor force growth rate. The variable $n_i + g + \delta$ is the growth rate of working age population plus the technology growth rate and the depreciation rate. Similar to Mankiw et al. (1992), $g + \delta$ is assumed to be equal to 0.05 for each country.

We use life-expectancy as an indicator of health capital. Adopting the transformation similar to Anand and Ravallion (1993), we define $LLE = -\ln(90 - LE)$, where $(90 - LE)$ is the shortfall of average life expectancy (LE) at birth from 90 years. This proxy for health capital is widely used in the literature (Knowles and Owen 1995 2008, McDonald and Roberts 2002). The data for the life expectancy is taken from the World Development Indicators. The life-expectancy data is available for 97 countries.

Similar to Islam (1995, 2003), Liberto et al. (2011) and Kumar and Kober (2012), we use a five-year span data instead of annual data. For each country, there are ten time points: 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, and 2005. All variables are averages over five years except for per worker income. For example, when t=1965, then t-1= 1960, and saving rate, labor force growth rate, and health capital are measured by the averages over the period 1961-65. However, the dependent variable is the real income per worker in 1965 and the lagged dependent variable is the real income per worker in 1960. The error term represents other factors besides explanatory variables that affect real income per worker over five years. The use of five-year data also reduces the serial correlation.

To analyze the TFP dynamics, we split the total period into two subperiods. The initial period is 1960-85 and the subsequent period is 1985-05.

3.3 Estimated Results of the Augmented Solow Model

Table 1 presents the results of the first stage regression. The upper panel shows the results for the initial period: 1960-85 and the lower panel for the subsequent period: 1985-2005. In both cases, we first perform the BP and the H tests. The results of these tests suggest that fixed effects model is the appropriate model for estimating (4).

The second column of the table report results from the LSDV estimation method. The third and the fourth columns report results from the AB method. Standard errors are reported in the parentheses. The AB method provides for one-step and two-step estimators. Before proceeding to discuss the results, we clarify their interpretations. The one-step method assumes the absence of heteroskedasticity and the Sargan test over-rejects when this is not true. The two-step estimator uses the differenced residuals from the first-step estimator for additional information. The standard errors of the two-step estimator tend to be biased downward in the case of small samples (Baltagi 2005). To correct for this bias, we apply the procedure suggested by Windmeijer (2005).

The upper panel of table 1 shows that all variables have expected sign and they are highly significant. Savings rate and LLE have a positive and significant effect on the per-capita income. The labor force growth rate have a negative and significant effect on the per-capita income. Results are very similar for the subsequent period (lower panel). All variables have expected sign. All variables are highly significant except for the labor force growth rate. The coefficient of the labor force growth rate turns out to be insignificant when the AB estimators are used. The Sargan test suggests that the over-identifying restriction are not rejected for all specifications. Also, the test for AR(2) does not reject the null hypothesis of the absence of the second order auto-correlations in all the specifications.

4 Cross-Country TFP and TFP Dynamics

Since we use three estimators, there are three estimates of TFP levels. This raises the question of which estimate of TFPs to use. For selecting among these three estimators, we use the procedure suggested by Bond et. al. (2001). They suggest to use the results obtained with LSDV and a pooling OLS estimator as benchmarks to detect the possible bias in other estimates. In particular, in the dynamic panels the OLS coefficient of the lagged dependent variable is known to be biased upwards. Conversely, the LSDV estimate of the coefficient of the lagged dependent variable is known to be biased downward. The true value of parameter should lie between these two estimates.

Table 1 shows that the estimated coefficient of the lagged dependent variable satisfies this criteria for the initial period (1960-85) for both the AB-1 and the AB-2 estimators.[3] However, only the AB-2 estimator satisfies this criteria for the subsequent period (1985-2005). Due to this, we take two-step specification as our preferred model and use its coefficient estimates to calculate TFP levels for both the periods.

The estimated values of TFPs, relative TFPs, and the rank of countries are reported in Appendix 2. We define relative TFP (ReTFP) as the ratio of

[3] For pooled regression (not reported), the coefficient of $y_{i,t-1}$ are 0.8543 and 0.8273 respectively for 1960-85 and 1985-2005, when LLE is used. The corresponding numbers in the case of LMR are 0.8328 and 0.8564.

a country's TFP relative to the United States (A_i/A_{US}), which is the country with the highest productivity in both the periods.

4.1 TFP Dynamics

First, we discuss some salient features of the whole cross-country distributions. We find that there is a very high rank correlation between the rank of a country in the initial period and the subsequent period (0.89). Table 2 provides summary statistics of TFPs and relative TFPs. The table shows that there are large productivity differences across countries, with the productivity level of the lowest ranked country being about 5% of the productivity level of the highest ranked country. It shows that the average and the median TFP have increased over time. However, the average and the median *relative* TFP have declined over time. This suggests that in many countries the growth rate in TFP has been less than that of the United States. This is evident in figure 1 which plots the relative TFP in the initial and subsequent periods. These figures show that most of the countries have under-performed the U.S. in terms of TFP growth. Our estimate shows that 53 countries out of 97 under-performed the U.S. in this period.

Figure 2 plots the distributions of relative TFP for the initial and subsequent periods. In the figure, one can observe twin-peaked distribution of TFP for both the initial period and the subsequent period, with low TFP countries forming a well defined group. These results are similar to ones reported in the previous studies (Feyrer 2008, Liberto et. al. 2010). The standard deviations of relative TFP (Table 2) are also roughly similar between these two periods. Overall, the evidence suggests that the dispersion of TFP has remained virtually the same and that there is lack of overall convergence in TFP.

While there does not seem to be notable changes in the overall distribution of TFP, there are significant changes in the TFP of many individual countries. Table 3 lists the top ten countries in terms of the TFP for both periods. The list is dominated by the North American and Western European countries with the United States being the country with the highest productivity levels in both the initial and the subsequent periods.

Over time there are significant changes in the list of top TFP countries. U.S., Austria, and Pureto-Rica remain among the top ten countries over these two periods. Many resource rich countries such as Venezuela, Jordan, and Gabon figure among top ten countries in the initial period. However, none of these countries were among top 10 in the subsequent period. Most notably, Ireland, Singapore, and Mauritius join the top ten list in the subsequent period. These countries experienced very high growth rate in income during

80's and 90's.

Table 4 lists the bottom ten countries in terms TFP. The list is dominated by African countries. What is interesting is that there is much less movement in the list of the bottom 10 countries. In our sample seven countries (all African), remained among the bottom 10 countries in both the periods.

Table 5 lists the countries whose rank changed by 15 or more over these two periods. Twelve countries experienced increase in rank by 15 or more. Singapore (+30), Thailand (+29), and Mauritius (+25) were the top three gainers. Large countries such as China and India who have experienced very high growth rate in income in the last two decades improved their ranking by 20 and 16 respectively. There were 10 countries which lost their ranking by 15 or more over this period. The top three losers were Jordan (-40), Nicaragua (-37), and the Democratic Republic of Congo (-29).

5 TFP Convergence and the Determinants of GRTFP

5.1 The Determinants of GRTFP

As discussed in the last section, there are significant differences in the TFP levels and the TFP dynamics across countries. It leads to questions such as why some countries have high GRTFP but many developing countries have relatively low GRTFP, what are the determinants of the catch up process, and what is the role of human capital. To answer these questions, we estimate the following regression model:

$$GRTFP_i = fIPL_i + bH_i + cS_i + dQ + u_i \tag{9}$$

where $GRTFP_i$ denotes the growth rate of TFP in country i, IPL_i indicates the log of the TFP level in the initial period, f is the associated coefficient; H_i is the indicator of health capital and b is the associated coefficient; S is the indicator of education capital and c is the associated coefficient; Q is the matrix of other regressors including a constant and d is the associated vector of coefficients; and u_i is the idiosyncratic error term. The description of each determinant is given in Appendix 1.

We include the initial level of TFP as regressor to test for the absolute and the conditional convergence in TFP separately. The absolute convergence assumes that there is a unique global long run level of TFP, and TFP levels of countries converge to that level. The notion of absolute convergence can be tested by regressing GRTFP on the TFP level in the initial period. The negative and significant coefficient of the TFP level in the initial period implies absolute convergence.

The conditional convergence assumes that each country has its own long run level of TFP and over time its TFP converges to this level. The long run level of TFP of a country depends on factors such as health capital, education and other explanatory variables. The notion of conditional convergence can be tested by regressing GRTFP on the TFP level in the initial period and other explanatory variables. The negative and significant coefficient of the TFP level in the initial period implies conditional convergence.

As discussed earlier, health capital can affect GRTFP in numerous ways. We use three indicators of health capital: two based on the mortality rate and one based on undernourishment. We define life expectancy based mortality rate as the shortfall of life expectancy relative to the target as before ($\frac{1}{90-LE}$) as in the previous section. In the regression, we use log of the average of life expectancy based mortality rate ($ILLE$) for the period 1960-1985. We also use log of the average infant mortality rate (IMR) for the period 1960-85. This data is available for 64 countries. Finally, we also use the log of the average proportion of the undernourished population ($LUND$) for the period 1960-85 as an alternative indicator of health capital. This data is available for 50 countries. All data are from World Development Indicators.

As discussed earlier, education can affect GRTFP in many ways. Education helps people build up knowledge and skills in order to enhance their capability to adopt technology, thereby improving the TFP. Follower countries with adequate education are more likely to take advantage of technology diffusion and catch up with advanced countries. Many studies (e.g., Benhabib and Spiegel 1994, Aiyar and Feyrer 2002, Liberto et al. 2011) find that education is positively and significantly related to GRTFP. We proxy education by log of the average years of schooling for the period 1960-1985 (LAV). The average years of schooling is supposed to be a better indicator of educational capital than enrollment ratios (Human Development Report 2010) and is widely used in the literature. The data are from Barro and Lee (2010).

Besides health and education, GRTFP can depend on other factors, such as openness to trade, urbanization, demographic and cultural factors, and legal origin. Openness to trade provides countries with opportunities to exchange information and technology with the rest of the world. It also provides domestic firms with larger market. All these factors may encourage adoption and use of latest technologies. Miller and Upadhyay (2002) find that a stable and high export-to-GDP ratio has a significant positive effect on productivity. However, Choudhri and Hakura (2000) find that openness to trade only enhances productivity growth in industries with potentially high growth. To measure openness to trade, we use log of the average of the ratio of export plus import to total GDP for the period 1960-1985 (LOP). The data are from the World Development Indicators.

Urbanization can also affect GRTFP in many ways. As industries gather in urban areas, firms benefit from agglomeration economies. Costs of production may decline because of an increased number of suppliers and opportunities to specialize. Moreover, urban areas with a cluster of firms may attract more workers to enter the labor market, especially specialized and skilled workers. An increase in the size of the labor market can lead to a better match between the skilled workers and the job requirements that result in productivity growth (Kim 1989). In addition, urbanization may lead to better provision of social infrastructure such as education and health and greater amenities. All these factors can lead to urbanization having a positive effect on GRTFP.

However, there may be negative association between urbanization and GRTFP. Firstly, advanced countries are associated with higher level of urbanization. These countries already have high level of TFP and may be near their steady level of TFP. These countries are expected have lower GRTFP. Kumar and Kober (2011) find that urbanization is positively and significantly related to the TFP level. On the other hand, less advanced countries with low TFP may be further away from their steady state level of TFP and thus expected to have a higher GRTFP. In addition, over-concentration in urban areas results in high costs and crowded areas which are less attractive for both firms and workers. Pollution caused by clustered industrial areas may also discourage firms and workers to move urban areas and discourage productivity. Henderson (2003) suggests that there is an optimal degree of urban concentration to maximize productivity. Thus, we may observe positive or negative association between urbanization and GRTFP. We measure urbanization by the log of the average ratio of urban population to total population for the period 1960-1985 (LUR). The data are from the World Development Indicators.

There is a large literature which suggests that legal origin of a country have a significant effect on productivity level and investment in health and educational capital. Legal system of a country determines the security and enforcement of private property rights, rights of the states, and also quality of governance (La Porta et. al. 1999, 2008). La Porta et. al. (1999, 2008) argue that common law countries with an English legal origin are more supportive of private outcomes compared to civil or socialist law. To capture the effects of legal origin, we use dummies for common law countries (ENGLISH). The data is from La Porta et. al. 1999.

Recently the effects of ethnic diversity on investment, growth, quality of government, civil wars, political instability etc. have received a great deal of attention (Alesina et. al. 2003, Easterly and Levine 2003). Ethnic diversity can affect productivity in many ways. Firstly, some authors have argued that ethnically diverse societies have tendency of ethnic conflicts, civil wars, and political instability. Such conflicts and instabilities have a negative impact on investment. Ethnic conflicts and political instability may generate a high level of corruption, private property may not be secure, and in general lead to lower quality of governance. All these factors can also negatively affect investment in health and education. Apart from that unstable political system and civil wars may lead to mass migration to urban areas leading to over-crowing and expansion of slums. We include the index of ethno-linguistic fractionalization (ETH) taken from La Porta et. al. (1999) as one of the regressors.

Religion has been used as a proxy for work ethic, tolerance, trust, and openness to new ideas. Weber (1958) emphasizes the historical importance of the protestant ethic in the spread of capitalism. He suggests that Protestants have better work ethics and more open to new learning and ideas. Landes (1998) argues that Catholic and Muslim religions have been historically hostile to new ideas and learning. These societies enormously increased power of religious organizations and states to maintain their political and religious influence. We use the percentage of muslim population ($MUSLIM$) as one of the regressors. The data is from rom La Porta et. al. (1999).

We also include dummy for African countries ($AFRICA$) as these countries face special challenges.

6 Estimation Results

Tables 6 and 7 show the estimated results. We first regress $GRTFP_i$ on the initial productivity level (IPL) (Table 6) and find that its coefficient is negative and significant at 1% level of significance. This suggests the presence of absolute convergence. Then we incorporate measures of health capital ($ILLE$) and educational capital (LAV) in models (2) and (3) respectively. We find that both these variables have expected signs and are highly significant. We also find that the coefficient of the initial productivity level becomes much larger. This suggests that the rate of conditional convergence is much higher.

In model (4), we incorporate indicators of both health and education capital and the degree of urbanization (LUR) and trade openness (LOP). Results suggest that the coefficients of the health and education capital remain significant. However, the coefficient of education capital is significant only at 10%. We also find that the coefficient of education is roughly half of the model (3). However, the size of the coefficient of the health capital remains roughly the same. Results also show that apart from human capital initial productivity level and urbanization have highly significant effect. But the coefficient of urbanization is negative.

Table 7 presents results from the full model. Model (5) shows that the coefficients of both health and education capital remain highly significant. In models (6) and (7), we use alternative measures of health capital (infant mortality rate and undernourished population). We find that in both models the coefficients of both health and education capital remain significant.

Apart from the indicators of human capital, initial productivity level and urbanization are other significant determinants of the productivity growth rate. Only in one specification (model 5), we find that the degree of trade openness is significant albeit at 10%.

Overall, the results suggest that human capital both health and education, the TFP level in the initial period, and urbanization are significant determinants of the growth rate on TFP. The results support the Nelson-Phelps hypothesis that education plays an important role in allowing less advanced countries to catch up with the more advanced countries. They also suggest that health capital, is a crucial determinant of the productivity growth. These results suggests that policies designed to improve education and health are likely to significantly increase TFP growth rate and allow less advance countries to reduce the productivity gaps.

7 Conclusion

In this paper, we studied the dynamics of the total factor productivity (TFP) and the impact of education and health on the growth rate of TFP in a sample of 97 countries for the period 1960-2005. We find that both health and education have a positive and significant effect on the growth rate of TFP. The findings support the hypothesis of Nelson and Phelps that education plays an important role in adopting and utilizing technologies and clarifies its role in the process of growth. Health capital significantly affects growth process directly as a factor of production as well as indirectly through its effect on TFP and its growth. On the other hand, education affects growth process indirectly through its effect on the growth rate of TFP at least in the cross-country regression set-up. The results suggest that in designing policies to facilitate the technology catch-up process, one needs to broaden the concept of human capital to include health. We also find evidence for the conditional convergence in TFP.

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Table 1
Growth Regression Results

Explanatory Variables	LSDV	AB 1-Step	AB 2-Step
Period:	1960-85		
$y_{i,t-1}$	0.587(0.087)*	0.599(0.147)*	0.595 (0.131)*
$ln(s_{i\tau}^{K})$	0.110(0.026)*	0.099(0.041)*	0.142(0.034)*
$\ln(n_{i\tau} + g + \delta)$	-0.120(0.047)**	-0.142(0.072)**	-0.098(0.060)**
$\hat{L}LE_{i\tau}^{*}$	0.330(0.179)**	0.178 (0.232)*	0.059 (0.216)**
p Values:			
BP Test	0.00		
H Test	0.00		
Sargan Test	NA	0.526	0.725
H(0): AR(2) is absent	NA	0.16	0.19
R^2	.985		
No. of Observations	490	392	392
No. of Countries	97	97	97
Period:	1985-05		
$y_{i,t-1}$	0.584(0.074)*	0.520(0.175)*	0.592 (0.137)*
$ln(s_{i\tau}^{K})$	0.121(0.021)*	0.148(0.052)*	0.139(0.047)*
$\ln(n_{i\tau} + g + \delta)$	-0.028(0.009)*	-0.029(0.028)	-0.024(0.023)
$\hat{L}LE_{i\tau}^{*}$	0.209(0.084)*	0.395 (0.124)*	0.392 (0.101)**
p Values:			
BP Test	0.00		
H Test	0.00		
Sargan Test	NA	0.352	0.693
H(0): AR(2) is absent	NA	0.17	0.21
R^2	.991		
No. of Observations	392	294	294
No. of Countries	97	97	97

Note:

1. $*$, $**$, and $***$ indicate significance levels of 1%, 5%, 10% respectively against two-sided alternatives for the t-tests. Number in brackets are standard errors.

2. All specifications included constant and time specific effects (not reported).

3. For AB two-step estimator the standard error is corrected for the small sample bias (Windmeijer 2005).

Table 2
TFP Dynamic: Summary Statistics

	$lnTFP_{60-85}$	$ReTFP_{60-85}$	$lnTFP_{85-05}$	$ReTFP_{85-05}$
Mean	9.44	0.39	11.14	0.37
Median	9.56	0.33	11.10	0.28
S.D.	0.79	0.26	0.76	0.25
Maximum	10.66	1	12.39	1
Minimum	7.42	0.04	9.45	0.05

Table 3
Top Ten Countries

1960-85	1985-05
Belgium	United Kingdom
Austria	Mauritius
Venezuela	Austria
Switzerland	Singapore
Canada	Belgium
Jordan	South Africa
Puerto Rico	Ireland
Netherlands	Norway
Gabon	Puerto Rico
United States	United States

Table 4
Bottom Ten Countries

1960-85	1985-05
Guinea-Bissau	Congo, Dem. Rep.
China	Tanzania
Tanzania	Guinea-Bissau
Malawi	Togo
Burkina Faso	Burundi
Burundi	Nicaragua
Ghana	Cen African Rep
Madagascar	Ethiopia
Togo	Madagascar
Cen African Rep	Burkina Faso

Table 5
Countries with Large Changes in Ranking

Gain ($\geq +15$)	Loss (≤ -15)
China (+20)	Algeria (-15)
Egypt (+24)	Congo, Dem. Rep. (-29)
Hong Kong (+16)	Gambia (-15)
India (+16)	Jordon (-40)
Ireland (+24)	Mexico (-17)
Malaysia (+18)	Nicaragua (-37)
Mali (+18)	Peru (-25)
Mauritius (+25)	Switzerland (-19)
Pakistan (+17)	Syria (-17)
Singapore (+30)	Venezuela (-27)
Sri Lanka (+18)	
Thailand (+29)	

Note: The table list the countries which have gained or lost ranking by 15 or more over the initial and the subsequent periods.

Table 6
GRTFP and the Multiple Forms of Human Capital (OLS)

Var	(1)	(2)	(3)	(4)
IPL	-0.0064^{*}	-0.0144^{*}	-0.0160^{*}	-0.0158^{*}
	(0.002)	(0.003)	(0.002)	(0.003)
$ILLE$		0.0226^{*}		0.0223^{**}
		(0.006)		(0.009)
LAV			0.0088^{*}	0.0046^{***}
			(0.002)	(0.003)
LUR				-0.0058^{**}
				(0.002)
LOP				-0.0022
				(0.002)
R^2	0.11	0.26	0.31	0.40
N	97	97	78	78

Note:

1. $*$, $**$, and $***$ indicate significance levels of 1%, 5% and 10% respectively against two-sided alternatives for the t-tests.
2. Numbers in parentheses are White Heteroskedasticity-Consistent standard errors.
3. Number of included observations vary as data for LAV is not available for all countries.

Table 7
GRTFP and the Multiple Forms of Human Capital
(Full Model)

Var	(5)	(6)	(7)
IPL	-0.0166^{*}	-0.0165^{*}	-0.0178^{*}
	(0.003)	(0.004)	(0.004)
ILLE	0.0320^{*}		
	(0.010)		
IMR		0.009^{**}	
		(0.004)	
LUND			0.0048^{***}
			(0.003)
LAV	0.0063^{**}	0.0099^{*}	0.0121^{*}
	(0.003)	(0.003)	(0.003)
LOP	-0.0034^{***}	-0.0029	-0.004
	(0.002)	(0.0024)	(0.003)
LUR	-0.0064^{**}	-0.0065^{**}	-0.0079^{**}
	(0.003)	(0.003)	(0.003)
AFRICA	0.0013	0.0004	-0.0007
	(0.004)	(0.006)	(0.005)
ETH	0.0142	0.0044	0.0110
	(0.010)	(0.009)	(0.009)
ENGLISH	-0.0041	-0.0048	-0.0054
	(0.003)	(0.003)	(0.004)
MUSLIM	0.0001	0.0001	0.00004
	(0.0001)	(0.0001)	(0.0001)
R^2	0.48	0.42	0.58
N	78	64	50

Note:

1. $*$, $**$, and $***$ indicate significance levels of 1%, 5% and 10% respectively against two-sided alternatives for the t-tests.
2. Numbers in parentheses are robust standard errors adjusted for small sample.
3. Number of included observations vary as data for LAV, IMR, and LUND are not available for all countries.

Appendix 1
Variables and Their Data Sources

- y: Real income per worker in 2005 at constant prices *PWT 7*
- s^K: Investment share of real GDP per capita *PWT 7*
- n: Calculated using LFPR and population *PWT 7*
- $LLE_{i\tau}$: Average life expectancy for the period τ *World Development Indicators*
- ILE: Average life expectancy for the period 1960-85 *World Development Indicators*
- IMR: Average infant mortality for the period 1960-85 *World Development Indicators*
- UND: Average proportion of the undernourished population for the period 1960-85 *World Development Indicators*
- LAV: The average years of schooling of the population aged 15 years and above for for the period 1960-85 *Barro and Lee (2010)*
- LOP: The average ratio of export and import to GDP for the period 1960-85 *World Development Indicators*
- LUR: The average ratio of urban population to the total population for the period 1960-85 *World Development Indicators*
- ENGLISH: Countries with English legal system *La Porta et. al. (1999)*
- ETH: Index of ethno-linguistic fractionalization *La Porta et. al. (1999)*
- MUSLIM: Proportion of muslim population *La Porta et. al. (1999)*
- AFRICA: Dummy for African countries

Appendix 2

TFP Ranking

Country	Relative TFP 1960-85	Rank 1960-85	Relative TFP 1960-85	Rank 1985-05	Change in Rank
Algeria	0.407742351	41	0.242387294	56	-15
Argentina	0.618653027	25	0.476309997	33	-8
Australia	0.735536403	14	0.640490769	19	-5
Austria	0.796113249	9	0.764268627	8	1
Bangladesh	0.140625626	76	0.137665309	80	-4
Belgium	0.78221931	10	0.815542128	6	4
Benin	0.115161066	84	0.113040429	85	-1
Bolivia	0.285750856	56	0.238487884	58	-2
Brazil	0.540911396	31	0.377279142	39	-8
Burkina Faso	0.077891714	93	0.098611123	88	5
Burundi	0.091670205	92	0.080618968	93	-1
Cameroon	0.297341562	53	0.264810241	51	2
Canada	0.815822995	6	0.667418687	17	-11
Central African Repul	0.101450364	88	0.088938407	91	-3
Chad	0.227139203	64	0.207179709	64	0
Chile	0.455449247	35	0.5414954	28	7
China Version 1	0.043945168	96	0.144097337	76	20
Colombia	0.385330098	43	0.301968348	46	-3
Congo, Dem. Rep.	0.173597444	68	0.053029223	97	-29
Costa Rica	0.458835485	33	0.281313471	48	-15
Cote d`Ivoire	0.280053205	58	0.296591588	47	11
Denmark	0.644574944	22	0.714184896	12	10
Dominican Republic	0.335670081	48	0.334865907	43	5
Ecuador	0.333593269	49	0.211950739	62	-13
Egypt	0.262798823	60	0.453256483	36	24
El Salvador	0.354825581	45	0.260855524	53	-8
Ethiopia	0.109693411	85	0.096224703	90	-5
Finland	0.544923173	30	0.640754168	18	12
France	0.733841257	15	0.707568883	13	2
Gabon	0.866386907	2	0.671606369	16	-14
Gambia, The	0.157310417	71	0.105733569	86	-15
Ghana	0.093410532	91	0.11900222	83	8
Greece	0.692721392	18	0.587824092	25	-7
Guatemala	0.418903283	40	0.371392748	40	0
Guinea	0.337266506	47	0.336808248	42	5
Guinea-Bissau	0.03923141	97	0.06101931	95	2
Haiti	0.171638991	69	0.137129891	81	-12
Honduras	0.248027776	61	0.161920962	73	-12
Hong Kong	0.595016989	27	0.731521705	11	16
India	0.123168846	82	0.205891397	66	16
Indonesia	0.171308997	70	0.224817692	61	9
Iran	0.653242876	20	0.475772588	34	-14

Ireland	0.560478157	28	0.882011577	4	24
Israel	0.739780856	13	0.621376745	21	-8
Italy	0.708931625	17	0.698686864	14	3
Jamaica	0.282421145	57	0.273818421	50	7
Japan	0.612700655	26	0.488899227	31	-5
Jordan	0.832149086	5	0.303794157	45	-40
Kenya	0.145220826	75	0.167629939	72	3
Korea, Republic of	0.339414929	46	0.546425595	27	19
Madagascar	0.096927931	90	0.097003895	89	1
Malawi	0.061360135	94	0.115790881	84	10
Malaysia	0.386527304	42	0.602303985	24	18
Mali	0.105359725	86	0.190029727	68	18
Mauritania	0.151753595	73	0.152809315	74	-1
Mauritius	0.456463767	34	0.761489661	9	25
Mexico	0.651946058	21	0.388315138	38	-17
Morocco	0.445755552	36	0.304244155	44	-8
Mozambique	0.155740605	72	0.184553382	70	2
Namibia	0.498115226	32	0.533620498	29	3
Nepal	0.12484616	79	0.130009281	82	-3
Netherlands	0.840878612	3	0.698584783	15	-12
New Zealand	0.709802255	16	0.506369641	30	-14
Nicaragua	0.292530537	55	0.087075049	92	-37
Niger	0.124424425	80	0.100321279	87	-7
Nigeria	0.176134851	67	0.250920743	55	12
Norway	0.745044729	12	0.898749973	3	9
Pakistan	0.190342996	66	0.276278521	49	17
Panama	0.298554324	51	0.261648964	52	-1
Papua New Guinea	0.139924987	77	0.14833946	75	2
Paraguay	0.274855289	59	0.206248619	65	-6
Peru	0.429954398	38	0.209060789	63	-25
Philippines	0.224185769	65	0.204501605	67	-2
Portugal	0.42513455	39	0.476767831	32	7
Puerto Rico	0.837448258	4	0.984502608	2	2
Romania	0.234066665	63	0.23509917	59	4
Rwanda	0.123217854	81	0.138819679	78	3
Senegal	0.243393739	62	0.18659909	69	-7
Singapore	0.444049447	37	0.792864018	7	30
South Africa	0.768606417	11	0.828103172	5	6
Spain	0.662370588	19	0.603349621	23	-4
Sri Lanka	0.1374234	78	0.225067695	60	18
Sweden	0.622867159	24	0.616106663	22	2
Switzerland	0.811359781	7	0.572238806	26	-19
Syria	0.294338697	54	0.177217485	71	-17
Tanzania	0.052797872	95	0.057409498	96	-1
Thailand	0.122025282	83	0.252296815	54	29
Togo	0.098997703	89	0.076025355	94	-5
Trinidad &Tobago	0.546476662	29	0.627879339	20	9

Turkey	0.297768675	52	0.369276602	41	11
Uganda	0.105330377	87	0.138341313	79	8
United Kingdom	0.635974233	23	0.732126379	10	13
United States	1	1	1	1	0
Uruguay	0.356122927	44	0.412357314	37	7
Venezuela	0.802557606	8	0.460670544	35	-27
Zambia	0.151301561	74	0.139510722	77	-3
Zimbabwe	0.305136916	50	0.241205227	57	-7

Figure 1

TFP Dynamics

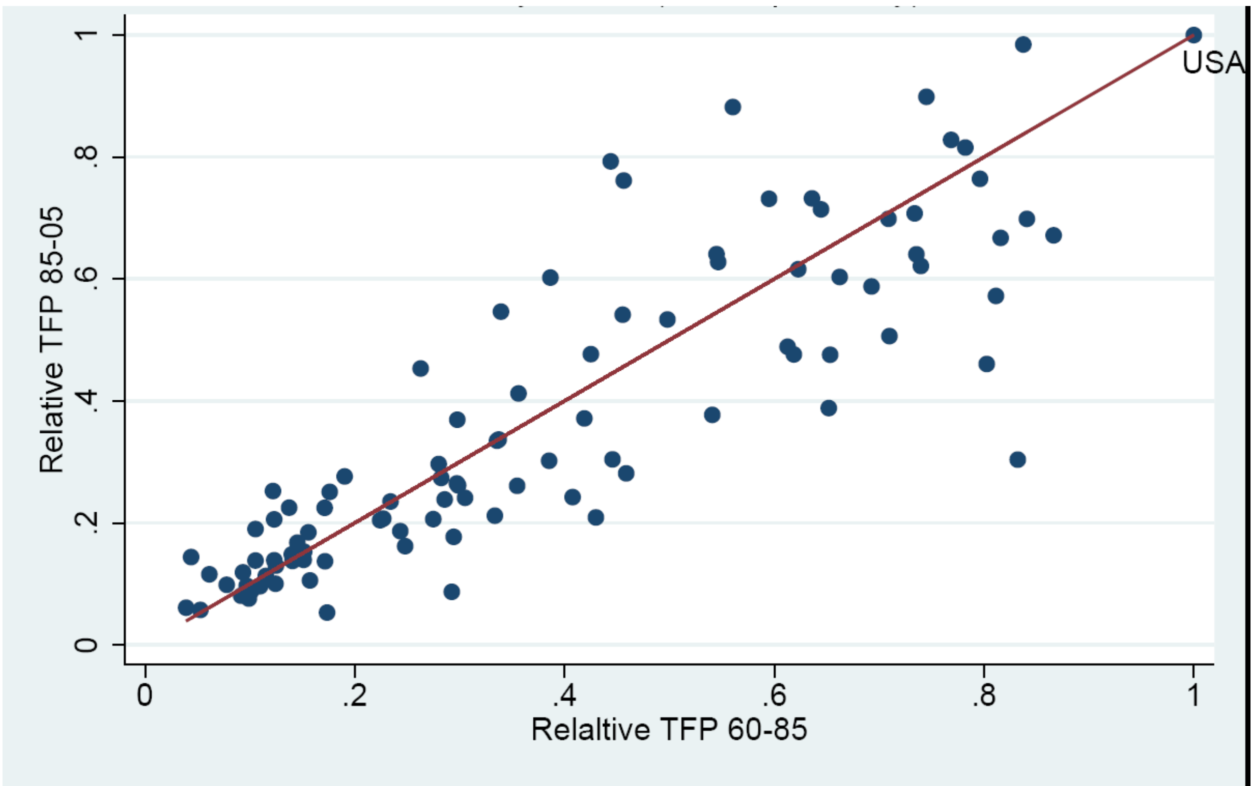

Figure 2

TFP Dynamics: Kernel Density