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. In particular, the morbidity rate has a significant and negative effect on GRTFP. The effects of health and education on GRTFP remain significant even after controlling for their *endogeneity.* The results support the Nelson-Phelps (1966) hypothesis that education plays an important role in technology diffusion. However, results suggest that in designing policies which facilitate technology diffusion, we need to broaden the concept of human capital to include health. We find evidence for the conditional convergence in the TFP.

Keywords: Augmented Solow Growth Model, Productivity, TFP Growth, Education, Health, Life-Expectancy, Infant Mortality, Panel Data, Instrument Variable

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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 2011). 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 low TFP countries do not 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, these studies suffer from two limitations.

Firstly, they do not control for the endogeneity of educational investment. In an environment where agents are forward looking, current investment in education in part is going to be based on the expected future return from education. The expected return from education is going to be determined by the expected growth rate in productivity. Also countries with higher TFP growth may have more resources to invest in education. Thus, a positive association between education and TFP growth cannot be interpreted as higher education leads to higher TFP growth.

Secondly, these studies do not examine the effect of health capital on the growth rate of TFP. As a crucial aspect of human capital, health capital can affect GRTFP through its impact on the incentive of firms to adopt new technologies and labor productivity. 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, Watanbe 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.

There are number of empirical studies which find that health capital has a significant positive effect on both the per-capita income (Knowles and Owen 1995, McDonald and Roberts 2002, Kumar and Kober 2011) and TFP (Cole and Neumayer 2006, Kumar and Kober 2011). However, there is no study which examines the effect of health capital on the TFP growth. 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 2011) 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 2011). 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. We estimate cross-country TFP for these two sub-periods and calculate the annual growth rate in TFP (GRTFP) by using these estimates.

In the second stage, we examine the effects of health and education on GRTFP. We first estimate a regression model which includes various indicators of education and health and other determinants of GRTFP using the Ordinary Least Squared (OLS). As discussed earlier, the OLS estimates suffer from the endogeneity bias. To control for the potential endogeneity of the human capital, we re-estimate the model using the instrument variable (IV) method. We instrument endogenous variables by the indicators of geography, culture, religion, and legal institutions.

The main findings of this paper are as follows: First, health indicators are significant determinants of GRTFP. In particular, the percentage of area under tropics is significantly and negatively related to GRTFP. 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). The coefficients of indicators of health and education capital remain significant even after controlling for endogeneity. Apart from human capital, degree of openness to trade is another important variable which positively and significantly affects GRTFP. We also find evidence for the conditional convergence of TFP across countries.

The results indicate that health capital affects growth process directly as a factor of production as well indirectly through its effect on TFP and the TFP growth. Education on the other hand affects growth indirectly through its effect on the TFP growth. 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.

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 analysisof the estimated results from the OLS and IV methods. 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

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

Assume that labor force in country i grows at the country specific rate, n_i, and technology 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^K_i and s^H_i denote the investment rates for physical and health capitals respectively in country i. Then, one can derive (see Mankiw et. al. 1992 and Islam 1995)

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

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

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:

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

with

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

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[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.

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

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

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

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 average 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 constant term, and u_i is the idiosyncratic term with mean zero. We estimate (7) by using both the OLS and the IV methods.

3 Estimation Method and Data for the Augmented Solow Model

3.1 Estimation Method

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

In the AB method, first difference 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 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.

Similarl to Mankiw et al. (1992), $g + \delta$ is assumed to be equal to 0.05 for each country.

There are numerous indicators of health capital. However, data are not consistently available for all the years between 1960 to 2005 for many variables. We use two proxies for health capital: one based on life-expectancy (LLE) and the other based on infant mortality rate (LMR). 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, McDonlad and Roberts 2002). We define $LMR = \ln IMR$ where IMR is the infant mortality rate. The data for the life expectancy and the infant mortality rate are taken from the World Development Indicators. The life-expectancy data is available for 97 countries. The data for the infant mortality rate is available for only 70 countries.

Similar to Islam (1995, 2003), Liberto et al. (2011) and Kumar and Kober (2011), 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 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. To analyze the TFP dynamics, we split the total period into two sub-periods. The initial period is 1960-85, and the subsequent period is 1985-05.

3.3 Estimated Results of the Augmented Solow Model

Tables 1 and 2 present the results of the first stage regression. Table 1 shows results for the initial period: 1960-85 and table 2 shows results for the subsequent period: 1985-2005. In both cases, we first perform BP and H tests. The results of these tests suggest that fixed effects model is the appropriate model for estimating (4).

The upper panel of both tables show results based on LLE (life-expectancy) and the lower panel shows results based on LMR (infant mortality). The second column of both the tables report results from the LSDV estimation method. The third and the fourth columns report results from 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).

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. On the other hand, LMR and the labor force growth rate have a negative and significant effect on the per-capita income. Results are very similar for the subsequent period (Table 2). All variables have expected sign. All variables are highly significant except for the labor force growth rate, when LLE is used as proxy for health capital. 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 may be accepted 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.

Tables 1 and 2 show that the estimated coefficient of the lagged dependent variable satisfies this criteria for the initial period (1960-85) for both AB-1 and AB-2 estimators.[2] However, only 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

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[2] 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.

are reported in Appendix 2 and 3. We define relative TFP (ReTFP) as the ratio of a country's TFP relative to the United States (A_i/A_{US}), which is the country with the highest productivity in the subsequent period (1985-05). Appendix 2 reports estimates based on life-expectancy and Appendix 3 reports estimates based on the infant mortality rate. These tables show that both estimates produce very similar rank. For the initial period (1960-85), the rank correlation between these two estimates is 0.93 and for the subsequent period (1985-05), the rank correlation is 0.98.

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. If we use life-expectancy based TFP ranking then the correlation is 0.89. For the infant mortality based TFP ranking the correlation is 0.79.

Table 3 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 figures 1 and 2, which plot 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. In particular, if we use life-expectancy based TFP, then 53 countries out of 97 under-performed the U.S. in this period. If we use infant mortality based TFP, then 50 countries out of 70 under-performed the U.S. in this period.

Figures 3 and 4 plot the distributions of relative TFP for the initial and subsequent periods. In both figures, 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 deviation of relative TFP (Table 3) 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 4 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. If we use life-expectancy based TFP, then the United States was the country with the highest productivity levels in both the initial and the subsequent periods. If we use infant mortality based TFP, then the U.S. had the third highest TFP level in the initial period and the highest TFP level in the subsequent period.

Over time there are significant changes in the list of top TFP countries. If we use life-expectancy based TFP, then U.S., Austria, and Pureto-Rica remain among the top ten countries over these two periods. If we use infant mortality based TFP, then U.S., Austria, and Italy 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 5 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. If we use life-expectancy based TFP seven countries (all African), remained among the bottom 10 countries in both the periods. If we use infant mortality based TFP, eight countries (all African), remained among the bottom 10 in both the periods.

Table 6 lists the countries whose rank changed by 15 or more over these two periods. If we use life-expectancy based TFP, then 12 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). If we use infant mortality based TFP, then 9 countries experienced increase in rank by 15 or more. Singapore (+28), Ireland (+27), and Finland (+22) were the top three gainers. The top three losers were Jordan (-37), Nicaragua (-28), and Philippines (-28).

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:

$$GRTFP_i = f \ln A_{i1960} + bH + cS + dQ + u_i \tag{9}$$

where $GRTFP_i$ denotes the growth rate of TFP in country i, A_{i1960} indicates the TFP level in the initial period, f is the associated coefficient; H is the matrix of variables measuring health capital and b is the associated vector of coefficients; S is the matrix of variables measuring education and c is the associated vector of coefficients; 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. Since there are two measures of GRTFP, we indicate the GRTFP based on life-expectancy by $GRTFP_{LE}$ and the GRTFP based on the infant mortality rate by $GRTFP_{MR}$. 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. In the regression, we use two measures of the TFP level in the initial period ($\ln A_{i,1960}$), one based on life-expectancy (IPL) and other based on the infant mortality (IPR).

As discussed earlier, health capital can affect GRTFP in numerous ways. Health capital depends not only on the longevity/mortality rate, but also on the morbidity rate and the disease burden. In particular, labor productivity is likely to depend on the morbidity rate. Cole and Neumayer (2006) and Kumar and Kober (2011) find that the morbidity rate and the disease burden significantly affect TFP. Life-expectancy and infant mortality rate largely capture the mortality rate. In the regression analysis, we use indicators of both the mortality rate and the morbidity rate.[3] As in the previous sections, we use two proxies for the mortality rate: one based on the life expectancy and the other on the infant mortality rate. We define life expectancy based mortality rate as the shortfall of life expectancy relative to the target as before $(\frac{1}{90-LE})$. In the regression, we use log of average of life expectancy based mortality rate (LLE_{60}) and the infant mortality rate (LMR_{60}) for the period 1960-1985. The data are from World Development Indicators.

In the literature, many indicators of the morbidity rate such as the incidence of malaria and other infectious diseases, incidence of under-nourishment, access to safe drinking water have been used. However, data for these variables are not consistently available for the period 1960-85. Due to paucity of data, we proxy morbidity rate by the percentage of area under tropics (TRO). There is a large literature which documents that tropical areas have higher disease burden (e.g. Gallup et. al. 1999, Sachs 2000). Murray and Lopez (1996) provide evidence that infectious disease are important cause of death and morbidity and these disease have heavy tropical concentration.The other advantage of this variable is that it is truly exogenous. Due to this, many empirical studies use the percentage of area under tropics as an instrument for health outcomes (Gallup et. al. 1999, Sachs 2000, Cole and Neumayer 2006, Knowles and Owen and 2008). The data for TRO is taken from Gallup et. al. (1999).

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. Kumar and Kober (2011) confirm the significant and positive effect of education on TFP. 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

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[3] Paucity of data precluded us to include indicators of the morbidity rate/disease burden in the first stage regression.

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 (2001).

Besides health and education, GRTFP can depend on other factors, such as openness to trade and urbanization. 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.

6 Estimation Results

6.1 The OLS Results

We first examine the determinants of GRTFP using OLS. Table 7 shows the results for $GRTFP_{LE}$. We first regress $GRTFP_{LE}$ on the initial productivity level (IPL) 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. In models (2) and (3), we incorporate LLE_{60} and the percentage of area under tropics (TRO) 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 regress $GRTFP_{LE}$ on the initial productivity level and education. We find that education capital has a positive and highly significant effect. In model (5), we incorporate measures of both health and education capital. Results suggest that the coefficients of the percentage of area under tropics and education remain significant. But the coefficient of LLE_{60} becomes insignificant. In column (6), we incorporate measures of trade openness and urbanization. We find that the coefficients of the percentage of area under tropics and education remain highly significant. Also, we find that the level of urbanization has a negative and significant effect on GRTFP. However, trade openness has a positive though insignificant effect. In model (7), we use LMR_{60} instead of LLE_{60}. The results remain largely the same, with the coefficient of LMR_{60} being negative, but insignificant.

Table 8 shows the results for $GRTFP_{MR}$. First, we examine the issue of absolute convergence (Model 8). We find that the TFP level in the initial period (IPR) has a negative, though insignificant effect on $GRTFP_{MR}$. This suggests lack of absolute convergence. However, when we add other variables, the coefficient of IPR becomes highly significant. This suggests that there is conditional convergence, but not absolute convergence.

Results suggest that the percentage of area under topics has a negative and education has a positive effect as before. Both variables are highly significant. The LMR_{60} has a negative though insignificant effect. Also, urbanization has a negative and significant effect. But the effect of trade openness remains insignificant. When we use LLE_{60}, we find that it has a negative effect and it is significant at 10% level of significance.

Overall, results suggest that both education and health, particularly the percentage of area under tropics significantly affect GRTFP. Urbanization has a significant negative effect. Regrading absolute convergence, evidence is mixed.

6.2 IV Results

Previous results show a strong association between TFP growth rate and the indicators of health and education. However, from these results we cannot infer that improved health and educational status leads to higher TFP growth. It is quite possible that the causation runs from the other direction with higher TFP growth leading to larger health and education capital. A higher TFP growth rate increases the return from human capital investment and thus encourages more human capital investment both in education and health. Also governments will have more resources leading to more public investment in education and health.

To control for endoegeniety we use IV approach. There are seven endogenous variables in the model IPL, IPR, LLE_{60}, LMR_{60}, LUR, LAV, and LOP. We instrument them using geographical, religious, cultural, and legal institutions indicators. In particular, we use distance from equator (LATI), average temperature (MEANTEM), the proportion of population within 100 kilometers of coastal areas (LT100), dummy for land-locked countries (LAND), dummy for countries with the socialist legal origin (SOC) and the French legal origin (FRENCH), dummy for African countries (AFRICA), ethnolinguistic fractionalization (ETH) and the percentage of Muslim (MUSLIM) and Catholic (CATH) population in a country as instruments.

These variables have been chosen as instruments as literature suggests that they are important determinants of human capital, urbanization, and trade openness. Disease burden and nutritional status are significant determinants of mortality rate (Murray and Lopez 1996, Gallup et. al. 1999, Knowles and Owen 2008). There is considerable evidence that infectious diseases have heavy tropical concentration (Murray and Lopez 1996, Gallup et. al. 1999, Sachs 2000, Knowles and Owen 2008), which is the main cause of higher mortality and morbidity observed in these areas.

The intake of food to a great extent depends on the domestic production of food particularly in developing countries, largely because of imperfections in international trade in food-grains and weak transport infrastructure. Climate and soil fertility and suitability are important determinants of agricultural productivity. Bloom and Sachs (1998) and Gallup et. al. (1999) argue that extreme heat and humidity in tropical countries contribute to low soil fertility and agricultural productivity. On the other hand, temperate zones have high soil fertility and agriculture productivity. Thus, we include LATI and MEANTEM in the list of our instruments. The data for LATI is taken from La porta et. al. (1999) and the data for MEANTEM is from Gallup et. al. (1999).

One of the precondition for urbanization is the existence of surplus food. Thus, LATI and MEANTEM are also likely to affect the urbanization level. Apart from the existence of surplus food, lower transport cost and ease of exchange of ideas are other important determinants of the urbanization level. Gallup et. al. (1999) argue that coastal areas are conducive for urban growth and thus countries with access to ocean are more likely to reap the benefit of agglomeration economies. Easy access to coasts enhances the extent of market (both internal and external) and thereby increases the opportunity of specialization. Transport cost has historically played important role in the diffusion of technology, ideas, and new products. Coastal areas with lower transportation cost compared to land-locked countries are likely to be more exposed to newer products, ideas and technical advancements. To capture the effects of transportation cost we include LT100 and LAND in the list of instruments. Gallup et. al. (1999) also suggest that a coastal economy may face a high elasticity of output response with respect to trade taxes, whereas an inland economy does not. This may induce governments in inland economies to impose harsh taxes on trade. These variables are also important determinants of trade openness. The data for LT100 is from Gallup et. al. (1999). We also use dummy for African countries as African countries have unique developmental challenges.

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, whereas civil law (French origin) seeks to replace such outcomes with state desired allocations. The socialist system is of course an extreme form of state intervention which completely supplants the market. We include legal origin in the list of instruments. To capture the effects of legal origin, we use dummies for socialist countries (SOC) and civil laws (FRENCH). 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 use the index of ethno-linguistic fractionalization (ETH) taken from La Porta et. al. (1999) as instrument.

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. Since openness to new ideas is crucial for agglomeration effect and also effectiveness of education, we use MUSLIM and CATH as instruments.

We find that these instrument variables explain significant proportion of cross-country variations in human capital, initial productivity levels, urbanization, and trade openness and are significant at the 1% level of significance. They explain 56% and 47% of the variations in IPL_{60} and IMR_{60} and 73% of variations in LLE_{60} and LMR_{60}. The proportion of variations in LUR, LAV and LOP explained by these instruments are at 52%, 35% and 22% respectively. The Shea's partial correlations for IPl_{60}, IMR_{60} LLE_{60}, LMR_{60}, LAV, LUR, and LOP are somewhat lowers at 0.21, 0.19, 0.26, 0.13, 0.12, 0.18, and 0.23 respectively.

The consistency of IV estimators requires that instruments be exogenous, i.e., uncorrelated with the error terms. As there are more instruments than endogenous variables, we report tests of over-identifying restrictions (Sargan test). These provide a test of the null hypothesis that the instruments are uncorrelated with errors in a correctly specified model.

Table 9 presents the IV results. Model 15 shows the 2SLS results when the dependent variable is $GRTFP_{LE}$. The results show that the coefficients of both the TFP level of in the initial period and the percentage of area under tropics are highly significant. The educational variable remains significant, but at 10% level of significance. The results show that the coefficient of the urbanization level becomes insignificant. But the coefficient of trade openness becomes significant. The estimated p-values for the Sargan tests imply that the over-identifying restrictions are not rejected.

To test for the robustness of results, we also use the limited information maximum likelihood (LIML) and the generalized method of moments (GMM) estimators. The LIML estimator yields less bias and a better coverage rate than the 2SLS estimator, particularly when instruments are weak. The GMM estimator is efficient for arbitrary heteroskedasticity. The results (models 16 and 17) show that different kinds of estimators yield broadly similar results. Only in the case of LIML estimator, the coefficient of education variable becomes insignificant.

To further test the robustness of results, we use $GRTFP_{MR}$ as the dependent variable (models 18, 19 and 20). The results show that the TFP level in the initial period and the percentage of area under tropics remain significant in most of the specifications. However, the coefficients of education and trade openness are insignificant in all the specifications.

Overall, the results suggest that human capital both health and education and the the TFP level in the initial period are significant determinants of the growth rate on TFP. Among the indicators of health, the percentage of area under tropics turns out to be the most significant. 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, particularly morbidity rate, is a crucial determinant of the productivity growth.

The results provide strong evidence of the conditional convergence in the TFP. The other important determinant of the GRTFP is the degree of trade openness. These results suggests that policies designed to reduce the disease burden and improve education 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. In particular, disease burden/morbidity rate have a significant adverse effect on the growth rate of TFP. The effects of health and education on the growth rate of TFP remain significant even after controlling for their endogeneity. 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:1960-85

Explanatory Variables	LSDV	AB 1-Step	AB 2-Step
Health Capital:	Life-Expectancy		
$y_{i,t-1}$	0.587(0.087)*	0.599(0.147)*	0.595 (0.131)*
$ln(s^{K}_{i\tau})$	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
Health Capital:	Infant Mortality		
$y_{i,t-1}$	0.615(0.102)*	0.643(0.141)*	0.657 (0.098)*
$ln(s^{K}_{i\tau})$	0.141(0.047)*	0.142(0.044)*	0.148(0.031)*
$\ln(n_{i\tau}+g+\delta)$	-0.135(0.065)**	-0.215(0.077)*	-0.212(0.051)*
$\hat{L}MR^{*}_{i\tau}$	-0.157(0.061)*	-0.132 (0.084)**	0.169 (0.061)*
p Values:			
BP Test	0.00		
H Test	0.00		
Sargan Test	NA	0.384	0.483
H(0): AR(2) is absent	NA	0.17	0.19
R^2	.988		
No. of Observations	355	284	284
No. of Countries	70	70	70

Note:

1. $*$, $**$, and $***$ indicate significance levels of 1%, 5%, 10% respectively against two-sided alternatives for the t-tests.
2. Number in brackets are standard errors.
3. All specifications included constant and time specific effects (not reported).

Table 2

Growth Regression Results:1985-05

Explanatory Variables	LSDV	AB 1-Step	AB 2-Step
Health Capital:	Life-Expectancy		
$y_{i,t-1}$	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	0.16	0.19
R^2	.991		
No. of Observations	392	294	294
No. of Countries	97	97	97
Health Capital:	Infant Mortality		
$y_{i,t-1}$	0.525(0.081)*	0.419(0.146)*	0.557 (0.129)*
$ln(s_{i\tau}^{K})$	0.164(0.039)*	0.159(0.056)*	0.153(0.053)*
$\ln(n_{i\tau}+g+\delta)$	-0.164(0.063)*	-0.195(0.044)*	-0.186(0.040)*
$\hat{L}MR_{i\tau}^{*}$	-0.157(0.061)*	-0.132 (0.084)**	0.169 (0.061)*
p Values:			
BP Test	0.00		
H Test	0.00		
Sargan Test	NA	0.761	0.821
H(0): AR(2) is absent	NA	0.17	0.19
R^2	.993		
No. of Observations	284	213	213
No. of Countries	70	70	70

Note:

1. $*$, $**$, and $***$ indicate significance levels of 1%, 5%, 10% respectively against two-sided alternatives for the t-tests.
2. Number in brackets are standard errors.
3. All specifications included constant and time specific effects (not reported).

Table 3
TFP Dynamic: Summary Statistics

	Life-Expectancy			
	$lnTFP_{60-85}$	$ReTFP_{60-85}$	$lnTFP_{85-05}$	$ReTFP_{85-05}$
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

	Infant Motality			
	$lnTFP_{60-85}$	$ReTFP_{60-85}$	$lnTFP_{85-05}$	$ReTFP_{85-05}$
Mean	8.77	0.49	9.92	0.41
Median	8.94	0.49	10.05	0.38
S.D.	0.62	0.25	0.69	0.23
Maximum	9.79	1.14	11.03	1
Minimum	7.13	0.08	8.23	0.06

Table 4
Top Ten Countries

Life	Expectancy	Infant	Mortality
1960-85	1985-05	1960-85	1985-05
Belgium	United Kingdom	Italy	France
Austria	Mauritius	Austria	United Kingdom
Venezuela	Austria	Argentina	Austria
Switzerland	Singapore	Canada	Italy
Canada	Belgium	Brazil	Trinidad &Tobago
Jordan	South Africa	Mexico	Belgium
Puerto Rico	Ireland	Belgium	Mauritius
Netherlands	Norway	United States	Ireland
Gabon	Puerto Rico	Venezuela	Norway
United States	United States	Jordan	United States

Table 5
Bottom Ten Countries

Life	Expectancy	Infant	Mortality
1960-85	1985-05	1960-85	1985-05
Guinea-Bissau	Congo, Dem. Rep.	Tanzania	Tanzania
China	Tanzania	Malawi	Burundi
Tanzania	Guinea-Bissau	Burkina Faso	Togo
Malawi	Togo	Ghana	Cen. African Rep
Burkina Faso	Burundi	Burundi	Nicaragua
Burundi	Nicaragua	Togo	Burkina Faso
Ghana	Cen African Rep	Gambia	Gambia
Madagascar	Ethiopia	Uganda	Malawi
Togo	Madagascar	Thailand	Ghana
Cen African Rep	Burkina Faso	Rwanda	Rawanda

Table 6
Countries with Large Changes in Ranking

Life	Expectancy	Infant	Mortality
Gain ($\geq$ +15)	Loss ($\leq$ -15)	Gain ($\geq$ +15)	Loss ($\leq$ -15)
China (+20)	Algeria (-15)	Egypt (+ 15)	Algeria (-18)
Egypt (+24)	Congo, Dem. Rep. (-29)	Finland (+22)	Brazil (-25)
Hong Kong (+16)	Gambia (-15)	Ireland (+27)	Costa Rica (-17)
India (+16)	Jordon (-40)	Korea (+19)	Jordan (-37)
Ireland (+24)	Mexico (-17)	Malaysia (+17)	Mexico (-22)
Malaysia (+18)	Nicaragua (-37)	Mauritius (+21)	Morocco (-21)
Mali (+18)	Peru (-25)	Norway (+18)	Nicaragua (-28)
Mauritius (+25)	Switzerland (-19)	Singapore (+28)	Phillipines (-28)
Pakistan (+17)	Syria (-17)	United Kingdom (+17)	Venezuela (-19)
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 7

GRTFP(Life-Expectancy) and the Multiple Forms of Human Capital (OLS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
IPL	-0.0064^{*}	-0.0144^{*}	-0.151^{*}	-0.0160^{*}	-0.0214^{*}	-0.0178^{*}	-0.0189^{*}
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)
LLE_{60}		0.0226^{*}	0.0157^{*}		0.0102	0.0093	
		(0.006)	(0.006)		(0.01)	(0.01)	
LMR_{60}							-0.0036
							(0.004)
TRO			-0.0072^{*}		-0.01156^{*}	-0.0124^{*}	-0.0114^{*}
			(0.004)		(0.004)	(0.004)	(0.005)
LAV				0.0088^{*}	0.0054^{***}	0.0075^{**}	0.0116^{*}
				(0.002)	(0.003)	(0.003)	(0.003)
LOP						0.0011	0.0014
						(0.003)	(0.003)
LUR						-0.0069^{**}	-0.0071^{*}
						(0.003)	(0.003)
R^2	0.11	0.26	0.34	0.31	0.47	0.50	0.47
N	97	97	92	76	76	76	63

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 and TRO are not available for all countries.

Table 8
GRTFP(Infant-Mortality) and the Multiple Forms of Human Capital (OLS)

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
IPR	-0.0031	-0.0138^{*}	-0.0152^{*}	-0.0172^{*}	-0.0208^{*}	-0.0177^{*}	-0.0189^{*}
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
LLE_{60}							-0.0171^{***}
							(0.01)
LMR_{60}		-0.0141^{*}	-0.0117^{*}	-0.0046	-0.0043	-0.0036	
		(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	
TRO			-0.0074^{***}		-0.0103^{**}	-0.0111^{*}	-0.0097^{**}
			(0.004)		(0.005)	(0.004)	(0.005)
LAV				0.0144^{*}	0.0094^{*}	0.0116^{*}	0.0099^{*}
				(0.001)	(0.003)	(0.003)	(0.002)
LOP						0.0003	0.00001
						(0.003)	(0.003)
LUR						-0.0052^{***}	-0.0056^{**}
						(0.003)	(0.003)
R^2	0.02	0.42	0.46	0.37	0.54	0.56	0.57
N	70	70	68	64	63	63	63

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. N: Number of included observations vary as data for LAV and TRO are not available for all countries.

Table 9
GRTFP and the Multiple Forms of Human Capital (Instrument Variable)

	GRTFP_{LE}			GRTFP_{MR}		
Var	(15) 2SLS	(16) LIML	(17) GMM	(18) 2SLS	(19) LIML	(20) GMM
IPL	-0.0233^{*}	-0.0244^{*}	-0.229^{*}	-0.0100^{***}	-0.0153	-0.0127^{***}
	(0.004)	(0.006)	(0.004)	(0.009)	(0.13)	(0.003)
LLE_{60}/	0.0048	0.009	0.0093	-0.0189	-0.0577	-0.0130
LMR^{a}_{60}	(0.019)	(0.025)	(0.019)	(0.023)	(0.19)	(0.02)
TRO	-0.016^{*}	-0.0167^{*}	-0.0162^{*}	-0.0022^{***}	-0.0211	-0.0047^{***}
	(0.005)	(0.006)	(0.005)	(0.013)	(0.115)	(0.004)
LAV	0.0139^{***}	0.0154	0.0153^{***}	0.0044	0.0518	0.0018
	(0.008)	(0.011)	(0.008)	(0.031)	(0.239)	(0.026)
LOP	0.0106^{**}	0.0121^{***}	0.0123^{**}	0.003	0.0034	0.0041
	(0.006)	(0.007)	(0.005)	(0.006)	(0.016)	(0.005)
LUR	-0.005	-0.0039	-0.0052	-0.0049	-0.0023	-0.0048
	(0.006)	(0.008)	(0.006)	(0.007)	(0.022)	(0.006)
R^2	0.38	0.33	0.34	0.32	0.31	0.44
N	75	75	75	63	63	63
Sargan/Hansen	0.61	0.75	0.61	0.44	0.83	0.44

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. P-value is reported for the Sargan(2SLS) or Anderson-Rubin (LIML) or Hansen (GMM) tests of the over-identifying restrictions.
4. a : In the case of $GRTFP_{LE}$, we use LLE_{60} and in the case of $GRTFP_{MR}$, we use LMR_{60}.
5. Number of included observations vary as data for LAV and TRO 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*
- LE: Average life expectancy for the period 1960-85 *World Development Indicators*
- IMR: Average infant mortality rate 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 (2001)*
- 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*
- LATI: The absolute distance from equator *La Porta et. al. (1999)*
- MEANTEM: Average Temperature *Gallup et. al. (1999)*
- TRO: The percentage of area of a country under tropics *Gallup et. al. (1999)*
- LT100: The proportion of population within 100 k.m. of coast *Gallup et. al. (1999)*
- LAND: Dummy for land-locked countries
- SOC: Countries with socialist legal system *La Porta et. al. (1999)*
- FRENCH: Countries with French 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)*
- CATH: Proportion of catholic population *La Porta et. al. (1999)*
- AFRICA: Dummy for African countries

Figure 1

TFP Dynamics (Life-Expectancy)

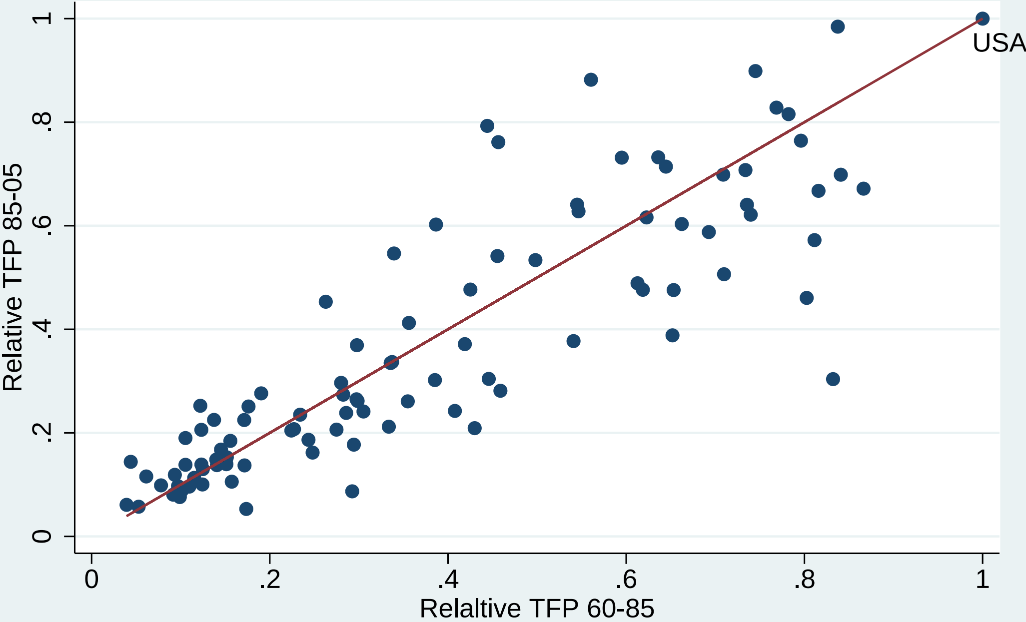
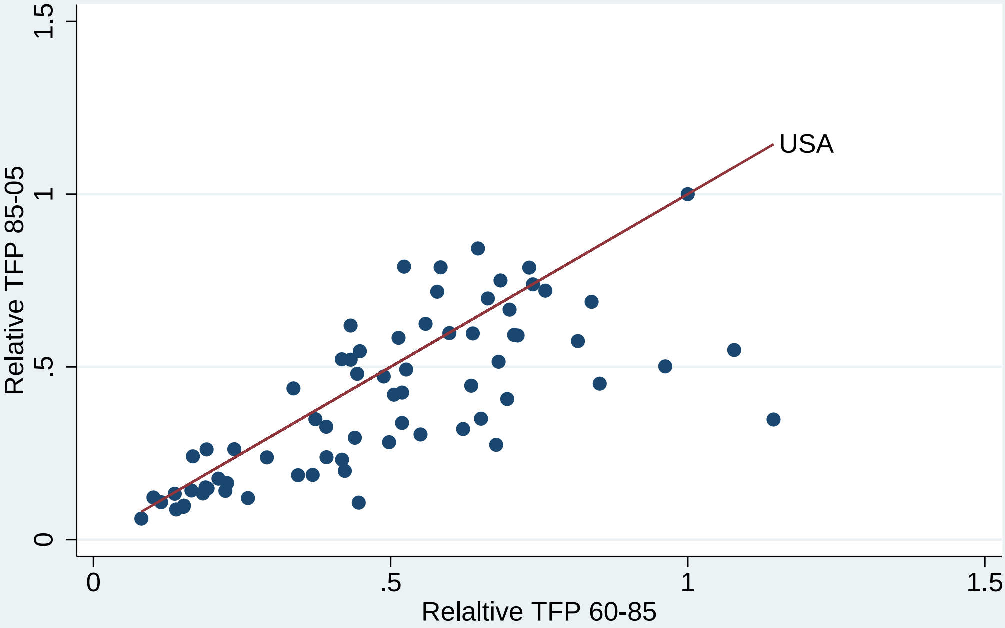


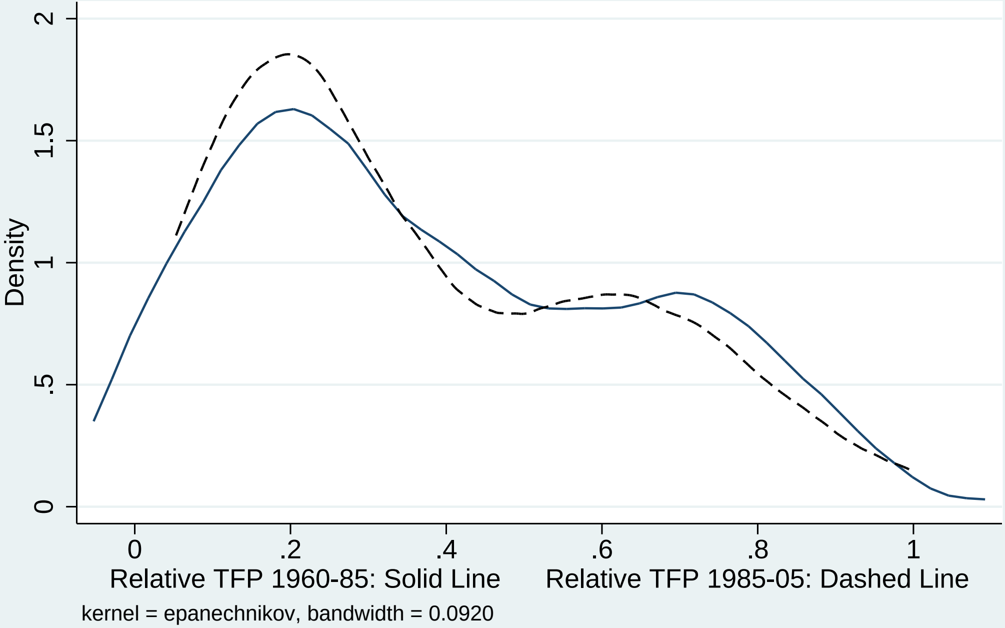
Figure 2

TFP Dynamics (Infant Mortality)



Graph 3: Kernel Density

TFP Dynamics: Relative TFP (Life Expectancy)



Graph 4: Kernel Density

TFP Dynamics: Relative TFP (Infant Mortality)