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Abstract:

Adopting a production function based approach we model the role of health as a regular factor of production on economic growth. Additionally we disaggregate the measures of human capital by including male and female life expectancy and school enrolments. Allowing for the dynamics of TFP to be embedded in the production function we estimate it in growth form using various estimators appropriate for our data. Our main finding is that male life expectancy has a positive effect on the *growth* of income while female life expectancy has a negative effect, controlling for unobserved time and country effects in a panel of 83 countries from 1960 - 2009. We use lag differences of life expectancy and school enrolments and lagged growth rates of other inputs as instruments for controlling the endogenity of health in the growth regressions. We check for the robustness of the results with use of 'deletion diagnostics' to identify influential observations and outliers. The results continue to show that male life expectancy has a *positive* effect on income growth while that of female has a *negative* effect.

Key Words – Health and economic development, economic growth, endogeneity, panel data, TFP convergence, economics of gender.

JEL Codes – I15, 047, J16

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1 Introduction

The importance of health in a country's economic growth has been well documented in the literature: Knowles and Owen (1995), Barro (1996), Bloom et al. (2003), Bloom et al. (2000), Bhargava et al. (2001), McDonald and Roberts (2002). Health, as a measure of human capital proxied by life expectancy, has been included in many cross-country regression studies. These studies in general find a positive contribution of health on growth. Although basic economic intuition suggests that health should matter for growth, the relationship is not absolutely clear beyond the shadow of doubt. For example, in most cross-country growth regressions which include health , it is not very clear whether health directly influences economic growth or whether it acts as a proxy for omitted variables (Barro and Sala-i-Martin,1995). Recently, Acemoglu and Johnson (2007) (henceforth AJ) presented an interesting finding that increases in population health, as measured by higher life expectancy, are negatively correlated with economic growth in cross-country panel data. In order to address the critical endogeneity issue, they construct country-varying instruments which are dependent on exogenous shocks to national health generated by improvements in health technology for life expectancy using the pre-intervention distribution of mortality from 15 diseases. On the contrary, Lorenzen, McMillan and Wacziarg (2008) (henceforth LMW) use seventeen instruments based on a malaria ecology index, climate variables and geographic features and find that increased adult mortality rates have a strong negative effect on economic growth. Much of the differences in the results obtained by AJ and LMW could be due to differences in their source model which are based on some form of endogenous growth from where their empirical strategy is derived. Aghion, Howitt and Murtin (2010) and Bloom, Canning and Fink (2009) have reconciled the findings in AJ and LMW by using a unified model by including initial level of life expectancy in the regression to allow for convergence in the form of human capital. Given that the influence of health on economic growth is unclear, this study attempts to contribute to this literature by investigating the relation between health capital and economic growth using appropriate models and data for 83 countries covering the 1960-2009 period. We show, using a production function based approach, life expectancy disaggregated by gender can explain much of the variation in cross country income after controlling for convergence in total factor productivity (TFP) and reverse causality between health capital and income growth.

A healthy population is able to contribute directly to economic growth through its influence on increased productivity and income (Bloom et al. 2004), and indirectly through its influence on investment in education (Barro 1996), and reduced fertility (Barro 1996). Evidence however, shows large differentials in life expectancy across regions (see Table 3). While life expectancy at birth is between the ages of 70 and 74 years in other regions, in South Asia it is 59 and Sub-Saharan Africa 49 years. The influence of health capital on economic growth therefore may not be the same across different regions. Has the lower stock of health capital in these regions contributed to slowing down economic growth? The focus of our analysis is therefore to investigate the effects of health capital on economic growth in a group of countries covering, East Asia and the Pacific, Europe and Central Asia, Latin America and the Carribean, the Moddle East and North Africa, South Asia and Sub-Saharan Africa.

Evidence also shows differences in life expectancy at birth by gender in favour of women. Morbidity rates however, are higher among women. Studies also show that women seek health services to a lesser extent than men (World Bank 1996, Hanson 2002). In a study of India, the World Bank (1996) finds that although women report more illness than men, that men receive more treatment than women. It is possible therefore that the female and male health capital stocks have differential impacts on economic growth. Consequently, the purpose of this study is to in addition to investigating the influence of health capital on economic growth, to examine if there are differential impacts of the male and female health capital stock on economic growth. Following the literature (Barro 1996, Barro and Sala-i-Martin 1995, Bloom et al. 2000, McDonald and Roberts 2002, Bloom et al, 2004), the health status of the economy is measured by using life expectancy at birth.

We contribute to the existing literature in two ways. One, our approach and methodology differ from the existing procedures in the empirical growth literature. We follow Bloom et al (2004) by adopting a production function based approach, but extend the specification to include gender disaggregated effects of health on growth. To the best of our knowledge, this paper is a pioneer in studying the effect of female and male life expectancy on economic growth. Second, unlike majority of the studies in the literature we recognise the endogeneity issue between health capital and income growth at the outset and try to control for this reverse causality by using different instruments and estimators. To account for the robustness of our results we employ a variety of checks including outlier detection and employment robust regression techniques.

The rest of this study is structured as follows. Section 2 presents the literature. Section 3 presents the model. Section 4 describes the data.

2 The Literature

Many studies that investigate the effects of human capital on economic growth use education as a proxy for human capital. In this study, we use health capital to measure human capital.

Table 1 summarises a few influential studies carried out on the influence of health capital on economic growth. Note that many studies use life expectancy to measure health capital (Bloom and Canning 2000, 2003, Bloom et al. 1998, 2000) while few studies use survival rates (Bhargava et al. 2001, Weil 2007). Weil (2007) employs microeconomic data to investigate macroeconomic effects of health on GDP per capita. Combining both cross-country and historical data on three measures of health including adult height, adult survival rates, and age at menarche, he finds that health has a significant effect on GDP per capita, particularly in the case of poorer countries. The majority of studies find that health capital has a positive effect on economic growth with the exception of the Caselli et al. (1996) who attribute this mainly to the use of GMM estimation.

Table 1

Author/s	Health Capital Measure	Sample	Estimation Technique	Coefficient Estimate	Conclusions
Barro (1996)	Life expectancy at birth	Panel data over 1960-1990.	Three Stage Least Squares	Life expectancy = 0.042 (Table 1, p.48)	An increase in life expectancy leads to an increase economic growth.
Bloom and Canning , Malaney (2000)	Life expectancy in initial year	Cross country and panel data for 70 countries over the 1965-1990 period.	OLS, IV	Life expectancy in initial year = 3.28 – 2.64 (Table 1, p.267 cross sectional results)	Life expectancy is found to have a robust effect on economic growth.
Bhargava, Jamison, Lau, Murray (2001)	Survival rate	Panel data in five year intervals over 1965-1990.	Random Effects	Survival rate = 0.181 and 0.358 (Table 1, pg 431)	Human capital as proxied by the adult survival rate has a significant effect on economic growth particularly in the poorer countries.
Bloom, Canning, Sevilla (2004)	Life Expectancy	Panel data in ten year intervals over 1960-1990.	Non-linear two stage least squares estimation	Life expectancy = 0.040 (Table 4, pg 10)	Health capital has a positive and statistically significant impact on economic growth.
Caselli, Esquivel,	Life expectancy	Panel data in five year	Arellano-Bond GMM	Life expectancy = -0.001	Life expectancy does not have a

Lefort (1996)		intervals over 1960-1985.	estimation method	Table 4, pg. 37)	significant effect on economic growth with the use of GMM.
Knowles and Owen (1995)	The shortfall in average life expectancy at birth from 80 years.	Cross sectional data on a group of developed and developing countries over 1960-1985.	OLS.	Life expectancy for the full sample unrestricted regressions in the range of = 0.342-0.381. (Table 1. P.103)	The existence of a robust relationship between life expectancy and income per capita.
McDonald and Roberts (2002)	The shortfall in life expectancy relative to a benchmark.	Five yearly panels covering 1970-1984 for 77 OECD and developing countries.	Pooled OLS	Life expectancy for the full sample = 0.120. (Table 1 p. 274)	The coefficient on health capital is significant for the full sample. When the sample is disaggregated by LDCs and OECD countries, health capital has a positive and significant effect on economic growth in the LDCs but not the OECD group.
Bloom, Sachs, Collier, Udry (1998)	Life expectancy in initial year	Cross country data over 1965-1990 for 18 African and 59 non-African countries.	OLS	Life expectancy in initial period = 4.25 for Africa and 3.06 for non-Africa (Table 6, p.257)	Life expectancy is found to be one of the main reasons for the gap in growth between Africa and the non-African countries.
Sachs and Warner (1997)	Life expectancy in 1970.	Cross country data covering 1965-1990 for 79 countries covering Africa, other fast growing developing and all other developing economies.	OLS	Life expectancy in 1970= 45.38-47.85 (Table 2, p.345)	The effect on growth of an additional year of life expectancy is higher at lower levels of life expectancy, and almost zero at higher levels of life expectancy.
Bloom and Williamson (1998)	Life expectancy in 1960.	78 Asian and non-Asian countries over 1965-1990.	OLS and IV	Life expectancy in 1960 = 5.81. (Table 2, p.434)	When life expectancy is added to the estimation,

					population has a significant effect on economic growth.
Acemoglu and Johnson (2007)	Life Expectancy at birth in 1940, 1980, 1990	120 countries	OLS, IV	Life expectancy at birth = 1.17 (OLS estimation, Table 3, p.994)	There is no evidence that an increase in life expectancy leads to faster growth in income per capita.

A number of studies investigate the reason for the low growth rate experienced by Africa. The lower life expectancy at birth faced by this region due to higher levels of disease and lower quality of health institution is cited as one factor among others (see Sachs and Warner 1997). Sachs and Warner (1997) find that the effect on growth of an additional year of life expectancy is higher at lower levels of life expectancy, and almost zero at higher levels of life expectancy. According to them, a reason for this conclusion could be due to the fact that at lower levels of life expectancy, improvements in life expectancy come from developments in public health and eradication of disease, which are expected to have a larger effect on economic growth compared to improvements in survival rates experienced at higher levels of life expectancy. The view that poorer countries benefit more due to increases in health capital is further supported in the work of (Bhargava et al. 2001, McDonald and Roberts 2002). Low life expectancy is attributed to be a factor contributing to the lower rates of growth in Africa compared to other countries also in Bloom et al. (1998). Similarly, in an investigation of demographic change and economic growth in Asia, Bloom et al. (2000) show that a large part of East Asia's rapid economic growth and South Asia's low progress are due to the influence of differences in demographic factors. They show that during the period of rapid economic progress, that life expectancy in East Asia increased substantially between 1965 and 1990. Similarly, Collins and Bosworth (1996) in a study of the reasons for East Asia's rapid growth, show that higher education and life expectancy account for about 0.75 percentage point per year of increased growth. This is supported by Bloom and Williamson (1998) who show that demographic factors play an important role in East Asia's rapid growth.

3 The Empirical Model

We follow Bloom et al (2004) and adopt their production function based approach to analyse the effect of health on growth. We extend their model by adapting it to include the gender disaggregated effect of health. The production function based approach decomposes sources of growth into two: growth in the level of input and growth in TFP. Our inputs include physical capital, labour and human capital as measured by health and education disaggregated by gender and level of education. Our production function thus models output as a function of inputs and technology which is represented for a country *i* at time *t* as follows:

$$Y = AK^{\alpha} L^{\beta} e^{\phi_1 LEM + \phi_2 LEF + \phi_3 MPRI + \phi_4 MSEC + \phi_5 FPRI + \phi_6 FSEC}, \qquad (1)$$

Where *Y* is output or real gross domestic product (GDP); *A* represents TFP; *K* is physical capital; *L* is labour force; and human capital consists of two aggregate components of health and education. We disaggregate this human capital factor into six components based on gender and levels of education: *LEM* is male life expectancy; *LEF* is female life expectancy; *MPRI* is male primary enrolment; *MSEC* is male secondary enrolment; *FPRI* is female primary enrolment and *FSEC* is female secondary enrolment. Note that the effect of human capital terms on output is expressed in exponential form. The main advantage of such a functional form is that it allows the log of Y to be dependent on health status and levels of education much similar to the specification of the Mincerian regression estimating returns to human capital (Mincer, 1974) where the log of wage depends on levels of schooling, experience and health status. Thus a production function specified this way is more compatible with the relationship estimated in microeconomic studies.

Note that our model gives a representation on how output depends on factors of production and TFP. Though we do not explicitly model TFP, i.e. *A* in our specification, we note that any other factors not mentioned on the right hand side variable must be working through this. Moreover it is also possible that some of these human capital variables actually work through TFP. In this case estimating the effect of human capital variables will become more complicated as we will have to specify another equation for TFP to model the dynamics of human capital factors and then estimate this with the equation for the production function as a system. The other alternative will be to estimate the production function in a reduced form after substituting an expression for *A* which captures the evolution of human capital. While these are viable approaches, we do not pursue these here rather model the term *A* in our production function as a two-way error component disturbances following Wallace and Hussain (1969) and Amemiya (1971). This is explained below.

Taking the logs of our aggregate production function, the following equation for log of output in country *i* at time *t* is derived:

$$y_{it} = a_{it} + \alpha k_{it} + \beta l_{it} + \phi_1 LEM_{it} + \phi_2 LEF_{it} + \phi_3 MPRI_{it} + \phi_4 MSEC_{it} + \phi_5 FPRI_{it} + \phi_6 FSEC_{it} , \qquad (2)$$

Where y_{it}, k_{it}, and l_{it} are logs of *Y*, *K* and *L* respectively from the aggregate production function (1). a_{it} which is the unobservable TFP of country *i* at time *t*, is modelled as a two-way error component as follows:

$$a_{it} = a_i^* + a_t^* + v_{it} , \qquad (3)$$

Where a_i^* represents the unobserved country specific time invariant level of TFP and a_t^* denotes the unobserved time effect represented by the worldwide technology frontier. The combined effect of ($a_i^* + a_t^*$) gives an account of the steady-state level of each country. Each country's actual TFP a_{it} deviates from the steady state level by the difference v_{it} . Note that this difference is not stochastic, but is assumed to follow an autoregressive process of order one AR(1) as in Lillard and Willis (1978). This is a reasonable assumption where a deviation of actual TFP from its steady-state value may be persistent because an unobserved shock to TFP in this period can carry forward to the next or even more periods. But we restrict our analysis to the case where is a v_{it} is a AR(1) process as follows:

$$v_{it} = \rho v_{i,t-1} + \varepsilon_{it} , \qquad (4)$$

Where $0 < \rho < 1$ can be treated as a convergence coefficient. As time passes, any deviation from long-run steady-state TFP for any country is eliminated at a rate (1-ρ). ε_{it} is a random shock having classical properties.

Estimating the production function, with the error term specified to hold the above characteristics would involve the generalised error component model to the serially correlated case. For example Baltagi and Wu (1999) propose a feasible generalised least square procedure which is simple and provide natural estimates of the serial correlation and variance component parameters.

However, rather than estimating a model with serially correlated error structure, we find it useful to transform our production function into a growth equation. Differencing equation (2) gives us:

$$\Delta y_{it} = \Delta a_t + \alpha \Delta k_{it} + \beta \Delta l_{it} + \phi_1 \Delta LEM_{it} + \phi_2 \Delta LEF_{it} + \phi_3 \Delta MPRI_{it} + \phi_4 \Delta MSEC_{it} + \phi_5 \Delta FPRI_{it} + \phi_6 \Delta FSEC_{it} + \Delta v_{it} \qquad (5)$$

Substituting out the error term Δv_{it} using equation (4) and noting that the lagged productivity gap $\Delta v_{i,t-1}$ is the difference between actual output and output at the average world TFP level at time *t – 1* gives us:

$$\begin{aligned}
&\Delta y_{it} = \Delta a_t + \alpha \Delta k_{it} + \beta \Delta l_{it} + \phi_1 \Delta LEM_{it} + \phi_2 \Delta LEF_{it} + \phi_3 \Delta MPRI_{it} + \phi_4 \Delta MSEC_{it} + \\
&\phi_5 \Delta FPRI_{it} + \phi_6 \Delta FSEC_{it} + (1-\rho)(a_{i,t-1} + \alpha k_{i,t-1} + \beta l_{i,t-1} + \phi_1 LEM_{i,t-1} + \phi_2 LEF_{i,t-1} + \\
&\phi_3 MPRI_{i,t-1} + \phi_4 MSEC_{i,t-1} + \phi_5 FPRI_{i,t-1} + \phi_6 FSEC_{i,t-1} - y_{i,t-1}) + \varepsilon_{it}
\end{aligned} \qquad (6)$$

Equation (6) is the equation we estimate which decomposes growth in output into four factors: growth in world TFP; growth in inputs; a catch-up term as the TFP gap is closed in some countries to enable them to converge to steady-state level TFP at a rate $(1-\rho)$ and an idiosyncratic shock to country's TFP $\varepsilon_{it} \sim IID(0, \sigma_\varepsilon^2)$.

There are several things to be noted from equation (6). First, the transformed growth equation (6) now has an error term with classical properties and unobserved country specific fixed factors in TFP are eliminated due to differencing. Second, the input growth variables, in particular the human capita variables, can all be endogenous as the growth rate of output can also affect growth rates of inputs. Third, equation (6) represents a nonlinear model because the endogenous explanatory human capital variables do not appear additively in the equation.

We address the endogeneity problem by using lagged levels and growth rates of inputs and output as instruments and using an appropriate estimator. Specifically, to control for the reverse causality human capital variables and output growth, we use 5 and 10 year lags primary and secondary enrolment ratios disaggregated by gender and lagged differences of female and male life expectancy. The validity of these lagged instruments depends on their being uncorrelated with the random shocks to TFP, i.e. ε_{it}. We test for overidentifying restrictions. To address the nonlinearity in the model, our preferred choice of estimator is the generalised methods of moments (GMM) which has been successfully applied to estimate certain nonlinear exponential regression functions with endogenous explanatory variables (Wooldridge, 2001). Arellano and Bover (1995) and Blundell and Bond (1998) proposed a system GMM (*SGMM*) estimator for nonlinear and dynamic models. Hence, to control for nonlinearity and endogeneity, we use the *SGMM* estimator to estimate our growth model given by equation (6).

4 Data

We use data from Bosworth and Collins (2003) (Henceforth BC) to estimate our growth model. The disaggregated human capital data on life expectancy and primary and secondary enrolment ratios are all taken from WDI (2011). There are several aspects of BC data. Reliable and internationally comparable data on output, capital stock, and labour force is hard to manage. BC has made a painstaking effort to compile data on real GDP, capital stock, and labour force in one single file for 84 countries across all regions for the period 1960 – 2003. We have updated these data up to 2009. Because our growth model requires data on capital stock, the most reliable available data in this regard is that of BC data.

The study uses panel data covering 57 Asian and African countries over the 1990-2008 period. Descriptive statistics and data sources are provided in Table 2.

Table 2
Descriptive Statistics and Data Sources for Selected Variables

Variable	Obs	Mean	Standard Deviation	Minimum	Maximum	Source
Change in Log Per Capita Income (Constant 2000 $US)	4067	0.0370	0.0465	-0.6981	0.3076	WDI
Enrolment Ratio Female Primary (Gross %)	2754	93.968	22.239	9.202	152.53	WDI
Enrolment Ratio Male Primary (Gross %)	2754	100.02	17.74	20.27	165.89	WDI

Enrolment Ratio Female Secondary (Gross %)	2338	63.23	36.68	1.47	175.07	WDI
Enrolment Ratio Male Secondary (Gross %)	2338	65.17	32.62	2.84	161.53	WDI
Life Expectancy Female (Years)	4146	66.04	12.41	28.53	86.44	WDI
Life Expectancy Male (Years)	4146	61.58	11.10	25.19	79.80	WDI
Note: WDI = World Development Indicators						

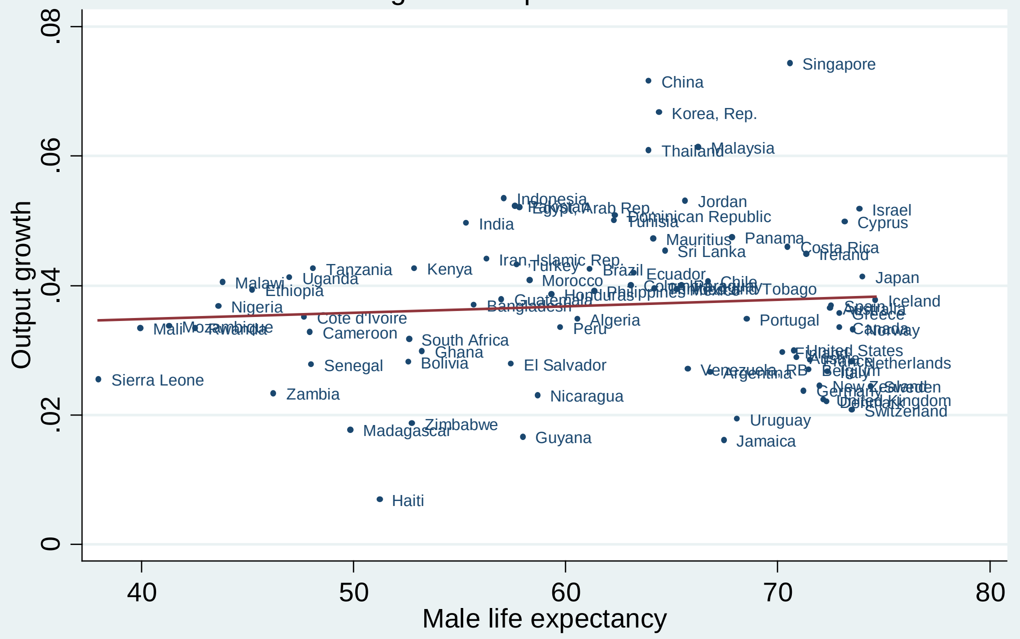
Table 3
Correlation in levels of input variables

	Log capital	Log labour force	Male life expectancy	Female life expectancy	Male primary enrolment	Female primary enrolment	Male secondary enrolment	Female secondary enrolment
Log capital	1.000							
Log labour force	0.478	1.000						
Male life expectancy	0.185	-0.051	1.000					
Female life expectancy	0.188	-0.064	0.988	1.000				
Male primary enrolment	0.115	0.127	0.458	0.462	1.000			
Female primary enrolment	0.149	0.028	0.632	0.650	0.913	1.000		
Male secondary enrolment	0.204	-0.014	0.848	0.850	0.366	0.529	1.000	
Female secondary enrolment	0.170	-0.066	0.861	0.861	0.371	0.567	0.977	1.00

The correlation matrix of the data for all the levels of input variables outlined in equation (6) is presented in Table 3. The correlation of regular input factors capital and labour with those of human capital factors health and enrolment are not very high. However the disaggregated human capital variables are highly correlated: female and male life expectancy, primary and secondary enrolments all have correlation coefficient exceeding 0.90. Although this poses a great challenge for us to disentangle the gender disaggregated effect, we get around this problem because our model is in first differenced form where the correlation is less. This eases our efforts to disentangle the effect of regular inputs from those of human capital on output growth. All the correlation coefficients are positive, except for gender disaggregated life expectancy and secondary enrolments with that of labour force although they are very mild in magnitude. Our variables of interest are female and male life expectancy and growth of output. A graphical representation gives us a preliminary idea about the relationship between these variable for average values for the whole sample period. These are shown in Figure 1 and 2. The scatter plots do not show an obvious relationship but hints towards a weak one. Whilst this simple pure-cross sectional scatterplot represents perhaps a slightly positive outlook, the relationship between male life expectancy and growth (Figure 1) seem to be a little stronger than that of female (Figure 2).

Figure 1. Output growth and male life expectancy

Average for the period 1960 - 2009



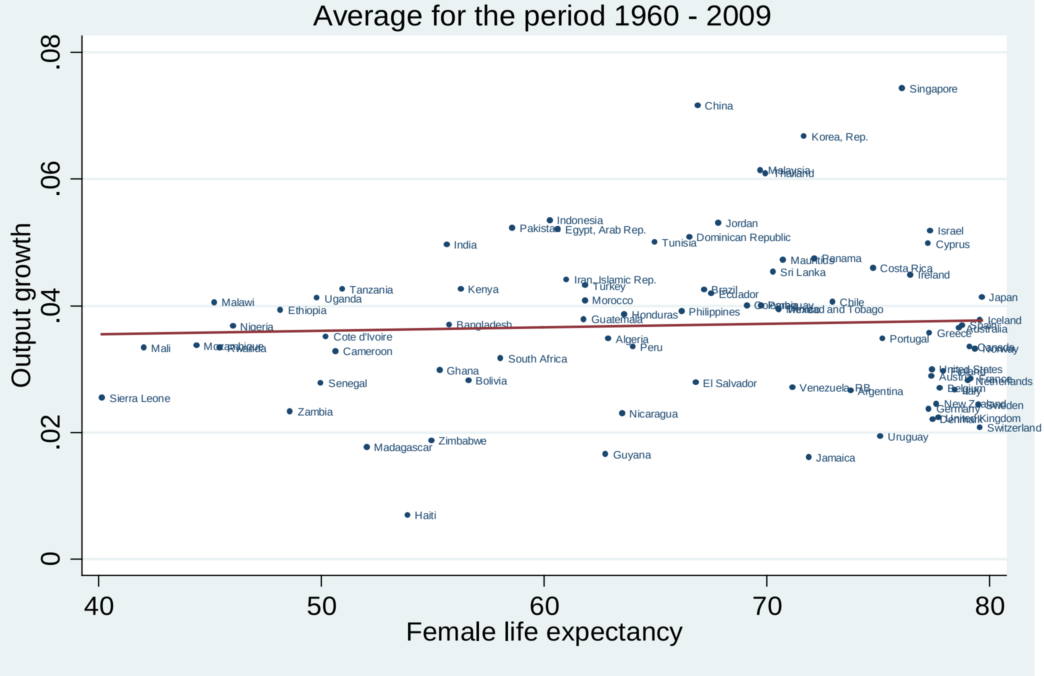


Figure 2. Output growth and female life expectancy

In both of these figures there are some interesting cases where over the sample period a country has either achieved higher growth rate relative to its level of life expectancy (for example India in Figure 1 and Pakistan in Figure 2) or had higher levels of life expectancy relative to its growth rate (for example Uruguay in Figure 1 and Argentina in Figure 2).

Table 4 reports averages for life expectancy over the 1960-2009 period for the different regions. Note that the life expectancy at birth in Europe and Central Asia is 74 while, in Africa it is 49 years and in South Asia 59 years reflecting significant regional heterogeneity in life expectancy at birth.

Table 4 Life Expectancy at Birth by Region Average 1960-2009

Region	Life Expectancy at Birth (years)
East Asia and Pacific	66
Europe and Central Asia	74
Latin America and Caribbean	64
Middle East and North Africa	65
South Asia	59
Sub Saharan Africa	49
Source: World Bank 2011	

5 Estimation and Results

We estimate equation (6) under the assumption that the steady state TFP is the same for all countries in the sample because the same unobserved country and time effects are applied for every country. The results are reported in Table 5 which is separated into four columns. In all the columns one can see that the share of physical capital and labour are different from the stylized value of one-third and two-thirds, respectively (Mankiw et al, 1992). In particular, the share of capital seems overestimated and that of labour underestimated from the stylized value. We prefer to extend an explanation for this at the outset. Because our sample includes developed as well as developing countries, the share of capital is higher than one-third.[3] In addition the share of labour has fallen from the stylized value because of the inclusion of several measures of human capital in the form of health and education being embodied in labour. To measure the consistency of data we compute elasticities of inputs without any human capital and technological catch up term by estimating a production function in growth form with only capital and labour as the inputs in addition to dummies for fixed country and time effects. The estimated elasticity of capital was 0.38 (which is slightly higher than the styled value) and that of labour was 0.53 (which is slightly lower than stylized value).

[3] By definition the share of profits is:

$$\alpha = \frac{\frac{\partial \ln(Y)}{\partial \ln(K)} \times K}{Y} \approx \frac{\Delta Y}{\Delta K}\left(\frac{K}{Y}\right)$$

The numerator is the remuneration for capital which is the marginal product of capital (*MPK*) multiplied by capital stock and (*K/Y*) is the capital-output ratio (*KYRAT*). It is to be expected that *MPK* will be higher in the developing countries because of their lower capital stocks and α should be higher. This effect will be partly offset by lower *KYRAT*s in the developing countries. But in proportionate terms the differences in *MPKs* are likely to be higher than *KYRATs*.

However, the Wald test for the restriction that share of capital plus labour equals one could not be rejected at any conventional level because the calculated Chi square test statistic is 0.80 with a p-value of 0.36.

We now turn to column (1) of Table 5 which reports the pooled OLS results showing that only the coefficients of physical capital, labour, male primary enrolment and TFP catch-up term are significant. The coefficients on capital and labour are 0.52 and 0.28 respectively. Our variables of interest are male and female life expectancies which have a positive and a

Table 5
Estimation of growth equation for full period 1960 - 2009
Dependent variable: output growth

	(1) OLS	(2) LSDVC	(3) SGMM	(4) SGMM
Lagged output		0.342 (7.08)***	0.429 (3.60)***	0.173 (0.63)
Capital	0.525 (12.63)***	0.415 (10.00)***	0.379 (4.77)***	0.577 (3.08)***
Labour	0.281 (4.47)***	0.144 (2.90)***	0.116 (4.90)***	0.159 (2.98)***
(1-ρ)	-0.002 (-2.19)**	0.608 (11.56)***	0.565 (4.77)***	0.726 (2.77)***
Male life expectancy	0.009 (1.87)	0.017 (1.33)	0.017 (4.84)***	0.023 (2.26)**
Female life expectancy	-0.007 (-0.17)	-0.018 (-1.34)	-0.017 (-4.81)***	-0.021 (-2.15)**
Male primary enrolment	0.002 (1.78)*	-0.001 (-0.69)	-0.001 (-2.43)**	-0.003 (-1.93)*
Female primary enrolment	-0.001 (-1.09)	0.002 (0.96)	0.001 (3.13)***	0.002 (1.55)
Male secondary enrolment	-0.001 (-1.38)	0.002 (0.93)	0.002 (3.77)***	0.004 (2.34)**
Female secondary enrolment	0.001 (1.20)	-0.001 (-0.26)	-0.001 (-2.24)**	-0.002 (-1.48)
Investment to GDP				$1.82e^{-10}$ (0.37)
M2 to GDP				-0.145 (-2.38)**
R^2	0.27			
Time effect	Yes	Yes	Yes	Yes
No of obs/countries	1531		1152/79	919/73
No of instruments			100	100
Arrelano-Bond test AR(2) (p-value)			0.34	0.31
Hansen (p-value)			0.59	0.93
Diff in Hansen (p-value)			0.55	0.92

Note: t-statistics on parentheses. ***, **, * means significance at 1%, 5% and 10% level. LSDVC has bootstrapped standard errors. SGMM estimation is based on two-step estimator with robust standard error.

negative sign respectively but not significant. Whilst the estimated coefficient of the catch-up term is significant, it has a negative sign implying countries are widening their TFP gaps from their steady state level. This is a less appropriate result and perhaps it is due to the OLS estimation which can be problematic because it neither takes into account the issue of nonlinearity or endogeneity. Additionally there might also be some issues related to misspecified dynamics.

Due to the business cycle effect it is quite possible that output growth is autocorrelated. If these dynamics of the data are not appropriately modelled, then it is likely that the estimated coefficients will be biased. A better option is to model these dynamics by introducing the lagged rate of output growth as an independent variable. This however, leads to some estimation problems that have to be dealt with by using Dynamic Panel Data (DPD) estimators. In our first attempt to capture these dynamics we include a lagged output term in the growth equation (6) and estimate it using the bias corrected least square dummy variable (LSDVC) estimator proposed by Kiviet (1995). The results are presented in column (2) of Table 5. The coefficients on the share of physical capital and output, which are significant and positive, have not changed much compared to their OLS counterparts but the catch-up term is now positive as expected and significantly different from zero giving the indication that the dynamics of the dependent variable has now been properly specified. None of the human capital variables though are significant but it is interesting note that the estimated coefficients on the male and female life expectancy variables are positive and negative respectively, similar to those in the OLS estimates. Moreover, the magnitude of the estimated coefficient on male life expectancy has increased to 0.017 from 0.009 in the previous estimation. Likewise, the magnitude of female life expectancy has dropped to -0.018 from a modest -0.007 in the OLS estimation. The estimations using LSDVC give us an indication of the effect of female and male life expectancy on growth, but it does not allow generalising the results because the coefficients may still suffer from bias due to nonlinearity and endogeneity in the data. We use a system GMM (SGMM) estimator to tackle both of these issues as well as to accommodate the dynamics in the dependent variables. The results are presented in column (3) of Table 4.

The SGMM estimates are our preferred results. All variables included are significantly different from zero at the conventional level. The estimated capital share is 0.38 which is close the stylized value but the share of labour is not. The catch-up term bears the correct sign but its magnitude is very high: almost half of the TFP gap is matched up every year. Our variable of interest is the health measure and it can be seen that male life expectancy has a positive effect on output growth but female life expectancy has a negative effect. The estimated coefficient on the male life expectancy is 0.017 which means, increasing male life expectancy by a year will improve labour productivity and increase output growth by roughly 2 percent. Surprisingly, the estimated coefficient on female expectancy is exactly the same as that of male but with an opposite sign implying that increasing female life expectancy by a year will actually reduce output growth by 2 percent. Although the effect of education is not a primary concern in this paper, we can see that male primary and female secondary enrolments have a negative effect on growth but male secondary and female primary enrolment has positive effects. The magnitudes of these effects are quite small though. For example increasing female primary enrolment by a 1 percent will increase output growth by only 0.1 percent. Similarly increasing secondary male enrolment by 1 percent will increase output growth by 0.2 percent. This result is consistent with that of Barro and Lee (1994) who argue that the coefficient on secondary female education could be negative due to the high spread between male and female education, with the much lower rates of female education suggesting higher growth potential through convergence.

The SGMM estimator suggested by Arellano and Bover (1995) and Blundell and Bond (1998) estimates a regression by using a system of equations. For example equation (6) is estimated as a system of two equations in its growth and level form. Since the right-hand-variables are typically endogenous and mismeasured with error, SGMM has instrumented those with lagged levels of the series in the first differenced equation and with lagged difference of the series for the level equation. We have also used additional instruments for life expectancy variables by using 5 and 10 year lags of primary and secondary enrolments to control for reverse causality. Thus the acceptability of the SGMM results depend not only on whether the overidentifying restrictions are valid but also whether too many instruments are used. The use of too many instruments can overfit endogenous variables and weaken the diagnostic statistic. However, as suggested by Roodman (2009) we limit the lag of GMM-style instruments by collapsing and report the number of instruments. We report the p-values of Hansen and difference-in-Hansen statistics which show that overidentifying restrictions are valid.

The results thus obtained implicitly assume all countries have the same level of steady state TFP. This is not an improper assumption given that we are willing to accept the proposition that each country's steady state TFP is ultimately determined by the world technology frontier. Country specific fixed factors such as geography and political institutions can also determine steady state TFP. But since equation (6) is in first differenced form, all unobserved fixed factors are removed and the results are free from any omitted variable bias from such factors. Nevertheless, there can be some short run policy effects which can lead to different steady state levels of TFP. As a result to check the robustness of the SGMM results in column (3), we re-estimate it using two additional control variables—investment to GDP and M2 to GDP ratio—which are frequently used in the empirical growth literature. Obviously we do not use all the control variables which are found significant in various studies. This is because we are estimating a production function but not a growth regression. The primary reason to include some control variables is to allow for steady state TFP to differ across countries. The results are reported in column (4) of Table 5.

The SGMM results in column (4) are very similar to those obtained in column ((3)?. All variables are significantly different from zero except for female education, investment ratio and the lagged output term. The signs and significances of the human capital are unchanged and their estimated magnitude has increased by small factor. While a one year increase in male life expectancy improves output growth by 2.3 percent, the same increase in female life expectancy would lower output growth by 2.1 percent. Note that the catch-up term has increased from its previous estimates in column (3) implying that controlling for short-run policy factors could lead to closing TFP gaps faster. The overidentifying restrictions are valid as can be seen from the p-values of the Hansen and difference-in-Hansen statistics.

Table 6
Estimation of growth equation for sub period
Dependent variable: output growth

	1980-2009		1990-2009	
	(1) OLS	(2) SGMM	(3) OLS	(4) SGMM
Lagged output		0.356 (4.24)***		0.371 (3.63)***
Capital	0.527 (12.78)***	0.427 (7.64)***	0.581 (11.55)***	0.416 (6.09)***
Labour	0.289 (4.55)***	0.131 (7.68)***	0.398 (4.79)***	0.128 (6.11)***
(1-ρ)	-0.002 (-2.03)**	0.636 (7.60)***	-0.003 (-2.86)***	0.624 (6.21)***
Male life expectancy	0.009 (1.99)**	0.019 (7.34)***	0.012 (2.01)**	0.018 (5.45)***
Female life expectancy	-0.001 (-0.18)	-0.020 (-7.57)***	-0.002 (-0.28)	-0.019 (-5.94)***
Male primary enrolment	0.002 (1.87)*	-0.002 (-2.84)***	0.002 (2.04)**	-0.002 (-3.40)***
Female primary enrolment	-0.001 (-1.30)	0.002 (3.48)***	-0.002 (-1.50)	0.002 (4.07)***
Male secondary enrolment	-0.001 (-2.12)**	0.002 (4.34)***	-0.001 (-1.34)	0.002 (4.53)***
Female secondary enrolment	0.001 (1.98)**	-0.000 (-1.80)*	0.001 (1.37)	-0.000 (-1.95)*
R^2	0.28		0.38	
Time effect	yes	yes	Yes	Yes
No of obs/countries	1482	914/79	960	822/78

No of instruments		84		82
Arrelano-Bond test AR(2) (p-value)		0.69		0.85
Hansen (p-value)		0.39		0.13
Diff in Hansen (p-value)		0.33		0.10
Note: t-statistics on parentheses. ***, **, * means significance at 1%, 5% and 10% level. SGMM estimation is based on two-step estimator with robust standard error.				

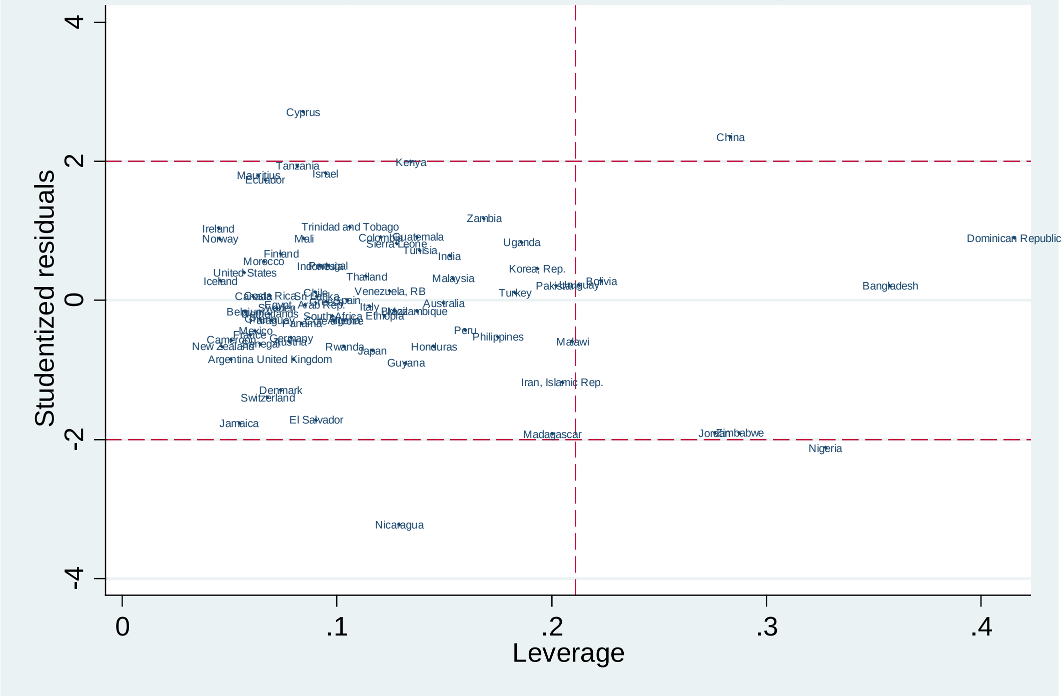
Given the results so far, our main conclusion is that if we use health capital as regular factors of production, then male life expectancy has a positive effect on growth and female life expectancy has a negative effect. We test it further by examining whether this result still holds if we truncate the sample period because measurement error in data is assumed to be less in later sample periods than in the earlier periods. As a result we re-estimate the growth equation using OLS and SGMM in two sub-samples – 1980-2009 and 1990-2009 and present the results in Table 6. We prefer the SGMM results where all the estimated coefficients are significant. SGMM results for the sub-sample period 1980-2009 are in column (2). The estimated coefficient on male life expectancy is 0.019 implying a year increase in this variable will enhance output growth by 1.9 percent. On the other hand, the estimated coefficient on female life expectancy is -0.02 meaning that a one year increases in female life expectancy reduces growth by 2 percent. The SGMM results for the sub-sample 1990-2009 are very similar which are reported in column (4) of Table 5. We can still see that increase in male life expectancy increases output growth while that in female life expectancy reduces growth.

6 Influential Observation and Outlier Detection

So far we have conducted our analysis assuming that our estimations are not biased due to the effect of any influential observation and outliers in the data. Influential observations are data points that can have a large or influential impact on some aspect of the estimation of the model of interest and outliers are points which are away from the rest of the data (Donald and Maddala, 1993). In this section we attempt to identify influential observations and outliers using a number of standard diagnostics. Belsley, Kuh and Welsch (1980) outline a number of 'deletion diagnostics' for detecting influential observations and outliers, based on the effect on the regression results of deleting individual observations. These include studentised residuals (RSTUDENT) and leverage (h). Donald and Maddala (1993) argue that the studentised residual is the most appropriate indicator for detecting influential observations and for detecting outliers. Tthey recommend that leverage should be used in conjunction with studentised residuals. Fiebig (1992) argue that examination of both leverage and studentised residuals may be necessary to detect influential observations as well as outliers

To find out the influential observations and outliers in our data set, we first collapse our data into a pure cross-section where each variable is expressed as average values for the whole sample period giving us a total of 83 observations. We then estimate equation (6) using OLS and obtain the studentised residuals (RSTUDENT) and leverage (h). The leverage-residual (L-R) plots which graphs the value of RSTUDENT against h is presented in Figure 3.

Figure 3. Leverage-residual plot



Based on the suggested cut-off points for |RSTUDENT| = 2.0 and |h| = 0.2118, we detect 9 influential observations and outliers in our sample which include the following countries: Bangladesh, Bolivia, China, Cyprus, Dominican Republic, Jordan, Nicaragua, Nigeria and Zimbabwe.

Having identified the influential observations and outliers there are two options for us. Either remove these from our sample or accommodate them with the use of some form robust regression method. Fiebig (1992) proposes that, in general, identification is more fundamental than accommodation and emphasize some of the drawbacks of robust estimation. Nevertheless, as a first strategy, we experiment with some different forms of robust estimation of growth equation (6), including quantile estimation, iteratively reweighted least square and MM-Estimator which are presented in columns (1), (2) and (3) respectively in Table 7. It can be seen that male life expectancy still exerts a positive impact on output growth while the effect female life expectancy is no longer significant. However, the results in Table 7 should be treated with caution because it is based on pooled data and unaccounts for endogeneity and nonlinearity. As a result, to finally check that our result is not driven by any influential observation and/or outlier, we remove the 9 countries from our sample and re-estimate the growth equation, the results of which are presented in Table 8. We present both OLS and SGMM estimations but our preferred estimator is the latter. It can be seen from column (2) in Table 8 that all variables are significant bearing the same signs as before. The effect of male life expectancy on growth is positive with an estimated impact of 0.016. On the other hand the estimated effect of female life expectancy on output growth in negative with an estimated impact of -0.017.

Table 7
Robust regression for full sample period

	(1) Median Regression Estimator	(2) Iteratively Reweighted Least Square	(3) MM-Estimator
Capital	0.443 (19.56)***	0.478 (20.34)***	0.477 (14.39)***
Labour	0.518 (11.54)***	0.466 (10.02)***	0.467 (9.29)***
(1-ρ)	-0.001 (-1.72)*	-0.001 (-1.66)*	-0.001 (-1.66)*
Male life expectancy	0.006 (1.91)*	0.008 (2.33)**	0.008 (1.88)*
Female life expectancy	0.001 (0.23)	-0.002 (-0.46)	-0.002 (-0.40)
Male primary enrolment	0.001 (2.79)***	0.001 (1.69)*	0.000 (1.45)
Female primary enrolment	-0.002 (-3.06)***	-0.001 (-1.48)	-0.001 (-1.40)
Male secondary enrolment	-0.000 (-0.77)	-0.000 (-0.95)	-0.000 (-0.83)
Female secondary enrolment	0.000 (0.64)	0.000 (0.50)	0.000 (0.49)
Constant	0.007 (5.42)***	0.006 (4.64)***	0.006 (4.44)***
Obs	1940	1940	

Note: t-statistics on parentheses. ***, **, * means significance at 1%, 5% and 10% level.

Table 8 Estimation of growth equation removing outliers Dependent variable: output growth		
	(1) OLS	(2) SGMM
Lagged output		0.421 (3.18)***
Capital	0.473 (10.94)***	0.384 (4.34)***
Labour	0.356 (5.98)***	0.118 (4.54)***
(1-ρ)	-0.002 (-1.72)*	0.571 (4.39)***
Male life expectancy	0.011 (2.54)**	0.016 (4.35)***
Female life expectancy	-0.002 (-0.41)	-0.017 (-4.42)***
Male primary enrolment	0.002 (1.99)**	-0.002 (-2.75)***
Female primary enrolment	-0.001 (-1.18)	0.002 (3.24)***
Male secondary enrolment	-0.000 (-0.65)	0.002 (3.78)***
Female secondary enrolment	0.000 (0.34)	-0.001 (-2.66)***
R^2	0.28	
Time effect	Yes	Yes
No of obs/countries	1397	1058/71
No of instruments		100
Arrelano-Bond test AR(2) (p-value)		0.32
Hansen (p-value)		0.98
Diff in Hansen (p-value)		0.97
Note: t-statistics on parentheses. ***, **, * means significance at 1%, 5% and 10% level. SGMM estimation is based on two-step estimator with robust standard error.		

7 Conclusion

It is widely believed by development economists that the role of human capital is one of the most fundamental determinants of economic growth. Sustained growth depends on the level of human capital whose stocks increase due to better education, higher levels of health, new learning and on-the-job-training. The intuition that good health raises the level of human capital and has a positive effect on productivity and economic growth has been modelled by enodogenous growth theorists. But empirically ascertaining the causal relationship between health and growth is more difficult due to the possible existence of endogeneity between these two variables. Previous studies on health and economics do not take the issue of reverse causality into consideration. In a recent study AJ and

LMW use instrumental variable techniques to arrive at different conclusions on health effects on growth. Using the same instruments and data in LMW's and AJ's respectively, Aghion, Howitt and Murtin (2010) and Bloom, Canning and Fink (2009) found a positive effect of health on growth by using a unified model including the initial level of life expectancy in the regression to allow for convergence in the form of human capital. Our paper contributes to the above debate by estimating the gender disaggregated effect of health. By controlling for endogeneity and excluding the impact of influential observations and outliers, we show whilst male health contributes positively in output growth, female health contributes negatively. Barro and Lee (1994) note that life expectancy could be acting as a proxy for other variables such as good work habbits and higher skills. It is possible that the life expectancy of females in the present study is acting as a proxy for the lower skill levels of females. Therefore skill levels and education opportunities for females should be increased in an attempt to promote growth.

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Data Appendix

Variable	Source
Per capita income(constant 2000 US$)	World Development Indicators 2010
Capital stock dollars	Bosworth and Collins 2003, from 2004-2009 World Development Indicators 2010 using perpetual inventory method.
Labour force number	Bosworth and Collins 2003, from 2004-2009 World Development Indicators 2010.
Enrolment ratio primary female gross %	World Development Indicators 2010
Enrolment ratio primary male gross %	World Development Indicators 2010
Enrolment ratio secondary female gross %	World Development Indicators 2010
Enrolment ratio secondary female gross %	World Development Indicators 2010
Life expectancy female years	World Development Indicators 2010
Life expectancy male years	World Development Indicators 2010
M2 to GDP %	World Development Indicators 2010
Investment to GDP %	World Development Indicators 2010