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AIDS and Economic Growth: A Panel Data Analysis

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PRELIMINARY DRAFT. PLEASE DO NOT QUOTE

1. Introduction

HIV/AIDS is the world's fourth biggest cause of death, after heart disease, strokes and acute lower respiratory infections (World Health Report, 1999). The former primarily affect people in old age, whereas AIDS deaths are concentrated among prime age adults who are at their productive and reproductive peak. Estimates of the prevalence of HIV/AIDS have increased markedly in recent years with infection rates reaching 25 per cent among the sexually active populations in the AIDS belt of Africa, which runs south from Sudan and the Central African Republic to South Africa. It is therefore not surprising that life expectancy estimates for sub-Saharan Africa (SSA) have declined sharply: estimates suggest that by 2005-2010 life expectancy at birth in the nine countries with HIV prevalence rates greater than 10 percent will decline by an average of 17 years. The human and social costs of the HIV/AIDS epidemic are inevitably and justifiably major causes for concern.

The epidemic is also likely to induce major changes in economic relationships, with the increases in morbidity and mortality threatening to eliminate 25 years of development gains. It might be argued that the consequences of the epidemic for income and growth pale into insignificance relative to the human and social consequences; however, deteriorations in economic performance are likely to compound the social and human effects and reduce the capacity of countries to counter the worst effects. It is reasonable to expect that reductions in labour supply, due to declining life expectancy, will adversely affect output; an effect that will be compounded by reductions in productive efficiency associated with increased incidences of ill health and shortages of critical skills. Moreover, such declines in economic activity will take place against a background of rising health care expenditures, both private and public, which will strain Government budgets and are likely to reduce (public and private) savings rates. Consequently, it is reasonable to hypothesise that the epidemic may pose one of the greatest current challenges to sustained economic development and human and social relationships.

Empirical analyses of the macroeconomic impact of the epidemic have been based largely upon standard neoclassical growth models. In the context of these models the epidemic would be expected to reduce productive efficiency, and hence output per worker, reduce the rate of growth of the labour force and lower the savings rate. Cuddington (1993a, pp 178-1) demonstrates that in a simple neoclassical growth model the epidemic may cause per capita income and the capital-labour ratio to either increase or decrease because the labour force and savings rate effects operate in opposite directions. Hence it is arguable that the impact of the epidemic upon economic growth is an empirical question.

Quantitative estimates in the early 1990s were compromised by a lack of appropriate data, and hence to a greater or lesser extent calibrated growth models were used to derive estimates of the macroeconomic effects of the epidemic. Over (1992) estimated that between 1990 and 2025 the 10 countries with the most advanced epidemics would see a reduction in growth per capita of around a third of a percentage point compared to a non-AIDS scenario. Similarly, Cuddington and Hancock (1994) suggest that between 1985 and 2010 Malawi could experience average real GDP growth up to 1.5 percentage points lower. And Cuddington (1993) also estimates that in Tanzania per capita GDP could be up to 10% smaller.

On the other hand a statistical study by Bloom and Mahal concluded that "there is more flash than substance to the claim that AIDS impedes national economic (income) growth." (1997, p 120), while acknowledging that the negative impact on life expectancy may affect development. There are reasons related to the data to doubt the robustness of Bloom and Mahal's results. The empirical estimates were based on data for the period 1980-92, but prevalence estimates for the early 1990s were typically one seventh to one fifth of those now produced. Furthermore, the AIDS epidemic was still in its early stages and hence its impacts upon morbidity and mortality were still relatively restrained. Given the data limitations it is not surprising that Bloom and Mahal's sample was constrained to 51 countries, although it is worrying that countries with high infection rates were not included, e.g., South Africa, Botswana, Rwanda, Namibia and Swaziland.[1] There are also theoretical and statistical reasons to reevaluate Bloom and Mahal's results (see below).

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1 Namibia is also excluded from the sample used in this study

The analyses reported in this paper are derivatives of the empirical research into economic growth that has developed since the late 1980s. A large part of the literature has sought to quantify the contribution of human capital to the growth process (Mankiw et al., 1992; Barro and Lee, 1993; Benhabib and Spiegel, 1994, among many others). Mankiw *et al*., (1992, p 408) note that a misspecification bias will arise if both physical and human capital exists and human capital is omitted from the estimating equation. They therefore augmented a neoclassical growth model with a human-capital variable, which was defined in terms of education. However human capital is a complex input, which consists of more than education. In particular it has been argued that health capital is an important dimension of human capital, e.g., Schultz, 1961; Mushkin, 1962. If these other dimensions of human capital are not included in estimating equations then the misspecification bias will only be partially addressed. Studies that report estimates of the effects of health on growth are limited, e.g., Hicks (1979), Wheeler (1980), Knowles and Owen (1995) and McDonald and Roberts (2000). The latter two studies in particular confirm the empirical significance of health capital, in terms of life expectancy and infant mortality, as a determinant of economic growth.

The vast majority of the empirical growth literature has adopted estimating equations that use the cross-country cross-section method, which has a number of potential weaknesses. First, the method requires the imposition of restrictions assuming common initial technologies, common rates of technical progress and common preferences across countries. And second, cross section regressions collapse dynamics and therefore discard potentially important information. Panel data methods on the other hand permit explicit testing of the assumptions required by the cross-section method and they make use of information arising from variation across countries and over time. In the context of economic growth, panel data studies have indicated that the results of cross-section studies may be suspect (Islam, 1995; Lee *et al*., 1997; Miller, 1996; Cellini, 1997; McDonald and Roberts, 1996; 1999).

The results reported in this paper are based upon an augmented Solow model that incorporates both health and education capital in a dynamic panel data model. More importantly, the model is estimated as a system wherein health capital is partially determined by health status, in particular the prevalence of HIV infection. The next section summarises the derivation of the growth and health capital equations, and comments on the panel data methods. Section 3 starts with a discussion of the available data and how they influence the specification of the estimating equations, and then reports and discusses the results. The final section contains concluding comments.

2. Health and Growth in an Augmented Solow Model

The Augmented Solow Model[2]

Augmenting the Solow model with terms for both education capital (*E*) and health capital (*H*) is a straightforward extension. Defining the aggregate production function as a Cobb-Douglas function with constant returns to scale and labour augmenting technical progress, the process of augmentation involves the addition of an argument for health capital, i.e.,

$$Y_{it} = [A_{it} L_{it}]^{1-a-b-y} K_{it}^{a} E_{it}^{b} H_{it}^{y} \tag{1}$$

where *Y* is output, *A* is technology, *L* is the stock of labour, *K*, *E* and *H* are respectively the stocks of physical, education and health capital, a, b and y are the elasticities of output with respect to the various capital terms, and the subscripts denote country (*i*) and time (*t*). Equation (1) can be re-written in intensive form as

$$y_{it} = k_{it}^{a} e_{it}^{b} h_{it}^{y} \tag{2}$$

where y_{it} is output per 'effective' labour unit $(A_{it} L_{it})$ in country *i* at time *t*, and k_{it}, e_{it} and h_{it} are respectively physical, education and health capital per 'effective' labour unit.

Assuming that the labour forces grow at country specific constant rates n_i, and technologies advance at period specific constant rates g_t, and that the physical, education and human capital stocks depreciate at the same constant rate, *d*, then it can be shown that the augmented steady state output per capita is

$$\ln y_{it}^{*} = \ln A_{i0} + g_t t - \frac{a+b+y}{(1-a-b-y)} \ln(n_i + g_i + d) + \frac{a}{(1-a-b-y)} \ln s_i^{k} + \frac{b}{(1-a-b-y)} \ln s_i^{E} + \frac{y}{(1-a-b-y)} \ln s_i^{H} \tag{3}$$

which is the same as Mankiw *et al.*'s equation 11 (p 417) except for the inclusion of a term for health capital.

Empirically (3) is difficult to implement because of an absence of disaggregated savings data. In general the available savings, or investment, data refer to physical capital, and estimates for education and health capital are likely to be missing. However underlying (3) is a steady-state condition in levels, which Mankiw *et al.*, exploited to derive alternative formulations of the estimating equation according to whether the augmenting capital terms are recorded as rates of accumulation, as in equation 3, or as levels, e.g.,

2 This model was developed in McDonald and Roberts (2000), which was itself a development of Knowles and Owen's (1995) model. Both models follow a lead established by Mankiw *et al.*, (1992).

$$\ln y_{it}^{*} = \ln A_{i0} + g_t t - \frac{a}{(1-a)}\ln\left(n_i + g_t + d\right) + \frac{a}{(1-a)}\ln s_i^k + \frac{b}{(1-a)}\ln e_{it}^{*} + \frac{y}{(1-a)}\ln h_{it}^{*} \quad (4)$$

The final choice of estimating equation is likely to be determined by the available data. But, although (3) is implicitly derived from a steady state expression in terms of levels, the use of (4) as a basis for empirical estimates does require the presumption of a steady state.

Linearising (4) around the steady-state level of income per effective unit of labour, y_{it}^{*}, by following the method used by Mankiw *et al*., produces

$$\begin{aligned}\ln y_{it}^{*} - \ln y_{i0}^{*} = f \ln A_{i0} + g_t t - \frac{fa}{(1-a)}\ln\left(n_i + g_t + d\right) + \frac{fa}{(1-a)}\ln s_i^k \\ + \frac{fb}{(1-a)}\ln e_{it}^{*} + \frac{fy}{(1-a)}\ln h_{it}^{*} - f \ln y_{i0}^{*}\end{aligned} \quad . \quad (5)$$

Equation (5) is the theoretical basis for the econometric growth model for which estimates are reported in this paper. It differs from the typical cross-section estimating equation in several important ways. It particular it allows for cross-time variations in the rates of growth of technology, g_t, country specific initial states of technology, $\ln A_{i0}$, and uses the time series information by being estimated as a dynamic data panel with two-way fixed effects, i.e., time-invariant country effects and time-specific technology effects. In standard panel data notation (5) can be written as

$$g_{it}^{*} = -f z_{i0}^{*} + \sum_{j=1}^{4} q_j x_{it}^{j} + h_t + m_i + n_{it} \quad (6)$$

where

$$g_{it}^{*} = \ln y_{it}^{*} - \ln y_{i0}^{*}$$
$$f = \left(1 - e^{lt}\right)$$
$$z_{i0}^{*} = \ln y_{i0}^{*}$$
$$q_1 = -q_2 = \frac{fa}{(1-a)}$$
$$x_{it}^{1} = \ln(n_i + g_t + d)$$
$$x_{it}^{2} = \ln s_i^k$$
$$q_3 = \frac{fb}{(1-a)}$$
$$x_{it}^{3} = \ln e_{it}^{*}$$
$$q_4 = \frac{fy}{(1-a)}$$
$$x_{it}^{4} = \ln h_{it}^{*}$$
$$h_t = g_t t$$
$$m_i = f \ln A_{i0}$$

An advantage of (6) is the ability to test the restrictions require for OLS estimation of the cross-section model. In particular the identifying assumption

$$\ln A_{i0} = a + e \; . \quad (7)$$

where a is a constant, invariant across countries, that all country differences are accounted for by the random term, e, and that the stochastic term is independent of all other explanatory variables, can be tested. When making comparisons across countries with substantially different initial levels of technology and technical progress it is particularly important to test the assumptions that they are common, i.e., $A_{i0} = A_0, g_i = g \forall i$. If these assumptions are not valid then doubts must be cast upon the results from empirical research dependent on these assumptions. Panel estimates of (6) using data for 1960 to 1989 (McDonald and Roberts, 2000) indicate that health capital has a positive, and often significant, impact upon economic growth. These results were obtained using a model that takes the health capital terms as being exogenously determined, and use data for a period that overwhelmingly precedes the substantive onset of the HIV/AIDS epidemic

The model in (6) differs appreciable from the growth equations specified by Bloom and Mahal (1997). First the variables that can be legitimately included when estimating variants of (6) are tightly specified by the theoretical derivation of the model. And second, and far more important, HIV/AIDS does not directly enter into the model, and it is not possible to retain a clear theoretical interpretation of the model by randomly introducing additional explanatory variables. Rather, it is preferable to identify relationships between the explanatory variables and the prevalence or incidence of HIV/AIDS. Hence it is hypothesised that the impacts of diseases enter into the determination of growth indirectly through their impact upon both the population growth terms and the health capital terms. This requires a model wherein health capital is explained.

Health Capital

There is no known or settled body of economic theory devoted to an explanation of the determinants of health capital. A substantial literature exists that seeks to measure the quality of life using such concepts as quality adjusted life years (QALYS) and disease adjusted life years (DALYS), but these serve more to identify the likely determinants rather than the specific (functional) relationships between them. In the present context it is postulated that health capital in a country is a consequence of the material standard of living, health care expenditures and the incidence of contagious diseases and/or ill health, e.g.,

$$h_{it} = f\left(w_{it}, m_{it}, d_{it}\right) \tag{8}$$

where w_{it} is some measure of the material standard of living, m_{it} is health care provision per capita and d_{it} is the incidence of diseases.

This formulation does not try to explain the prevalence or incidence of disease as an economic phenomenon. If there is a degree of simultaneity between income growth and the incidence of disease this formulation may be problematic. Indeed it has been suggested that the extent of commercial sex may be related to income (Over, 1992) and that the prevalence of untreated sexually transmitted diseases may decline as income grows because of improved health care provision (Over and Piot, 1993).

As with the macroeconomic growth model, the equation for health capital sidesteps potentially important distributional questions. Simple national average measures of the explanatory variables may not be appropriate in circumstances where there are wide differences in the standard of living, access to health care systems and incidences of disease within countries. While these questions are relevant they are beyond the scope of this study.

3. Analysis

Data

The main source of data is the World Bank (1999). The data used are real GDP per capita adjusted for purchasing power parity, shares of real GDP invested (I), and population (POP). The GDP data are an update of Penn World Tables (PWT) (see Summers and Heston, 1988 and 1991), which was developed by the World Bank using data from the Global Development Finance & World Development Indicators databases. The real GDP per worker and number of worker series produced for the PWT have not been updated beyond 1990, and therefore these preferred data could not be used. The data for investment rates were calculated from current price data on GDP and domestic investment reported in World Development Indicators (World Bank, 1994 and 1997). The same source provided the population data. The rates of growth of GDP and population are estimated by log linear regression of the GDP and population series. The three education series, primary school enrolment rates, secondary school enrolment rates and tertiary enrolment rates, were also from World Development Indicators (World Bank, 1994 and 1997).[3]

The proxy for health capital is the shortfall of life expectancy relative to a nominal benchmark, i.e., LE = - ln(80 – life expectancy).[4] This proxy can be criticised for making "no allowance for the quality of health beyond survival" (Knowles and Owen, 1995, p 102), but Sen (1998) has defended it in the context of developing countries. Life expectancy at birth is defined as the mean age at death of a fictitious generation subject to the mortality conditions of the period considered, and the data were obtained from World Development Indicators (World Bank, 1994 and 1997).

Data on health care expenditures are limited in terms of both coverage of countries and time series. While there are reasonably comprehensive estimates for OECD countries, the data for developing countries are very sparse. Possible proxies would include the numbers of doctors, nurses and hospital beds available and the extent of immunization programmes (World

3 The GDP, population and school enrolment data are available on the web: http//::www.worldbank.org.

4 This transformation is typical of the Human Development Report (e.g., UN, 1998) and has been used by Anand and Ravallion (1993) and Knowles and Owen (1995).

Bank, 1994 and 1997). Of these only data on the numbers of doctors are reasonably comprehensive. There is a substantial body of evidence that health care expenditures are highly correlated with income levels (Roberts, 1999; Blomqvist and Carter 1997), and hence income per capita represents a potential proxy. Income per capita is also a potential proxy for material standard of living. An alternative is nutritional status. Estimates of calorie and protein supplies per capita were compiled using data from the FAO's FAOSTAT database (FAO, 2000).

The estimates of disease burden were limited to the prevalence of HIV. The estimates of the prevalence were obtained from UNAIDS, as were the years in which HIV or AIDS was first reported. The econometric model reported in this paper uses crudely derived estimates of the prevalence of HIV between the year of first report and 1997. These will be revised when the embargo on more recent HIV estimates from UNAIDS expires.

The database consists of time series data for 104 countries over the period 1960 to 1997, although for a number of variables the data is only available at 5 yearly intervals. There are various samples, a 34-country sub-Saharan Africa sample, a 21-country OECD sample and a 15-country South and East Africa sample. The countries are listed in the Appendix. All the variables are in logarithms.

Estimation Method and Results[5]

Equations (6) and (8) were estimated as a system using seemingly unrelated regression (SUR) (Zellner, 1962). The dependent variable in equation (11) is the average growth rate of GDP per capita over each five-year period (AYC) and the income term used as an explanatory variable in equation (8) is the log of GDP per capita (LYC). As such the system is not simultaneously determined. However, it is reasonable to expect the errors from these two equations to be contemporaneously correlated, hence SUR provides more efficient estimates than OLS estimation of each equation separately. This structure is a first attempt at linking growth, while allowing for both country and time specific fixed effects in the estimation.

Results for both OLS and SUR are reported in Table 1. In all cases Brueusch-Pagan tests confirm the presence of country specific effects and Hausman tests suggest that fixed effects are the appropriate specification. For the full sample of countries the results for the life expectancy equation are very similar and conform to *a priori* expectations. These results indicate that life expectancy increases with nutritional status and income, the proxies for well-being and health care expenditures respectively, and that these relationships are strongly significant. The impact of AIDS on life expectancy is negative and significant. It is no surprise that the incidence of disease impacts upon life expectancy; however both the magnitudes and

5 All estimation was carried out using STATA v6.0 and Eviews v3.1.

the degrees of significance of the coefficient on the AIDS variables are greater than expected, given the period of the epidemic covered by the data. The results are similar across linear and log linear interpolations of AIDS prevalence and thereby encourage confidence in the reliability of these results, but it remains desirable to devote greater attention to the time series of AIDS data.

Table 1: Two Way Error Components Fixed Effects Models

	OLS Estimates			**SUR estimates**			
	Full Sample i = 104 n = 816			**Full Sample**		**Sub-Saharan Africa** i = 34 n = 272	
Growth							
I	0.022* (0.004)	0.017* (0.004)	0.019* (0.004)	0.019* (0.004)	0.019* (0.004)	0.026* (0.005)	0.026* (0.005)
n+g+d	0.011 (0.017)	0.0003 (0.016)	0.010 (0.017)	0.006 (0.016)	0.005 (0.016)	0.023 (0.026)	0.023 (0.026)
ped	-0.022* (0.006)		-0.023* (0.006)	-0.018* (0.006)	-0.017* (0.006)	-0.003 (0.009)	-0.003 (0.009)
le	0.011* (0.006)	0.012* (0.005)		0.025* (0.006)	0.028* (0.006)	-0.018 (0.025)	-0.020 (0.025)
YC(-1)	-0.060* (0.006)	-0.059* (0.005)	-0.054 (0.005)	-0.064* (0.006)	-0.065* (0.006)	-0.094* (0.009)	-0.094* (0.009)
R^2	0.46	0.45	0.45	0.45	0.45	0.55	0.55
Life Expectancy							
LYC	0.329* (0.034)	0.313* (0.034)		0.329* (0.035)	0.325* (0.034)	0.032 (0.025)	0.049 (0.026)
AIDS log	-0.032* (0.003)			-0.032* (0.003)		-0.010* 0.002	
AIDS lin		-0.043* (0.004)			-0.043* (0.004)		-0.013* (0.002)
LPRO	0.167* (0.033)	0.131* (0.033)		0.187* (0.033)	0.144* (0.033)	0.078 (0.067)	0.016 (0.068)
R^2	0.95	0.95		0.95	0.95	0.87	0.87

Panel estimation based on five yearly averages 1960 to 1998 i.e., t = 1,2, …, 8.
Both country specific fixed effects and time specific effects are allowed for but are not reported.
Standard errors in parentheses.

The OLS and SUR results from the full sample for the growth equation (upper half of the table) do not differ very much, but are less impressive. The coefficients on ln(n+g+d) are not significant and the signs on the education capital term (lnPED) are negative. The education terms are of concern since it is common to find the coefficients on education variables are positive and significant. Moreover the results are very similar when secondary enrollment rates are used as an alternative to primary as a measure of education capital. There are reasons however to be cautious with the education variables used in this study. School enrollment rates are arguably capturing, albeit in a crude manner, investments in education, but these are durable investments that should produce a flow of services over the life times of those educated. It is therefore arguable that the stock of education capital may be a better variable to use, but it was not possible to derive such a series through till the late 1990s. Earlier results (McDonald and Roberts, 2000) indicate that for the period 1960 to 1989 the coefficients on the stock of education capital are positive and significant.

The coefficients on investment (I) and lagged income (YC(-1)) both have the expected signs and are strongly significant. The lagged income terms indicate that convergence is taking place. The positive and significant coefficients on investment are important. The underlying economic model emphasizes the role of investment, while the simple analytics of the model indicate that the diversion of income from savings to consumption (in response to an AIDS epidemic) will reduce the long run level of income per capita.

The coefficients on health capital (LE) are positive and significant, and much larger for the SUR estimates than OLS. This is consistent with earlier results (Knowles and Owen, 1995, McDonald and Roberts, 2000) that highlight the importance of health capital in the growth process. Given the pronounced downturn in life expectancies in many of those countries most affected by HIV/AIDS, and the results for the life expectancy equations, this result further emphasizes the potentially large adverse consequences of the epidemic. In light of the unexpected education results it is worth noting that the size and sign of the coefficients on education and health capital are robust to the omission of the other variable, suggesting that this is not a collinearity problem.

SUR results are also reported for a sample of sub-Saharan African economies (n = 34). Despite this being the region most affected by the HIV/AIDS epidemic, the results are less clear-cut. In the life expectancy equation the coefficients on income and protein have the expected signs but are not significant.[6] The coefficients on the AIDS variables remain negative and significant, but they are noticeably lower than for the full sample; a result that is counter intuitive. One possible reason is that the prevalence of life threatening diseases in Africa is far greater than the other countries in the sample. More disappointing is the poor performance of the growth equation. The coefficients for neither of the human capital terms are significantly different form zero, which suggest that human capital is less important in the African context than elsewhere (McDonald and Roberts, 2000, found a similar result for a sample of 55 developing countries). However it is noticeable that the coefficients on investment are

6 These results persist even when calories are used as the proxy for well-being.

appreciably larger; results that points to the importance of physical capital investment in Africa and the potential adverse consequences of declining investment rates.

5 Concluding Comments

Despite the need to qualify these results they do produce useful additional information, and they do indicate that the macroeconomic affects of the HIV/AIDS epidemic may be substantial. There are a number of data issues pointed up by these analyses. There is a need to improve the *a priori* reliability of the education capital series, and additional information of the prevalence of life threatening diseases and the provision of health care services is needed.

The pronounced impact of HIV/AIDS prevalence on life expectancies suggests that the epidemic may now be entering what has been termed stage 6, where the loss of life is starting to impact appreciably upon social indicators and especially upon life expectancies. The growth equations confirm the importance of life expectancy and physical capital investment to recorded economic performance, and thereby lend support to the argument that the economic implications of the epidemic deserve close and careful consideration. More importantly the results cast substantial doubt upon the reliability of Bloom and Mahal's (1997) conclusion that there appears to be no significant relationship between HIV/AIDS prevalence of economic growth. Further exploration of these relationships is important if only to direct policy makers attention to the economic implications of AIDS. More important in the long run is likely to be research that provides a greater understanding of the mechanisms by which sustained epidemics impact upon economic performance.

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Appendix

Derivation of Equation ??

Assuming that the labour forces grow at country specific constant rates n_i, and technologies advance at period specific constant rates g_t, and that the physical, education and human capital stocks depreciate at the same constant rate, d, then the capital stocks in country i at time t are

$$\begin{aligned} K_{it} &= I^{K}_{i,t-1} + (1-d)K_{i,t-1} \\ E_{it} &= I^{E}_{i,t-1} + (1-d)E_{i,t-1} \; . \\ H_{it} &= I^{H}_{i,t-1} + (1-d)H_{i,t-1} \end{aligned} \qquad \text{(A1)}$$

If savings are divided between physical, education and human capital accumulation, i.e., education and health capital accumulation is treated as an investment activity, such that

$$s_{it} = s^{K}_{it} + s^{E}_{it} + s^{H}_{it} = \frac{S_{it}}{Y_{it}} = \frac{I_{it}}{Y_{it}} = \frac{I^{K}_{it} + I^{E}_{it} + I^{H}_{it}}{Y_{it}} \; . \qquad \text{(A2)}$$

then the rates of physical, education and health capital growth per unit of labour are defined as

$$\begin{aligned} \dot{k}_{it} &= s^{K}_{it} y_{it} - (n_i + g_t + d)k_{it} \\ \dot{e}_{it} &= s^{E}_{it} y_{it} - (n_i + g_t + d)e_{it} \\ \dot{h}_{it} &= s^{H}_{it} y_{it} - (n_i + g_t + d)h_{it} \end{aligned} \qquad \text{(A3)}$$

and the steady state values of k^*, e^* and h^* are

$$\begin{aligned} k^* &= \left[\frac{\left(s^k_i\right)^{1-b-y} \left(s^E_i\right)^{b} \left(s^H_i\right)^{y}}{n_i + g_t + d} \right]^{1/(1-a-b-y)} \\ e^* &= \left[\frac{\left(s^k_i\right)^{a} \left(s^E_i\right)^{1-a-y} \left(s^H_i\right)^{y}}{n_i + g_t + d} \right]^{1/(1-a-b-y)} \\ h^* &= \left[\frac{\left(s^k_i\right)^{a} \left(s^E_i\right)^{b} \left(s^H_i\right)^{1-a-b}}{n_i + g_t + d} \right]^{1/(1-a-b-y)} \end{aligned} \qquad \text{(A4)}$$

and therefore

$$\begin{aligned} \ln k^*_i &= \frac{1}{(1-a-b-y)} \left[\ln\left(\left(s^k_i\right)^{1-b-y} \left(s^E_i\right)^{b} \left(s^H_i\right)^{y} \right) - \ln\left(n_i + g_t + d\right) \right] \\ \ln e^*_i &= \frac{1}{(1-a-b-y)} \left[\ln\left(\left(s^k_i\right)^{a} \left(s^E_i\right)^{1-a-y} \left(s^H_i\right)^{y} \right) - \ln\left(n_i + g_t + d\right) \right] \\ \ln h^*_i &= \frac{1}{(1-a-b-y)} \left[\ln\left(\left(s^k_i\right)^{a} \left(s^E_i\right)^{b} \left(s^H_i\right)^{1-a-b} \right) - \ln\left(n_i + g_t + d\right) \right] \end{aligned} \qquad \text{(A5)}$$

from which the augmented steady state output per capita can be derived.

<u>Samples</u>

Country	**Sub-Saharan Africa**	**Country**	**Sub-Saharan Africa**	**Country**	**Sub-Saharan Africa**	**Country**	**Sub-Saharan Africa**
Argentina		Spain		Lesotho	o	Rwanda	o
Australia		Ethiopia	o	Luxembourg		Saudi Arabia	
Austria		Finland		Morocco		Sudan	o
Burundi	o	Fiji		Madagascar	o	Senegal	o
Belgium		France		Mexico		Singapore	
Benin	o	Gabon	o	Mali	o	Sierra Leone	o
Burkina Faso	o	United Kingdom		Malta		El Salvador	
Bangladesh		Ghana	o	Mauritania	o	Suriname	
Bolivia		Gambia, The	o	Mauritius		Sweden	
Brazil		Guinea-Bissau	o	Malawi	o	Swaziland	o
Barbados		Greece		Malaysia		Syrian Arab Republic	
Botswana	o	Guatemala		Niger	o	Chad	o
Central African Republic	o	Guyana		Nigeria	o	Togo	o
Canada		Hong Kong, China		Nicaragua		Thailand	
Switzerland		Honduras		Netherlands		Trinidad and Tobago	
Chile		Haiti		Norway		Tunisia	
Cote d'Ivoire	o	Indonesia		Nepal		Turkey	
Cameroon	o	India		New Zealand		Tanzania	o
Congo, Rep.	o	Ireland		Oman		Uganda	o
Colombia		Israel		Pakistan		Uruguay	
Costa Rica		Italy		Panama		United States	
Denmark		Jamaica		Peru		Venezuela	
Dominican Republic		Japan		Philippines		South Africa	o
Algeria		Kenya	o	Papua New Guinea		Congo, Dem. Rep.	o
Ecuador		Korea, Rep.		Portugal		Zambia	o
Egypt, Arab Rep.		Sri Lanka		Paraguay		Zimbabwe	o

Definitions

Variable	Definition	Source
YC	real GDP per capita[3]	World Bank Macroeconomic Series – updated PWT data
POP	Population[4]	Global Development Finance & World Development Indicators
I	share of real GP invested	Global Development Finance & World Development Indicators
AYC	Average annual growth rate of YC	Derived from a regression of the logarithm of YW on a time trend
YC0	real GDP per worker in first year of each five year period (initial income)	World Bank Macroeconomic Series – updated PWT data
NGD	(n + g + d) n = rate of growth of population force g = rate of growth of technology d = depreciation rate of all capital stocks	World Bank Macroeconomic Series – updated PWT data
PED	primary enrollment rate.	World Data, (World Bank 1997)
LE	shortfall in life expectancy	World Data, (World Bank 1997)
CAL	Calories per capita per day[1]	FAO
PRO	Protein per Capita per day (gms)[2]	FAO

Data Notes

1. a) Belgium and Luxemburg are a single entry in the FAO series – it was assumed that nutrient consumption levels in Belgium and Luxemburg were identical.

b) The FAO report two series for Czech Republic, one upto 1992 and the other after 1993. These series were merged since there was little evidence of a discontinuity in the series.

c) The FAO report two series for Ethiopia, one upto 1992 and the other after 1993. These series were merged since there was little evidence of a discontinuity in the series.

d) The FAO report two series for Yugoslavia, one upto 1991 and the other after 1992. These series were merged although there was an appreciable decline in calorie intake for 1992 compared to 1991.

e) The FAO report a series for the USSR upto 1991. This series was discarded.

2. a) Belgium and Luxemburg are a single entry in the FAO series – it was assumed that nutrient consumption levels in Belgium and Luxemburg were identical.

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d) The FAO report two series for Yugoslavia, one upto 1991 and the other after 1992. These series were merged although there was an appreciable decline in protein intake for 1992 compared to 1991.

e) The FAO report a series for the USSR upto 1991. This series was discarded.

3. a) All countries without complete RGDP series from 1960 to 1995 were eliminated. This included all the former USSR states and East European satellite states.

4. Comores was eliminated due to lack of population data.