# What Do We Know About the Impact of AIDS on Cross-Country Income So Far?*

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**Abstract**

This paper sheds new light on the impact of AIDS on cross-country income levels. We consider new UNAIDS/WHO data on officially reported AIDS cases for a panel of 89 countries over a 15 year period from 1986-2000 during which AIDS has spread across the world. These data are used to estimate cross-country level regressions employing panel data techniques. Our findings are threefold: First, when using the entire sample of countries we find that AIDS has a negative albeit marginally significant effect on the level of income. Second, when we control for regional effects we show that this negative effect is driven entirely by the sub-Sahara African sample. Third, using AIDS data by age group, we find that the disease has a significantly negative impact on income only via infected people between the ages 16 and 34.

**Keywords:** Health, economic development, reported AIDS cases, AIDS by age group, cross-country income levels.

**JEL Classification:** O30, O40, O47

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# 1 Introduction

The World Heath Organization (WHO) reported that as of November 2006, 39.5 million people were living with the human immunodeficiency virus (HIV) or the acquired immune deficiency syndrome (AIDS). According to the latest figures new cases of HIV in 2006 totaled 4.3 million with 2.8 million (65%) occurring in sub-Saharan Africa. AIDS related deaths in 2006 were estimated to be around 2.9 million. HIV/AIDS now ranks as the world's fourth largest cause of death, after heart disease, strokes and acute lower respiratory infections (Dixon, McDonald, Roberts (2002)).[1] AIDS has surpassed tuberculosis (1.6 million deaths in 2002) and malaria (1.3 million deaths in 2002) as the top single agent/disease killer. While the number of deaths due to nearly every disease has decreased, deaths due to HIV/AIDS have increased fourfold.

AIDS' alarming infection rate coupled with no known cure has very important social, political, demographic and certainly economic implications. A central point of analysis for economists is to evaluate the impact of AIDS on economic welfare and, in particular, on per capita income. The main goal of this paper is to provide new evidence on the potential effect of AIDS on income in a panel of countries using aggregate AIDS data. Our dataset is compiled from the UNAIDS/WHO *Epidemiological Fact Sheets* (2003) and represents the number of newly reported infections occurring each year for the period 1979-2000 across 115 countries.

Our main findings are as follows: AIDS, as proxied by the number of officially reported cases per 100,000 people, has a negative albeit marginally statistically significant effect on per capita income across a panel of countries. When we incorporate regional interactions with AIDS, we find that only sub-Saharan Africa is negatively affected by the disease whereas Latin America and OECD subsamples obtain insignificant coefficient estimates. Finally, using more disaggregated (but less detailed) AIDS data by age group, we find that the disease may be most disruptive via its negative effects in productive people between the ages 16 and 34.

There is a small but rapidly expanding literature related to the economic effects of AIDS. Several theoretical papers suggest large negative economic consequences of the pandemic. For example, Cuddington (1993), simulating a modified Solow model, conclude that AIDS, via its impact on

[1] For a very insightful introduction to AIDS and the various ways that is embedded within social, cultural, political, ideological and economic contexts see the book by Kalipeni et al. (2004). Extensive information on the AIDS epidemic and its economic consequences is available online at: *http://www.worldbank.org/aids-econ/*. For updates on recent academic and nonacademic papers, surveys, and field studies on HIV/AIDS in developing countries visit the website of the International AIDS Economics Network at: *http://www.iaen.org/papers/*.

morbidity and mortality rates, will reduce GDP in Tanzania in 2010 by 15 to 20 percent relative to a counterfactual of no-AIDS scenario. Similarly, Cuddington and Hancock (1994) using a similar methodology simulate the impact of AIDS on the Malawian economy and find that the average annual real per capita GDP growth over the 1985-2010 period is projected to be 0.2-0.3 percentage points lower compared to the alternative no-AIDS scenario. More recently, Ferreira and Pessoa (2003) have proposed a model in which AIDS impacts negatively on income by affecting the incentives for schooling attainment due to shorter expected longevity. Based on their model, the most affected countries in sub-Saharan Africa are predicted to become about 25 percent poorer than they would have been without AIDS, with schooling declining by about 50 percent. Finally, Corrigan, Glomm, and Mendez (2005) show that their model exhibits substantial negative growth effects of the AIDS epidemic through the detrimental impact of lower life expectancy on investment combined with a sizable number of orphans created by the epidemic. Perhaps the most notable and controversial paper on AIDS is Young (2005) that, through simulations, arrives at the conclusion that as a result of a significant decrease in population AIDS will increase the welfare of the future generations in South Africa by increasing their per capita income.[2] Largely owing to data constraints, these studies calibrate the impact of HIV/AIDS, but do not provide a meaningful empirical analysis.

At the empirical side, the literature on AIDS and development has recently picked up due to the emergence of new datasets on AIDS.[3] The first notable empirical contribution using cross-country data is Bloom and Mahal (1997). These authors use standard epidemiological models to estimate the number of reported AIDS cases from information on HIV prevalence at a point in time. Utilizing a rather scarce set of cross-country estimates on reported AIDS cases and using novel econometric techniques they arrive at the conclusion that the AIDS epidemic has had an insignificant effect on the growth rate of per capita income. Bonell (2000) and McDonald and Roberts (2006) also contact a cross-country empirical investigation and find a negative relationship between growth and AIDS whereas Lorentzen, McMillan and Wacziarg (2005) test the hypothesis that high adult mortality reduces economic growth by shortening time horizons and find substantial long-run economic costs

[2] Other recent notable theoretical papers include Levy (2002), Auld (2003), Clark and Vencatachellum (2003) and Young (2006).

[3] A selective set of papers that use microlevel data on AIDS include Wachter, Knodel and VanLandingham (2003), de Walque (2004), and Thornton (2006).

of the ongoing AIDS epidemic.[4]

More recently, a series of papers use macro data on AIDS but primarily focusing on sub-Saharan Africa. These papers include, Dixon, McDonald and Roberts (2001), Oster (2005, 2007a,b), Kalemli-Ozcan (2006), and Werker, Ahuja and Wendell (2006). Oster's papers primarily focus on the response of sexual behavior to HIV in sub-Saharan Africa whereas Kalemli-Ozcan's paper explores the effect of AIDS epidemic on demographic transition. Werker, Ahuja and Wendell (2006) use male circumcision to instrument for AIDS in growth regression for sub-Saharan Africa and find no effect of AIDS on economic output.

Our paper is more closely related to Bloom and Mahal (1997) but departs from it in two important ways: First, in order to address the economic implications of the disease on welfare, our framework focuses on levels rather than growth of per capita income.[5] Second, we use an alternative more comprehensive dataset. Although broader in scope, our paper also relates to the papers focusing on Africa in that we explicitly control for regional effects and show that sub-Saharan Africa is the only region that is negatively and significantly affected economically from the disease.

The remainder of the paper is organized as follows. Section 2 takes a first look at the AIDS data used in our empirical analysis. Section 3 presents our panel estimation results for the full sample of countries. In addition, this section present results using age-specific AIDS data. Section 4 discusses of our main results in relation to the existing literature and section 5 concludes.

## 2 A Look at the AIDS Dataset

We begin by describing the AIDS data used in our estimation.[6] Later on, we explain how we obtain the rest of the data needed for our analysis.

Our AIDS dataset is constructed using UNAIDS/WHO *Epidemiological Fact Sheets on HIV/AIDS*

[4]McDonand and Roberts (2006) investigate the effect of AIDS on economic growth in a system of two equations, a structural growth equation based on the augmented Solow model and a reduced form health equation used to estimate the effect of HIV on some measure of health capital.

[5]For this and other arguments in favor of using levels rather than growth regressions, see Hall and Jones (1999, pp. 85-86). Other papers that use level regressions include Frankel and Romer (1999), Acemoglu, Johnson and Robinson (2001), and Caselli and Wilson (2004), just to name a few.

[6]The AIDS datasets used in this paper are available from the authors upon request.

*and Sexually Transmitted Infections* (2002).[7,8] These are the number of officially reported AIDS cases for each country in each year (when available). Our entire dataset includes 115 countries for the period 1979-2000. AIDS case reporting is carried out in most countries. Data from individual AIDS cases are aggregated at the national level and sent to WHO. However, case reports come from surveillance systems of varying quality. Reporting rates vary substantially from country to country and low reporting rates are common in developing countries due to weaknesses in the health care and epidemiological systems.[9] In addition, AIDS case reporting provides information on transmission patterns and levels of infection approximately 5-10 years in the past, limiting its usefulness for monitoring recent HIV infections. Despite these caveats AIDS case reporting across a broad number of countries is valuable in estimating the effect of AIDS on cross-country per capita income, which is the focus of this paper.

We multiply the number of reported AIDS cases by 100,000 and divide by total population in each year (data on population is from the *World Development Indicators* (2002)) to obtain reported AIDS cases per 100,000 per country per year. Thus, we obtain AIDS reported cases, which is a flow measure. Due to data constraints associated with explanatory variables necessary for our empirical analysis other than AIDS, our country coverage is reduced from 115 countries to 81. In addition, to eliminate major measurement error at the beginning of the epidemic we start our time coverage from 1986 rather than 1979. Therefore the sample used in our empirical investigation is further reduced to a panel of 81 countries for the time period 1986-2000. To explore the panel dimension of the data, we average them into 5 year periods and produce three non-overlapping five-year time intervals 1986-1990, 1991-1995 and 1996-2000.[10]

Next, we take a first look at the AIDS dataset by presenting correlations and descriptive statistics at the regional and country levels. In addition, we exploit a nice feature of our dataset and

[7] We were able to update the reported AIDS cases using UNAIDS/WHO Epidemiological Fact Sheets-2004 Update for the following countries: Canada, Chile, Columbia, El Salvador, Iran Israel, Thailand, Turkey, Austria, Belgium, Czech Republic, Denmark, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Spain, Sweden, Switzerland, U.K. of Great Britain, Fiji.

[8] Of note is the exclusion of South Africa from our dataset due to the gross under-reporting observed and documented by many field researchers. We thank participants at the North East Universities Development Consortium (NEUDC) 2004 conference and in particular Mark Gersovitz, Damien de Walque, Désiré Vencatachellum, for their insights on the substantial measurement errors present in the South African AIDS dataset.

[9] The serious problem of under-reporting is proliferated from luck of willingness to diagnose the problem by potential infected individuals. Thornton (2006) finds that in a recent randomized experiment performed in Malawi, only less than half of the participants attended clinics to learn their HIV status.

[10] For more information about the sample of countries and relevant variables used in the estimation, see Appendix A, Table A1. For detailed discussion on our definition of AIDS see Appendix B.

Table 1: Regional descriptive statistic

| Regions | Variable | Mean | Stand. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| Africa | GDP per worker ($) | 3626.9 | 3353.1 | 895.6 | 15515.0 |
| | AIDS cases per 100,000 | 23.418 | 38.146 | 0.021 | 173.043 |
| Americas | GDP per worker ($) | 10632.5 | 8772.2 | 2179.4 | 39872.0 |
| | AIDS cases per 100,000 | 7.335 | 7.647 | 0.244 | 30.103 |
| Asia | GDP per worker ($) | 12610.3 | 10636.1 | 2096.1 | 31888.1 |
| | AIDS cases per 100,000 | 1.269 | 4.282 | 0.001 | 19.809 |
| Europe | GDP per worker ($) | 24076.3 | 8984.3 | 6649.7 | 44509.2 |
| | AIDS cases per 100,000 | 2.416 | 2.629 | 0.022 | 10.471 |
| Oceania | GDP per worker ($) | 16966.5 | 12093.4 | 5635.9 | 30342.0 |
| | AIDS cases per 100,000 | 1.094 | 0.401 | 0.729 | 1.527 |
| World | GDP per worker ($) | 11499.5 | 10838.1 | 895.7 | 44509.3 |
| | AIDS cases per 100,000 | 10.576 | 24.660 | 0.001 | 173.043 |

Notes: The mean, standard deviation, minimum and maximum values presented above are computed for 41 countries in Africa, 25 countries in the Americas, 21 countries in Asia, 24 countries in Europe, and 4 countries in Oceania. Mean levels of GDP per worker and AIDS reported cases are for the period 1986-2000.

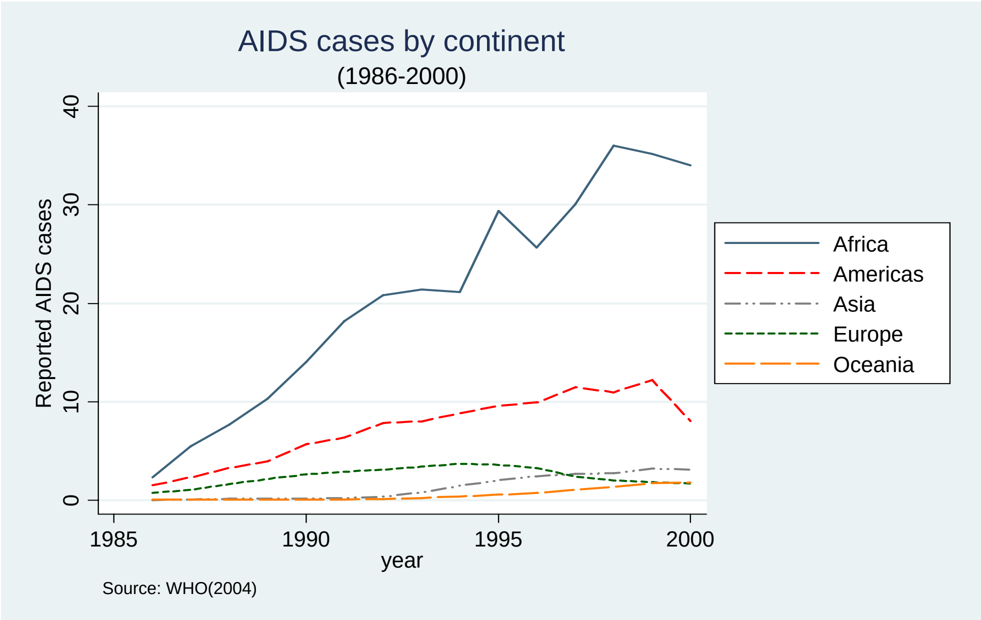
disaggregate our data into AIDS cases by four age groups (0-4, 5-15, 16-34, 35-60+).[11] We present examples from this disaggregated dataset for selected countries.

Table 1 presents the mean, standard deviation, minimum and maximum of AIDS and mean GDP per worker for five regions and the world.[12] The main reason for grouping countries into regions is to examine whether geographical location matters. We note that the mean for AIDS in Africa (23.418) is much higher than in all other regions/continents. Another interesting observation is the quite high number of AIDS cases in the Americas (with mean 7.335). It is much higher than

[11] We were able to assemble data on reported AIDS cases for different age groups from UNAIDS/WHO Global Surveillance fact sheets (2002).

[12] **Africa:** Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, C. African Rep., Chad, Comoros, Congo, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bis., Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe. **Americas:** Argentina, Barbados, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Dominican Rep., Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Tri.&Tobago, USA, Uruguay, Venezuela. **Asia:** Bangladesh, China, Hong Kong, India, Indonesia, Iran, Israel, Japan, Jordan, Korea, Malaysia, Oman, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Syria, Thailand, Turkey, Yemen. **Europe:** Austria, Belgium, Czech Republic, Denmark, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Malta, Norway, Poland, Portugal, Romania, Russian Fed., Slovakia, Spain, Sweden, Switzerland, UK. **Oceania:** Australia, Fiji, New Zealand, Papua N.G..

Figure 1: AIDS cases by continent

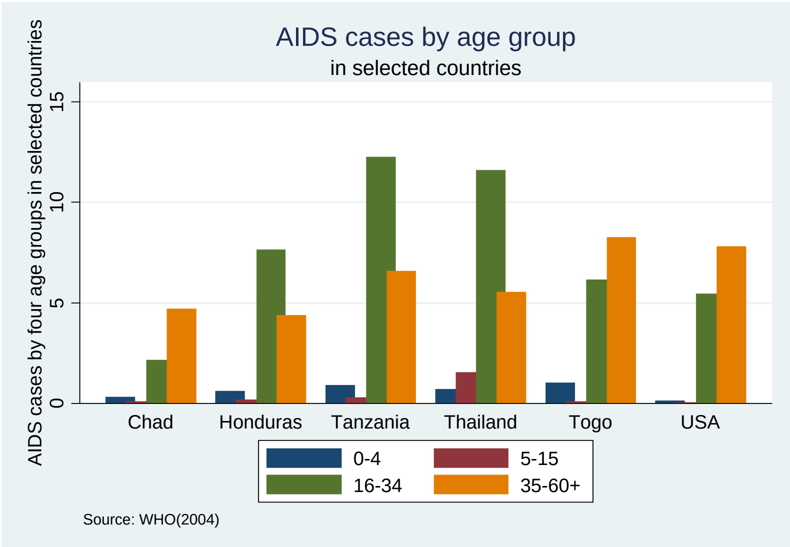



Notes: This plot illustrates the evolution of AIDS in 5 regions over the period 1986-2000.

in Europe, where the mean AIDS cases is 2.416. Finally, it is readily seen that Asia and Oceania are experiencing considerably lower AIDS cases than Africa, the Americas and Europe even though, as the standard deviation reveals, there also exists substantial variation between countries in these regions. The world mean AIDS cases is quite large at 10.576 but obviously upward biased by the African subsample.

Figure 1 adds a dynamic element to the descriptive statistics of Table 1 by illustrating the rate by which the infectious disease spread in each region. Three features stand out in Figure 1. First, is the rapid spread of the disease in Africa. This is a concern that is well-documented in the literature and echoed loudly in the public media. Second, a reversal of the AIDS spread rate is observed in Africa and Latin America after 1997, and after 1995 in Europe. A possible explanation for this slowdown is the combination of substantial increases in funding, increases in global political leadership (which is key to international development planning), and the beginning of pay off from policies and educational programs for promoting AIDS awareness that was initiated by many local, national and international agencies. Third, is the recent increase in reported AIDS cases in Asia. This is a major concern because AIDS cases in particular South Asian countries (i.e. Thailand and

Figure 2: AIDS cases by age




Notes: This figure illustrates AIDS cases by age group. We were able to assemble a dataset with 63 countries for which AIDS cases could be dissagregated into four age groups. For details see Appendix C.

China) have increased at an alarming rate over the last few years.

Next, we present AIDS cases for individual countries to highlight the great variation that exists among them. Table 2 presents the top and bottom 25 countries in our sample of 115 countries. Among the countries with highest reported AIDS cases 20 are located in sub-Saharan Africa. This speaks directly to the major concerns raised by international organizations, such as the World Bank, WHO and UN, and governments of advanced nations like the U.K., France and the U.S.[13] It is interesting to notice, however, that the U.S. and Thailand are also part of the top 25 list. This suggests that AIDS may be different from other determinants of economic development that typically are inherently dependent on per worker income. This argument is reinforced by looking at the list with the bottom 25 countries as many developing and less developed countries experience very low AIDS cases. A notable feature of the low-AIDS-cases list is that the primary religion in 12 out of the 25 countries is Islam. This is consistent with the hypothesis that religion may be influential to the culture of these countries keeping AIDS cases very low.

Finally, we take advantage of a nice feature of our dataset and present AIDS cases by four

[13]For example, during their campaign for the November 2004 U.S. presidential election both president Bush and senator Kerry highlighted AIDS in sub-Saharan Africa as one of the most stressing socioeconomic and humanitarian problems of modern times.

Table 2: Countries with highest and lowest AIDS cases

Top 25

| Country | Rank | Mean AIDS cases |
|---|---|---|
| Namibia* | 1 | 173.043 |
| Congo | 2 | 168.600 |
| Botswana | 3 | 57.084 |
| Zimbabwe | 4 | 55.472 |
| Lesotho* | 5 | 49.333 |
| Zambia | 6 | 46.390 |
| Malawi | 7 | 40.971 |
| Swaziland* | 8 | 38.525 |
| Tanzania | 9 | 31.148 |
| Barbados* | 10 | 30.103 |
| Burundi | 11 | 27.484 |
| Gabon* | 12 | 26.618 |
| Kenya | 13 | 24.953 |
| Uganda | 14 | 22.979 |
| Rwanda | 15 | 22.221 |
| Togo | 16 | 21.910 |
| C. African Rep. | 17 | 20.396 |
| USA | 18 | 20.079 |
| Thailand | 19 | 19.809 |
| Tri. &Tobago | 20 | 18.936 |
| Guyana | 21 | 17.806 |
| Ghana | 22 | 16.679 |
| Honduras | 23 | 14.134 |
| Jamaica | 24 | 13.321 |
| Chad | 25 | 12.770 |

Bottom 25

| Country | Rank | Mean AIDS cases |
|---|---|---|
| Hungary* | 91 | 0.246 |
| Bolivia | 92 | 0.244 |
| Morocco | 93 | 0.207 |
| Poland* | 94 | 0.178 |
| S. Arabia* | 95 | 0.158 |
| Jordan | 96 | 0.147 |
| Algeria | 97 | 0.116 |
| Yemen* | 98 | 0.109 |
| Japan | 99 | 0.101 |
| Czech Rep.* | 100 | 0.096 |
| India | 101 | 0.073 |
| Philippines | 102 | 0.047 |
| Sri Lanka | 103 | 0.047 |
| Turkey | 104 | 0.041 |
| Syria | 105 | 0.036 |
| Korea | 106 | 0.031 |
| Egypt | 107 | 0.029 |
| Slovakia | 108 | 0.029 |
| Iran* | 109 | 0.024 |
| Russian Fed.* | 110 | 0.022 |
| Madagascar | 111 | 0.021 |
| Indonesia | 112 | 0.016 |
| Pakistan | 113 | 0.011 |
| China* | 114 | 0.005 |
| Bangladesh | 115 | 0.001 |

Notes: Mean AIDS cases is the average of reported AIDS cases during the period 1986-2000.
* countries not in our estimation sample.

different age groups for selected countries. This disaggregation reveals that there is significant variability in the way AIDS affects different age groups across countries. For example, Figure 2 illustrates that for countries like the U.S., Togo and Chad the most affected age group is 35-60+ whereas for Tanzania, Thailand and Honduras the most affected age group is 16-34. This variability is explored further in our empirical analysis.

# 3 Estimation and Results

Our empirical estimation is based on the neoclassical growth model as presented in Mankiw, Romer and Weil (1992) (MRW). More precisely, MRW assumed a production function, $Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$, where $Y$ is output, $K$ is the stock of physical capital, $H$ is a measure of human capital, $A$ is a technological parameter that grows exponentially at rate $\gamma$, $L$ is raw labor and $\alpha, \beta$ and $(1-\alpha-\beta)$ are the shares of physical capital, human capital and augmented labor, respectively. Following standard arguments, MRW (pp. 416-17) derived output per worker in country $i$, at period $T+r$ as

$$\ln\left(\frac{Y}{L}\right)_{i,T+r} = \ln(A_0) + \gamma r + \frac{\alpha}{1-\alpha-\beta}\ln s_i^k - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n_i+\gamma+\delta) + \frac{\beta}{1-\alpha-\beta}\ln s_i^h, \tag{1}$$

where $s^k, s^h$ are investment rates in physical and human capital, respectively, $n$ is the average population growth of the working age population, $\gamma$ is an exogenous technological progress parameter, and $\delta$ is a constant physical capital depreciation rate. Our empirical specification is motivated by equation (1) in which we consider AIDS as a productivity shock. To most efficiently use the information provided in our AIDS dataset, we follow recent contributions and employ panel data techniques over three 5-year periods (1986-1990, 1991-1995 and 1996-2000).[14] Specifically, we consider the following regression equation:

$$\ln\left(\frac{Y}{L}\right)_{it} = a_0 + a_1 Dum_t + a_2 Dum_j + a_3 \ln s_{it}^k + a_4 \ln(n_{it}+g+\delta) + a_5 \ln s_{it}^h + a_6 \mathrm{AIDS}_{it} + \varepsilon_{it}, \tag{2}$$

where $Dum_t$ are time dummy variables for the three 5-year periods, and $Dum_j$ are regional dummy variables for sub-Saharan Africa, Latin America and OECD countries. The use of time dummies

[14]We also present an extensive cross-country estimation analysis in Appendix D. Results from the cross-country estimation are consistent with the baseline panel estimation.

to identify the time period over which the model is estimated is justified by equation (1). Regional dummies are used, as in most previous cross-country studies, to absorb idiosyncrasies in Africa, Latin America and OECD. Our measure for physical capital investment, $s^k_{it}$, is the ratio of average investment to GDP from Penn World Tables version 6.1, and $s^h_{it}$ is the percentage of secondary school attained in the total population from Barro and Lee (2001). $n_{it}$ is the average population growth of the working age population from World Development Indicators (WDI-2002), and $g+\delta = 0.05$ as in MRW. Finally, $\text{AIDS}_{it}$ is the reported AIDS cases per 100,000 people averaged for the periods considered.[15] Following much of the literature on cross-country panel estimation, we average the data in five-year time intervals; 1986-1990, 1991-1995 and 1996-2000. Due to data constraints our full sample of is now reduced from 115 to 81 countries with a maximum of three and a minimum of one time observations for each country.

Our empirical investigation is based on three sets of results. First, Table 3 presents results from the panel data analysis motivated by equation (2). Recognizing that AIDS is a potentially endogenous variable we extend this analysis to panel Instrumental Variable (IV) estimation using lagged AIDS as our instrumental variable. These results are presented in Table 4. Finally, we report coefficient estimates from a cross-country estimation in which we exploit disaggregated data on AIDS by age group.

Model 1 in Table 3 presents results without any regional dummies. Models 2, 3 and 4 present results from the same specification but now adding regional dummies starting with a Sub-Saharan Africa dummy ($Dum_{SSA}$), then including a Latin America dummy ($Dum_{LATIN}$), and finally including an OECD dummy ($Dum_{OECD}$), respectively. The coefficient estimate for AIDS from Model 1 is negative and strongly significant. When we move to our preferred specifications that include regional dummies (Models 2-4), the AIDS coefficient estimate drops to about half in magnitude (from $-0.044$ to $-0.024$) and but still negative and significant, albeit at the 10% level. It is interesting to note that the magnitude of the AIDS estimate is very stable in Models 2, 3 and 4 when we include additively the different regional dummies. In Model 5 we examine the possibility of parameter heterogeneity due to regional differences by interacting the regional dummies with the AIDS variable. Results reveal that the marginal effect of AIDS is only negative and significant for the Africa region whereas not significant for the Latin and OECD subsamples. This is consistent with the popular view that the epidemic's effects on income is particularly pronounced in sub-Saharan

[15] Following Gallup and Sachs (2000) and McCarthy, Wolf and Wu (2002), $\text{AIDS}_i$ enters the regressions in levels.

Table 3: Panel cross-country income regressions

| Model Specification | Model 1 time dum. | Model 2 time dum. reg. dum. (SSA) | Model 3 time dum. reg. dum. (SSA LAT) | Model 4 time dum. reg. dum. (SSA LAT OECD) | Model 5 time dum. reg. dum. interactions |
|---|---|---|---|---|---|
| Constant | 5.6594*** | 5.2965*** | 5.3876*** | 9.2590*** | 9.3524*** |
| | (0.6708) | (0.6860) | (0.6993) | (0.9048) | (0.8897) |
| $\ln s_{it}^k$ | 0.5810*** | 0.5031*** | 0.4904*** | 0.4857*** | 0.4743*** |
| | (0.0715) | (0.0760) | (0.0807) | (0.0805) | (0.0819) |
| $\ln(n_i + g + \delta)$ | −1.9623*** | −2.0235*** | −1.9871*** | −0.4370 | −0.3941 |
| | (0.2162) | (0.2162) | (0.2249) | (0.3219) | (0.3167) |
| $\ln s_{it}^h$ | 0.5377*** | 0.4716*** | 0.4673*** | 0.4655*** | 0.4826*** |
| | (0.0548) | (0.0569) | (0.0577) | (0.0592) | (0.0608) |
| $\text{AIDS}_{it}$ | −0.0044*** | −0.0024* | −0.0023* | −0.0024* | 0.0070 |
| | (0.0016) | (0.0012) | (0.0013) | (0.0014) | (0.0051) |
| $\text{Dum}_{86}$ | −0.1507** | −0.1362** | −0.1360** | −0.1628*** | −0.1541** |
| | (0.0701) | (0.0702) | (0.0705) | (0.0654) | (0.0656) |
| $\text{Dum}_{96}$ | 0.0329 | 0.0306 | 0.0330 | 0.1285* | 0.1410* |
| | (0.0783) | (0.0768) | (0.0765) | (0.0724) | (0.0733) |
| $\text{Dum}_{SSA}$ | | −0.3112*** | −0.3551*** | −0.2088 | −0.1773 |
| | | (0.1096) | (0.1375) | (0.1396) | (0.1435) |
| $\text{Dum}_{LATIN}$ | | | −0.0589 | 0.1667* | 0.2222** |
| | | | (0.0859) | (0.0929) | (0.1040) |
| $\text{Dum}_{OECD}$ | | | | 0.7604*** | 0.7024*** |
| | | | | (0.1255) | (0.1302) |
| $\text{AIDS*Dum}_{SSA}$ | | | | | −0.0098* |
| | | | | | (0.0054) |
| $\text{AIDS*Dum}_{LATIN}$ | | | | | −0.0167 |
| | | | | | (0.0122) |
| $\text{AIDS*Dum}_{OECD}$ | | | | | 0.01246 |
| | | | | | (.0075) |
| Adj. $R^2$ | 0.81 | 0.81 | 0.82 | 0.84 | 0.85 |
| Obs. | 241 | 241 | 241 | 241 | 241 |

Notes: Dependent variable is the log of per capital GDP in 2000. Standard errors are in parentheses. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level.

Africa and perhaps have little if any negative effect in other regions.

Consistent with the existing literature based on the neoclassical growth model, the estimated coefficients for the remaining estimates, $\ln(s_{itk})$, $\ln(n_{it} + g + \delta)$, and $\ln(s_{ith})$ have the expected signs and are significant at the 1% level in Models 1-4 (an exception is the coefficients for human capital in Models 4-5 which are insignificant). In addition, also consistent with the vast majority of cross-country regressions, the OECD dummy coefficient is positive, large in magnitude and very significant (in Models 4-5), the Latin America dummy positive and marginally statistically significant (in Models 4-5) and the sub-Sahara African dummy negative but only significant in Models 2-3 (negative but insignificant in Models 4-5).

In summary, our panel estimation shows evidence of a negative impact of AIDS on per capita income. This result is shown to hold robust to the inclusion of the sub-Saharan Africa dummy and also the Latin and OECD dummies. Finally, our results indicate that the negative impact of AIDS is primarily absorbed by sub-Saharan Africa.

A potential concern about the empirical strategy used thus far is that it does not consider the potential endogeneity of the AIDS variable. To check the robustness of the results we use an instrumental variable strategy where the first lag of AIDS (for the period 1986-1990) is our instrument.[16,17] As a consequence our sample is now reduced from 241 to 159 observations.

The first stage regression (not shown) indicates a significant and positive relationship between the past and current AIDS cases (in all specifications considered, coefficient estimates are around 2 with standard error around 0.16). The results of the second stage instrumental variable regressions are presented in Table 4. We consider Models 1-4 as in Table 3 but not Model 5 as it is impossible to justify an acceptable set of instruments under the interactions specification. For Model 1 (without regional dummies) the coefficient estimate for AIDS $-0.0074$ and significant at the 5% level. When we add a sub-Saharan Africa dummy the coefficient estimate remains negative but its magnitude declines to $-0.0056$ and becomes only significant at the 10% level. These results are robust to adding the Latin America and OECD dummies (Models 3 and 4, respectively) with the magnitude of the AIDS coefficient taking the values of $-0.0052$ and $-0.0064$, respectively. Comparing the IV

[16] We have also instrumented AIDS with initial AIDS (i.e. as far back as we could get data for each country) with results being very similar. A potential concern with using lagged explanatory variable as instrument is that if the dependent variable is correlated over time, then the instrument may not be exogenous. This concern would be more severe if we were using annual data on AIDS.

[17] Werker, Ahuja and Wendell (2006) are using an alternative instrument for AIDS, namely male circumcision. Unfortunately, we could not use this instrument in our estimation as Werker et al.'s data cover only African countries.

Table 4: Panel IV cross-country income regressions

| *Model Specification* | *Model 1* time dum. | *Model 2* time dum. reg. dum. (SSA) | *Model 3* time dum. reg. dum. (SSA LAT) | *Model 4* time dum. reg. dum. (SSA LAT OECD) |
|---|---|---|---|---|
| *Constant* | 5.2993*** | 5.0133*** | 5.2078*** | 9.2876*** |
| | *(0.8158)* | *(0.8530)* | *(0.8673)* | *(1.1489)* |
| $\ln s_{it}^k$ | 0.5387*** | 0.4881*** | 0.4707*** | 0.4903*** |
| | *(0.0881)* | *(0.0931)* | *(0.0961)* | *(0.0981)* |
| $\ln(n_{it} + g + \delta)$ | −2.0906*** | −2.1471*** | −2.0732*** | −0.4713 |
| | *(0.2669)* | *(0.2726)* | *(0.2825)* | *(0.4096)* |
| $\ln s_{it}^h$ | 0.5606*** | 0.5176*** | 0.5082*** | 0.5218*** |
| | *(0.0679)* | *(0.0707)* | *(0.0728)* | *(0.0756)* |
| $AIDS_{it}$ | −0.0074** | −0.0056* | −0.0052* | −0.0064* |
| | *(0.0032)* | *(0.0031)* | *(0.0031)* | *(0.0034)* |
| $Dum_{96}$ | 0.0187 | 0.0171 | 0.0220 | 0.1191 |
| | *(0.0798)* | *(.0783)* | *(0.0774)* | *(0.0751)* |
| $Dum_{SSA}$ | | −0.2088 | −0.2901* | −0.0840 |
| | | *(0.1445)* | *(0.1790)* | *(0.1330)* |
| $Dum_{LATIN}$ | | | −0.1048 | 0.1330 |
| | | | *(0.1020)* | *(0.1330)* |
| $Dum_{OECD}$ | | | | 0.7500*** |
| | | | | *(0.1487)* |
| *Hausman (p-values)* | 0.94 | 0.95 | 0.95 | 0.76 |
| *Obs.* | 159 | 159 | 159 | 159 |

Notes: Dependent variable is the log of per capital GDP in 2000. Standard errors are in parentheses. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level.

results for AIDS in Table 4 with the panel results in Table 3 we note that they share a similar decrease in the magnitude and significance when we add the sub-Saharan Africa dummy (and the other two regional dummies). In addition, it is worth noting that although significance in the IV results stays only marginal the magnitude more than doubles. This may be caused by the change in our sample (from 241 to 159) due to the use of lagged AIDS in the IV estimation. Finally, in all specifications, the coefficients on $\ln(s_{itk}), \ln(s_{ith})$ and $\ln(n_{it} + g + \delta)$, as well as those of all three regional dummies are qualitatively similar to those obtained in the panel estimation without instrumental variables (with the exception of the coefficient on $\ln(n_{it} + g + \delta)$ in Model 4 that becomes insignificant). To summarize, the instrumental variable regression results support a negative but marginally statistically significant effect of AIDS on per capita income.

In addition to obtaining data on annual AIDS cases, we were also able to assemble data on the officially reported AIDS cases for the period of study on different age groups. In particular we were able to disaggregate our original AIDS dataset into four age-group samples as follows: AIDS[0-4] (*infancy period*), AIDS[5-15] (*schooling period*), AIDS[16-34] (*productive period*) and AIDS[35-60+] (*less productive period*). A caveat of this dataset is that AIDS cases by age is quite incomplete and these breakdowns exists only for selected years. Due to these data constraints our original sample was further reduced to 63 countries and were limited to applying OLS to Models 1-4 (without regional or time dummies).[18]

Although this analysis is quite preliminary and should be interpreted with caution, some interesting findings emerge from exploiting this dimension of our data. Table 5 presents regression results using AIDS cases by three age groups.[19] The main result from this exercise is that only the coefficient on AIDS[16-34] is statistically significant (albeit marginally in Models 2-4) with a negative sign. It is also important to notice that the magnitude of the AIDS[16-34] coefficient estimate ($-0.09$) is quite stable across the different models and substantially larger compared to respective cross-sectional estimate. The other two groups with ages 5-15 and 35-60+ do not obtain significant coefficient estimates. The estimates on $\ln(s_{ik})$, $\ln(s_{ih})$ and $\ln(n_i + g + \delta)$, remain significant at the 1% level of significance with the expected sign. This finding is quite intriguing suggesting that the

[18]These countries are marked with an asterisk in Table A1 in Appendix A. A detailed explanation of how we construct AIDS cases by age group appears in Appendix C.

[19]Due to the high correlation between AIDS[0-4] and AIDS[16-34], 0.825 we decided to exclude AIDS[0-4] from our regression to reduce the possibility of multicollinearity. This high correlation is present because infants till the age of 4 are infected almost exclusively by their parents who are HIV positive or they are already infected by AIDS.

Table 5: Cross-country income regressions using AIDS by age group

| Model Specification | Model 1 Cross-section | Model 2 Cross-section reg. dum (SSA) | Model 3 Cross-section reg. dum (SSA LAT) | Model 4 Cross-section reg. dum (SSA LAT OECD) |
|---|---|---|---|---|
| Constant | 5.2621*** | 5.2060*** | 5.4003*** | 6.5420*** |
| | (1.0457) | (1.1049) | (1.1126) | (1.5849) |
| $\ln s_{ik}$ | 0.7231*** | 0.7122*** | 0.6671*** | 0.6540*** |
| | (0.1461) | (0.1599) | (0.1609) | (0.1675) |
| $\ln(n_i + g + \delta)$ | −2.5612*** | −2.5603*** | −2.4758*** | −1.9900*** |
| | (0.3184) | (0.3238) | (0.3363) | (0.6285) |
| $\ln s_{ih}$ | 0.4986*** | 0.4815*** | 0.4845*** | 0.4768*** |
| | (0.0880) | (0.1010) | (0.1020) | (0.1062) |
| AIDS[5-15] | −0.0230 | −0.0278 | −0.0874 | 0.0436 |
| | (0.2010) | (0.2009) | (0.2215) | (0.2687) |
| AIDS[16-34] | −0.0961*** | −0.0973* | −0.0878* | −0.0918* |
| | (0.0030) | (0.0528) | (0.0531) | (0.0526) |
| AIDS[35-60+] | 0.0584 | 0.0619 | 0.0584 | 0.0536 |
| | (0.0782) | (0.0777) | (0.0768) | (0.0756) |
| $\text{Dum}_{SSA}$ | | −0.0625 | −0.1612 | −0.1002 |
| | | (0.2271) | (0.2701) | (0.2804) |
| $\text{Dum}_{LATIN}$ | | | −0.1190 | −0.0184 |
| | | | (0.1524) | (0.1987) |
| $\text{Dum}_{OECD}$ | | | | 0.2677 |
| | | | | (0.3056) |
| Adj. $R^2$ | 0.85 | 0.85 | 0.85 | 0.86 |
| Obs. | 63 | 63 | 63 | 63 |

Notes: Standard errors are in parentheses. White's heteroskedasticity correction was used. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level. AIDS[X1-X2] = AIDS for people within ages X1-X2.

negative impact of AIDS on income is may be primarily due to the most productive age group, AIDS[16-34], being affected by AIDS.

## 4 Discussion

Beyond the negative impact of AIDS on cross-country income that emerges from our estimation results it is interesting to examine the magnitude of this impact. AIDS coefficient estimates are quite robust across the models that include regional dummies within the panel, panel-IV and cross-section-group estimations, respectively. However, they more than double in absolute magnitude when we compare panel to panel-IV estimation (i.e. $-0.0024$ to about $-0.0056$ in Model 2). Taking an estimate of about $-0.003$ as a conservative lower bound would imply that for the period 1979-2000 each additional AIDS incident per 100,000 people per year was associated with a 0.003 percentage point reduction in income per worker.

To better understand what these numbers mean we use the estimate of $-0.003$ to back out "lower-bound" direct cost estimates for the epidemic for selected countries with different AIDS severity. Table 6 reports AIDS severity (column 2), GDP per worker (column 3), cost of AIDS to GDP (column 4), and cost of AIDS per worker (column 5), in the year 2000 for nine non-OECD countries. As expected the total cost to GDP ratio varies with the epidemic's severity across countries. In particular, total cost to GDP ratio was 0.228% for Botswana with the second highest AIDS rate in our sample, whereas the same ratio was only 0.0001% for South Korea. Cost per worker indicates the difference in average income loss in countries with a range of AIDS cases. Overall, these simple calculations show that the direct impact of AIDS vary dramatically across countries in our sample and can have especially devastating effects in those countries with high reported cases but low per capita income.[20]

How do our results compare with those in the existing literature? Our work is closely related to the influential paper by Bloom and Mahal (1997) that also uses cross-country regressions but instead finds no significant impact of AIDS on growth. The difference between the Bloom-Mahal and our papers may well be explained by the central question asked; on the one hand, we are interested in the effect of AIDS on *income*, considering income as a good proxy for welfare. On the other hand Bloom and Mahal are interested in the effect of AIDS on *growth*, considering growth

[20] Notice that in this analysis we can only discuss "direct" effect of AIDS on income. Indirect effects, such as education, (see, Fortson, 2007), and savings and investment (see, e.g. Chakraborty, 2005) can be very substantial .

Table 6: Cost of AIDS in selected countries

| Country | AIDS Severity (cases/100,000) | GDP/worker (PPP $) | Cost/GDP (%) | Cost/worker (PPP $) |
|---|---|---|---|---|
| | Severe | | | |
| Botswana | 57.084 | 14,770 | 0.228 | 33.73 |
| Thailand | 17.047 | 9,858 | 0.068 | 6.72 |
| Honduras | 13.256 | 3,947 | 0.053 | 2.09 |
| | Moderate | | | |
| Nigeria | 3.148 | 1,593 | 0.013 | 0.20 |
| Venezuela | 2.647 | 11,758 | 0.011 | 1.25 |
| Hong Kong | 0.494 | 38,179 | 0.002 | 0.75 |
| | Low | | | |
| Bolivia | 0.217 | 5,205 | 0.001 | 0.05 |
| India | 0.073 | 4,361 | 0.0003 | 0.01 |
| Korea | 0.031 | 20,720 | 0.0001 | 0.03 |

Notes: Authors' calculations for the year 2000.

as a good proxy for the development process. Another possibility for the different results is the more extensive coverage of countries and years we have for the AIDS series (Bloom and Mahal's sample is for 51 countries and ends in 1992). In Appendix D, we report cross-sectional estimates of regressions with income growth per worker as the dependent variable in the spirit of Bloom and Mahal (1997). Consistent with these authors' results we find that there is an insignificant effect of AIDS on growth. Our analysis therefore suggest that AIDS has a different effect in level versus growth regressions (as indicated in e.g., Hall and Jones (1999, p.85)).

Another influential paper in the AIDS-development literature is the contribution by Young (2005). Young shows that as a result of a significant decrease in population, AIDS will increase the welfare of the future generations in South Africa by increasing their per capita income. Young argues that in South Africa infection lowers fertility both through a reduction in the willingness to engage in unprotected sexual activity and by increasing the scarcity of labor. He argues that the fertility effect dominates, thus his quite controversial result. A more recent contribution by Kalemli-Ozcan (2006), however, finds that extending the sample to a panel of 44 African countries, AIDS positively affects fertility rates and negatively affects enrollment rates. Our result, that after controlling for various regional interactions only sub-Saharan Africa's income is negatively and significantly affected by AIDS, is consistent with the finding of Kalemli-Ozcan. As argued in Kalemli-Ozcan, extending the careful analysis of Young on South Africa to a panel of African countries (and in our case a world sample) may be the reason for the difference between the two results.

In our paper we use AIDS cases across a panel of countries to investigate the impact of the epidemic on income. We have shown that regardless of the limitations with the data, there is substantial information in them to make valuable contributions to cross-country estimation. We further extend this argument and suggest that development/growth cross-country regressions, regardless of whether testing for growth, health or other aggregate output, should incorporate AIDS as a key control variable to capture the unprecedented negative effect of the disease, especially on the sub-Sahara African region.[21]

## 5 Conclusion

In this paper, we investigate the impact of AIDS on cross-country income levels. Our measure of AIDS comes from the officially reported AIDS cases compiled by UNAIDS/WHO on 81 countries for the period 1986-2000, during which the AIDS epidemic has spread across the globe. Our main results are threefold: First, using the full sample without controlling for regional effects, we find the coefficient estimate for AIDS to be negative albeit marginally statistically significant. Second, upon adding regional dummies we show that the negative effect is primarily due to the sub-Sahara African countries in our sample. Third, using AIDS cases by age group reveals that only the coefficient on AIDS between the ages 16-34 is significant with a negative sign. In addition, the magnitude of the AIDS[16-34] coefficient estimate has more than doubled compared to that obtained when using the aggregated AIDS data. A sensitivity analysis shows robustness of these results to various alternative specifications.

We note that our analysis is subject to three limitations. First, the AIDS data used in this study are likely to suffer from measurement and under-reporting errors. Second, lack of an ideal instrument for AIDS suggests that we can only make qualified statements about the causal effect of the relationship. Third, the AIDS epidemic is still an evolving phenomenon and therefore as newer

[21] For example, see Papageorgiou, Savvides and Zachariadis (2007) who investigate a cross-country relationship between health output (life expectancy and infant mortality) and medical technology diffusion. They show that an important control variable is the AIDS data that controls for the reversion of life expectancy in many sub-Sahara African countries in mid-1980s. Omission of the AIDS data would result in biased estimates as the authors note. A similar result is obtained in Mishra and Newhouse (2006) who investigate a cross-country regression between infant mortality and heath aid.

data become available we can better capture its economic effects. Notwithstanding these caveats, our results point to quite a strong negative relation between AIDS and income, and add to the mounting evidence on the disease's disruptive force on economic outcomes.

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# Appendix A

Table A1: Data

| Country information | | | Mean values for relevant variables | | | | |
|---|---|---|---|---|---|---|---|
| Name | PWT Code | Reg. Dummy | $Y/L$ | $I/Y$ | SCHOOL | $n+g+\delta$ | AIDS |
| Algeria* | DZA | SSA | 10005.4 | 13.67 | 0.107 | 0.075 | 0.116 |
| Angola | AGO | SSA | 4360.1 | 6.27 | 0.029 | 0.074 | 3.776 |
| Argentina* | ARG | Latin | 18742.5 | 15.67 | 0.094 | 0.064 | 3.366 |
| Australia | AUS | OECD | 40452.0 | 24.00 | 0.111 | 0.060 | 0.777 |
| Austria* | AUT | OECD | 36615.7 | 25.60 | 0.108 | 0.053 | 1.687 |
| Bangladesh | BGD | — | 3046.7 | 10.47 | 0.038 | 0.069 | 0.001 |
| Belgium* | BEL | OECD | 38061.8 | 23.27 | 0.113 | 0.051 | 1.772 |
| Benin | BEN | SSA | 2406.2 | 7.53 | 0.031 | 0.077 | 5.776 |
| Bolivia* | BOL | Latin | 5205.1 | 9.47 | 0.071 | 0.070 | 0.243 |
| Botswana | BWA | SSA | 14769.7 | 17.00 | 0.082 | 0.073 | 57.084 |
| Brazil* | BRA | Latin | 11723.9 | 17.40 | 0.063 | 0.068 | 8.890 |
| Burkina Faso* | BFA | SSA | 2051.0 | 11.20 | 0.010 | 0.070 | 11.231 |
| Burundi | BDI | SSA | 1248.1 | 6.00 | 0.008 | 0.066 | 27.484 |
| Cameroon | CMR | SSA | 4321.1 | 6.60 | 0.044 | 0.073 | 10.862 |
| Canada* | CAN | OECD | 42080.2 | 25.20 | 0.112 | 0.058 | 4.080 |
| C.African Rep. | CAF | SSA | 2357.0 | 5.00 | 0.024 | 0.069 | 20.396 |
| Chad* | TCD | SSA | 1903.4 | 6.67 | 0.015 | 0.071 | 12.769 |
| Chile* | CHL | Latin | 16137.4 | 19.67 | 0.101 | 0.062 | 1.960 |
| Colombia* | COL | Latin | 9276.3 | 11.93 | 0.093 | 0.068 | 2.183 |
| Congo | COG | SSA | 5024.4 | 7.40 | 0.127 | 0.072 | 168.599 |
| Costa Rica* | CRI | Latin | 9391.8 | 16.60 | 0.082 | 0.074 | 4.055 |
| Denmark* | DNK | OECD | 42759.9 | 22.40 | 0.118 | 0.053 | 2.885 |
| Dom. Rep.* | DOM | Latin | 9089.1 | 13.80 | 0.091 | 0.069 | 5.074 |
| Ecuador* | ECU | Latin | 6051.4 | 15.93 | 0.107 | 0.072 | 0.882 |
| Egypt* | EGY | — | 7282.9 | 6.13 | 0.125 | 0.074 | 0.029 |
| El Salvador* | SLU | Latin | 7778.1 | 8.20 | 0.057 | 0.071 | 4.321 |
| Ethiopia | ETH | SSA | 1388.1 | 4.33 | 0.022 | 0.069 | 7.163 |
| Finland* | FIN | OECD | 36433.6 | 24.13 | 0.111 | 0.052 | 0.402 |
| France* | FRA | OECD | 36165.8 | 24.27 | 0.109 | 0.052 | 6.007 |
| Ghana* | GHA | SSA | 2464.5 | 6.20 | 0.079 | 0.077 | 16.679 |
| Greece* | GRC | OECD | 23087.6 | 21.40 | 0.103 | 0.052 | 1.396 |
| Guatemala* | GTM | Latin | 8202.7 | 7.47 | 0.044 | 0.075 | 2.513 |
| Haiti | HTI | Latin | 6235.0 | 4.77 | 0.034 | 0.074 | 9.346 |
| Honduras* | HND | Latin | 3947.2 | 14.67 | 0.068 | 0.078 | 14.133 |
| Hong Kong* | HKG | — | 38179.1 | 25.27 | 0.089 | 0.068 | 0.523 |
| India | IND | — | 4360.6 | 12.33 | 0.068 | 0.070 | 0.073 |
| Indonesia* | IDN | — | 6263.5 | 17.67 | 0.0770 | 0.0684 | 0.0159 |
| Ireland* | IRL | OECD | 40520.7 | 19.73 | 0.1553 | 0.0638 | 1.2876 |
| Israel* | ISR | — | 30942.5 | 26.33 | 0.1236 | 0.0753 | 0.9041 |
| Italy* | ITA | OECD | 33816.6 | 21.93 | 0.0882 | 0.0507 | 5.5837 |
| Jamaica* | JAM | Latin | 5648.5 | 17.80 | 0.1300 | 0.0627 | 13.3205 |
| Japan* | JPN | OECD | 38057.5 | 32.60 | 0.1040 | 0.0497 | 0.1010 |
| Jordan* | JOR | — | 7490.8 | 15.13 | 0.1741 | 0.0888 | 0.1469 |
| Kenya | KEN | SSA | 2451.1 | 8.13 | 0.0505 | 0.0817 | 24.9535 |
| Korea* | KOR | — | 20719.5 | 36.07 | 0.1404 | 0.0613 | 0.0306 |

Notes: The sources for these data are Barro and Lee (2001), UNAIDS/WHO and PWT 6.1.
* denotes the 63 nations included in the sample used to carry out age-sepcific AIDS estimation.

Table A1: Data (cont.)

| Country information | | | Mean values for relevant variables | | | | |
|---|---|---|---|---|---|---|---|
| Name | PWT Code | Reg. Dum. | $Y/L$ | $I/Y$ | SCHOOL | $n+g+\delta$ | AIDS |
| Madagascar* | MDG | SSA | 1677.6 | 3.13 | 0.047 | 0.075 | 0.021 |
| Malawi | MWI | SSA | 1591.9 | 7.67 | 0.018 | 0.069 | 43.880 |
| Malaysia | MYS | — | 15251.6 | 25.53 | 0.094 | 0.075 | 1.642 |
| Mali | MLI | SSA | 1995.9 | 8.13 | 0.018 | 0.070 | 3.970 |
| Mauritania | MRT | SSA | 2984.3 | 9.21 | 0.027 | 0.077 | 2.082 |
| Mauritius* | MUS | SSA | 21132.0 | 12.47 | 0.086 | 0.062 | 0.402 |
| Mexico* | MEX | Latin | 15629.6 | 18.20 | 0.112 | 0.069 | 3.508 |
| Morocco* | MAR | — | 7024.9 | 11.93 | 0.066 | 0.070 | 0.207 |
| Mozambique | MOZ | SSA | 2107.5 | 3.53 | 0.013 | 0.068 | 9.823 |
| Netherlands* | NLD | OECD | 37847.2 | 22.60 | 0.128 | 0.054 | 2.380 |
| New Zealand* | NZL | OECD | 30608.2 | 21.40 | 0.121 | 0.057 | 1.340 |
| Nicaragua* | NIC | Latin | 3584.3 | 12.27 | 0.093 | 0.078 | 0.431 |
| Niger* | NER | SSA | 1875.0 | 4.60 | 0.012 | 0.078 | 4.239 |
| Nigeria | NGA | SSA | 1592.5 | 9.47 | 0.047 | 0.075 | 3.148 |
| Norway* | NOR | OECD | 49423.1 | 28.27 | 0.116 | 0.055 | 1.054 |
| Pakistan* | PAK | — | 3956.5 | 11.07 | 0.039 | 0.073 | 0.011 |
| Panama* | PAN | Latin | 10528.0 | 19.80 | 0.115 | 0.069 | 8.795 |
| Papua N.G.* | PNG | — | 5778.8 | 10.36 | 0.023 | 0.073 | 1.527 |
| Paraguay* | PRY | Latin | 8423.9 | 12.67 | 0.063 | 0.077 | 0.694 |
| Peru* | PER | Latin | 7767.1 | 18.20 | 0.122 | 0.071 | 2.799 |
| Philippines | PHL | — | 6896.7 | 14.53 | 0.131 | 0.072 | 0.046 |
| Portugal* | PRT | OECD | 25241.1 | 23.47 | 0.086 | 0.052 | 5.594 |
| Rwanda | RWA | SSA | 1839.0 | 4.13 | 0.012 | 0.085 | 22.221 |
| Senegal | SEN | SSA | 3161.3 | 6.73 | 0.028 | 0.074 | 2.554 |
| Sierra Leone | SLE | SSA | 1388.0 | 4.69 | 0.030 | 0.068 | 0.595 |
| Singapore* | SGP | — | 40393.7 | 42.47 | 0.090 | 0.071 | 1.366 |
| Spain* | ESP | OECD | 27861.2 | 24.60 | 0.131 | 0.052 | 10.470 |
| Sri Lanka* | LKA | — | 5695.3 | 12.47 | 0.109 | 0.066 | 0.046 |
| Sweden* | SWE | OECD | 38254.8 | 21.00 | 0.101 | 0.051 | 1.316 |
| Switzerland* | CHE | OECD | 41885.1 | 27.73 | 0.098 | 0.051 | 6.890 |
| Syria* | SYR | — | 7742.7 | 9.20 | 0.112 | 0.084 | 0.036 |
| Tanzania* | TZA | SSA | 932.4 | 13.93 | 0.008 | 0.077 | 31.147 |
| Thailand* | THA | | 9858.3 | 33.40 | 0.063 | 0.061 | 19.808 |
| Togo* | TGO | SSA | 1760.4 | 8.07 | 0.051 | 0.077 | 21.910 |
| Tri.&Tobago* | TTO | Latin | 20072.5 | 8.93 | 0.128 | 0.065 | 18.936 |
| Tunisia | TUN | — | 11064.1 | 13.27 | 0.080 | 0.070 | 0.442 |
| Turkey* | TUR | OECD | 11548.5 | 19.20 | 0.083 | 0.066 | 0.041 |
| Uganda | UGA | SSA | 2132.7 | 3.20 | 0.021 | 0.072 | 22.979 |
| UK* | GBR | OECD | 37153.1 | 18.93 | 0.105 | 0.053 | 1.975 |
| Uruguay* | URY | Latin | 16503.9 | 10.93 | 0.097 | 0.054 | 3.018 |
| USA* | USA | OECD | 53979.1 | 21.27 | 0.109 | 0.060 | 20.079 |
| Venezuela | VEN | Latin | 11757.8 | 14.33 | 0.062 | 0.074 | 2.825 |
| Zambia | ZMB | SSA | 1664.6 | 9.00 | 0.042 | 0.070 | 46.390 |
| Zimbabwe | ZWE | SSA | 5053.0 | 13.53 | 0.077 | 0.070 | 55.472 |

Notes: The sources for these data are Barro and Lee (2001), UNAIDS/WHO and PWT 6.1.
* denotes the 63 nations included in the sample used to carry out age-specific AIDS estimation.

# Appendix B

## AIDS Definition

The 1985 World Health Organization AIDS surveillance case definition was developed in October 1985, at a conference in Bangui, Central African Republic (known as the "Bangui definition"). It was developed to provide surveilling case definition of AIDS for use in countries where testing for HIV antibodies was not available. The 1994 expanded World Health Organization AIDS case definition was introduced to incorporate the statement that HIV testing should be done. However, if testing was unavailable, then the Bangui definition should be used (Weekly Epidemiological Record, 1994, issue 69, pp. 273-280).

**1985 WHO AIDS surveillance case definition**

For the purposes of AIDS surveillance an adult or adolescent ($> 12$ years of age) is considered to have AIDS if at least 2 of the following major signs are present in combination with at least 1 of the minor signs listed below, and if these signs are not known to be due to a condition unrelated to HIV infection.

**Major signs**

- weight loss $\geqq 10\%$ of body weight
- chronic diarrhoea for more than 1 month
- prolonged fever for more than 1 month (intermittent or constant)

**Minor signs**

- persistent cough for more than 1 month
- generalized pruritic dermatitis
- history of herpes zoster
- oropharyngeal candidiasis
- chronic progressive or disseminated herpes simplex infection generalized lymphadenopathy

The presence of either generalized Kaposi sarcoma or cryptococcal meningitis is sufficient for the diagnosis of AIDS for surveillance purposes.

**1994 extended WHO AIDS surveillance case definition**

For the purposes of AIDS surveillance an adult or adolescent ($> 12$ years of age) is considered to have AIDS if a test for HIV antibody gives a positive result, and 1 or more of the following conditions are present:

- $\geqq 10\%$ body weight loss or cachexia, with diarrhoea or fever, or both, intermittent or constant, for at least 1 month, not known to be due to a condition unrelated to HIV infection
- cryptococcal meningitis
- pulmonary or extra-pulmonary tuberculoses
- Kaposi sarcoma
- neurological impairment that is sufficient to prevent independent daily activities, not known to be due to a condition unrelated to HIV infection (for example, trauma or cerebrovascular accident)
- candidiasis of the oesophagus (which may be presumptively diagnosed based on the presence of oral candidiasis accompanied by dysphagia)
- clinically diagnosed life-threatening or recurrent episodes of pneumonia, with or without etiological confirmation
- invasive cervical cancer

# Appendix C

**Constructing AIDS cases by age**

- The officially reported AIDS cases for the different age groups are reported as a total before 1997 and annually for 1997, 1998, 1999 and 2000.

- In addition to the officially reported cases per age group, UNAIDS/WHO also reports "Not Specified" (NS) representing cases in which an age group was not specified along with AIDS reporting. We can not use NS cases in our calculation of the age groups and recognize that this is a source of measurement error due to aggregation.

- We chose aggregate AIDS cases into four age-group samples as follows: AIDS[0-4] (*infancy period*), AIDS[5-15] (*schooling period*), AIDS[16-34] (*productive period*) and AIDS[35-60+] (*less productive period*).

- We divide the total number of reported AIDS cases in each age group by the number of years cases are reported and multiply by 100,000 and divide by average population. This the mean AIDS cases reported per 100,000 people by each of the four age groups.

- Data on population are taken for the WDI (2002).

# Appendix D

### Cross-sectional estimation

Our empirical analysis is based on the extended unrestricted Solow specification in which we consider AIDS as a productivity shock. Specifically, we consider the following regression equation:

$$\ln y_{it} = a_0 + a_1 \ln s_{ik} + a_2 \ln(n_i + g + \delta) + a_3 \ln s_{ih} + a_4 \mathrm{AIDS}_i + \varepsilon_i, \quad \text{(D1)}$$

where $\left(\frac{Y}{L}\right)_{it}$ is output per working age person in country $i$ in year 2000,[22] $s_{ik}$ is the ratio of average investment to GDP over 1986-2000, $s_{ih}$ is secondary school enrollment of working-age population, $n_i$ is average population growth, $g + \delta = 0.05$ as in MRW, $\mathrm{AIDS}_i$ is the reported AIDS cases per 100,000 people averaged for the period 1986-2000, and $\varepsilon$ is an error term.[23]. It is important to clarify that for human capital we use the Bernanke and Gürkaynak datatset[24] for our cross-sectional estimation rather than the Barro and Lee dataset used in our panel estimation. We do so because the former dataset offers more observations for our cross-sectional estimation, whereas the latter dataset offers more entries for our panel estimation.

Table D1 presents estimates for the *extended Solow model* for the period 1986-2000 for the full sample and arbitrarily chosen OECD and non-OECD subsamples using ordinary least squares (OLS). First, we estimate the MRW specification with our extended data. These results are consistent with MRW using data from PWT 4.0 for the period 1960-1985. They are also qualitatively similar to Bernanke and Gürkaynak (2001) who extend the data until 1995, using PWT 6.0. Next we add AIDS as a regressor, therefore treating it as a productivity shock.

When we reestimate the MRW specification using PWT 6.1 for the full sample of 89 countries (now we have access to 8 countries more than in the panel estimation), we find that the model explains 81.9% of the overall variation in per worker income (column 2). Adding AIDS into the regression improves Adj. $R^2$ slightly to 82.4% (column 5). The estimates from the two models have the expected signs, but differ a bit in magnitude. The estimated coefficient for physical capital decreases from 0.6483 in the model without AIDS to 0.6183 in the model with AIDS, keeping the same significance level at 1%. The coefficient for human capital increases in magnitude in magnitude from 0.6012 to 0.6070 in the model with AIDS and remains significant at 1%. The

[22] Results are insensitive to using output *per capita*.

[23] Following Gallup and Sachs (2000) and McCarthy, Wolf and Wu (2002), $\mathrm{AIDS}_i$ enters the regressions in levels.

[24] Bernanke and Gürkaynak (2001) follow MRW and obtain their human capital measure by multiplying the fraction of population in the ages of 12-17 that is enrolled in secondary school by the fraction of the working-age population that is of school age (15-19). We average human capital for the period 1980-1995.

estimated coefficient for $\ln(n_i + g + \delta)$ is $-2.7627$ in the model without AIDS and increases to $-2.7361$ in the model with AIDS, remaining highly significant at the 1% level. Most importantly, for our full sample the estimated coefficient on AIDS is negative ($-0.0041$) and significantly different from zero at the 10% level. This result suggests that each additional AIDS case per 100,000 people per year is associated with a 0.0041 percentage point reduction in per worker income. This is first evidence that AIDS has a negative impact on cross-country income.

Table D1: Cross-country regressions (Global, OECD and Non-OECD)

| Dependent variable: ln(GDP per Worker in 2000) | | | | | | |
|---|---|---|---|---|---|---|
| Specification | Extended Solow Model *(PWT 6.1)* | | | Extended Solow Model with AIDS *(PWT 6.1 – WHO 2002)* | | |
| | Non-oil | OECD | Non-OECD | Non-oil | OECD | Non-OECD |
| Constant | 1.582* | 8.462*** | 4.549** | 1.785** | 8.199*** | 4.659** |
| | (0.884) | (2.703) | (1.880) | (0.888) | (2.091) | (1.847) |
| $\ln s_{ik}$ | 0.648 *** | 0.629 | 0.617*** | 0.618*** | 0.642** | 0.588*** |
| | (0.147) | (0.387) | (0.159) | (0.147) | (0.405) | (0.159) |
| $\ln(n_i + g + \delta)$ | −2.763* | −0.900 | −1.617** | −2.736*** | −0.946 | −1.627** |
| | (0.377) | ( 1.263) | (0.768) | (0.377) | (1.124) | (0.757) |
| $\ln s_{ih}$ | 0.601*** | 1.161** | 0.574*** | 0.607*** | 1.166** | 0.5803*** |
| | (0.095) | (0.563) | (0.099) | (0.089) | (0.564) | (0.093) |
| AIDS | | | | −0.004** | 0.021 | −0.004* |
| | | | | (0.002) | (0.018) | (0.002) |
| Adj. $R^2$ | 0.82 | 0.39 | 0.69 | 0.82 | 0.48 | 0.70 |
| Obs. | 89 | 21 | 68 | 89 | 21 | 68 |

Notes: Standard errors are in parentheses. It is assumed that $g + \delta = 0.05$ as in MRW. All regressions are estimated using OLS. White's heteroskedasticity correction was used. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level. Investment and population growth rates are averages for the period 1986-2000. $s_h$ is the average percentage of the working-age population in secondary school for the period 1980-1995.

Next, we examine our results by arbitrarily splitting the full sample into OECD and non-OECD countries. In the model without AIDS, for the non-OECD countries, we obtain a positive and highly significant coefficient for $\ln(s_{ik})$, 0.6171, a positive and highly significant coefficient for $\ln(s_{ih})$, 0.5738, and a negative and significant coefficient for $\ln(n_i + g + \delta)$,$-1.6171$ (column 4). There is little change in the coefficient estimates between the specification with and without AIDS (column 7). What is important to notice is that the coefficient estimate for AIDS remains negative ($-0.0040$) and significant at the 10% level.

When we compare the coefficient estimates from the models without and with AIDS for the OECD countries (columns 3 and 6, respectively) we find that the coefficient on $s_{ik}$ increases from

0.6292 to 0.6416, but remain insignificant. The coefficient on $s_{ih}$ remains almost identical in terms of magnitude (1.2) and highly significant. The estimated coefficient for $\ln(n_i + g + \delta)$ is $-0.8900$ and insignificant in the model without AIDS, and decreases to $-0.9456$ when we include AIDS, but remains insignificant. The estimated coefficient for AIDS (quite surprisingly) changes sign but is insignificant, suggesting that the epidemic has no significant impact on the level of income for developed countries.

A possible explanation for this result may be that AIDS in non-OECD countries affects those in their most productive ages who can not afford treatment. More precisely, since people in advanced countries can afford treatment using antiretroviral drugs, this can increase productivity, delay the transmission of the disease, and potentially cause positive externalities by protecting other people.[25] In developing countries, the effect of the pandemic may be different. People cannot afford the expensive drugs and because of the very low level of education, they are not even familiar with the basic protection measure – the use of a condom. Kalemli-Ozcan (2004) provides new evidence on the empirical relationship between the mortality rate changes and the quality-quantity trade-off for a panel of African countries, where parents choose to have more children and provide them with less education facing a high probability of getting infected with AIDS.

We have also reestimated all of the specifications in Table D1 excluding Botswana, Congo, Malawi, Zimbabwe and Zambia (the countries in our sample with the highest concentration of the epidemic). Results from this exercise appear in Figure D1 and Table D2. The main result is that when we exclude these countries with highest AIDS incidence, the coefficient estimate for AIDS remains negative and increases in magnitude and significance for the non-OECD subsample.

In an influential paper Bloom and Mahal (1997) reach the conclusion that "... there is more flash than substance to the claim that AIDS impedes national economic growth." A criticism of this paper is that given the scarcity of the data used (authors use *estimated* AIDS cases for 51 countries for the period 1980-1992) it is too early to tell what the impact of AIDS on growth may be. In addition to the problem of data scarcity, it is the problem of quality of early data on HIV/AIDS which forced the authors to resort to estimates of AIDS cases using epidemiological models. Even though measurement errors associated with HIV/AIDS data are likely to be large primarily due to lack of adequate reporting, early on these errors are very likely to be significantly larger.

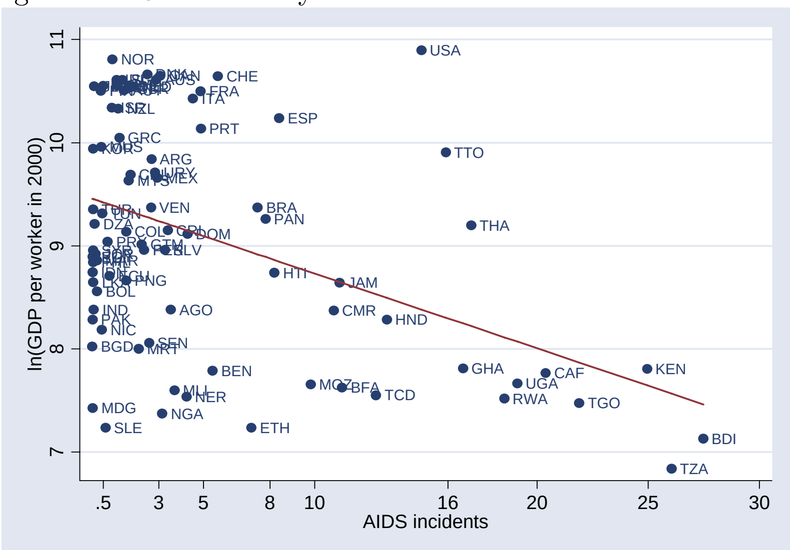
[25] However, the impact of antiretrovirals on the spread of the epidemic is yet unclear (Kremer (2002)). Advocates of antiretroviral drugs for HIV/AIDS support the view that the effect of these drugs is expected to lead to prevention and slowdown of transmission. Alternatively, there exists the possibility that due to the availability of such drugs people choose to have more and riskier sexual contacts.

Table D2: Cross-country regressions (Robustness)

| Dependent variable: ln(GDP per worker in 2000) | | | |
|---|---|---|---|
| Specification | Extended Solow model with AIDS (*PWT 6.1 – WHO 2002*) | | |
| | Non-oil | OECD | Non-OECD |
| Constant | 4.5334*** | 10.0434*** | 5.8110*** |
| | (0.9542) | (2.0069) | (1.5857) |
| $\ln s_{ik}$ | 0.6092*** | 0.5142 | 0.5874*** |
| | (0.1267) | (0.3173) | (0.1386) |
| $\ln(n_i + g + \delta)$ | −2.7933*** | −1.3294** | −2.2245*** |
| | (0.3017) | (0.5799) | (0.6147) |
| $\ln s_{ih}$ | 0.5575*** | 1.2162*** | 0.5078*** |
| | (0.0945) | (0.2401) | (0.0991) |
| AIDS | −.0141 | 0.0247 | −0.0188** |
| | (0.0094) | (0.0174) | (0.0094) |
| Adj. $R^2$ | 0.86 | 0.66 | 0.75 |
| Obs. | 84 | 21 | 63 |

Notes: Standard errors are in parentheses. It is assumed that $g + \delta = 0.05$ as in MRW. All regressions are estimated using OLS. White's heteroskedasticity correction was used. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level.

Figure D1: Cross-country correlation between income and AIDS




Notes: The plot above includes 84 countries. We exclude Botswana, Congo, Malawi, Zimbabwe, Zambia with very high AIDS incidents.

Given the severe criticism of this paper in the literature and public media we decided to reexamine Bloom and Mahal's result using our data and model specification. More precisely, in addition to the level regressions, we examine the effect of AIDS on growth of GDP per worker for the period 1979-2000. We present the results of this exercise in Table D3. It is shown that standard growth regressors ($\ln y_{i0}$, $\ln(s_{ik})$, $\ln(s_{ih})$ and $\ln(n_i + g + \delta)$) in the alternative samples and specifications considered are consistent with those obtained in other growth regressions commonly found in the literature. When we include AIDS in the regressions, the AIDS coefficients are found *not* to be significantly different from zero for the full and non-OECD samples. For the OECD sample the coefficient is positive and significant which may indicates an endogeneity problem being present. In general, these results suggest that AIDS has an insignificant impact on cross-country growth and therefore are supportive of the evidence and main conclusion in Bloom and Mahal (1997).

Table D3: Growth regressions for the full sample and OECD and non-OECD subsamples

| Dependent variable: Growth GDP per worker (initial-2000) | | | | | | |
|---|---|---|---|---|---|---|
| Specification | Extended Solow Model (*PWT 6.1*) | | | Extended Solow Model with AIDS (*PWT6.1 – WHO 2000*) | | |
| | Non-oil | OECD | Non-OECD | Non-oil | OECD | Non-OECD |
| Constant | 1.8918 | 2.7079 | 1.9609 | 1.9513 | 2.9759 | 2.0686 |
| | (1.6168) | (1.6568) | (2.3318) | (1.6465) | (1.8789) | (2.3836) |
| $\ln y_{i0}$ | $-0.4544^{**}$ | $-0.1285$ | $-0.4748^{**}$ | $-0.4600^{**}$ | $-0.1758$ | $-0.4823^{**}$ |
| | (0.1976) | (0.1565) | (0.2111) | (0.2016) | (0.1596) | (0.2165) |
| $\ln s_{ik}$ | $0.4606^{***}$ | $-0.2290$ | $0.4677^{***}$ | $0.4585^{***}$ | $-0.1776$ | $0.4649^{***}$ |
| | (0.1568) | (0.2180) | (0.1546) | (0.1570) | (0.2261) | (0.1547) |
| $\ln(n_i + g + \delta)$ | $-1.6132^{***}$ | $-0.1404$ | $-1.6480^{***}$ | $-1.6133^{***}$ | $-0.2232$ | $-1.6373^{***}$ |
| | (0.3948) | (0.4732) | (0.4601) | (0.3972) | (0.4031) | (0.4602) |
| $\ln s_{ih}$ | $0.3058^{**}$ | $0.6203^{***}$ | $0.3010^{**}$ | $0.3092^{**}$ | $0.6333^{**}$ | $0.3056^{**}$ |
| | (0.1337) | (0.2013) | (0.1394) | (0.1365) | (0.2395) | (0.1430) |
| AIDS | | | | $-0.0008$ | $0.0176^{**}$ | $-0.0009$ |
| | | | | (0.0013) | (0.0073) | (0.0015) |
| Adj. $R^2$ | 0.50 | 0.36 | 0.45 | 0.50 | 0.52 | 0.45 |
| Obs. | 89 | 21 | 68 | 89 | 21 | 68 |