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Abstract

This paper sheds new light on the impact of AIDS on cross-country income levels. Our empirical analysis uses data for 89 countries spanning the period 1979 to 2000 during which AIDS has spread across the world. We control for a variety of factors that are potentially related to income as suggested by our empirical model and existing related literature. Using the extended (for human capital) Solow model as our baseline empirical specification, we consider cross-sectional and panel estimation. For the full sample it is shown that AIDS has a negative and significant effect on the level of income in both the cross-sectional, and panel estimations. In addition, using data on age groups we find that only the AIDS coefficient corresponding to the age group 16-34 is significant and obtains a negative sign. When we arbitrarily split our full sample into OECD and non-OECD countries, we find that the AIDS coefficient continues to be negative and significant for the non-OECD subsample but not for the OECD subsample. Finally, using Hansen's (2000) endogenous splitting methodology we find evidences in favor of AIDS as a threshold variable. Our main quantitative result is that an increase in AIDS incidence by 1 in 100,000 people is associated with a $0.003\% - 0.004\%$ reduction in income per worker.

Keywords: AIDS incidence, AIDS incidence by age group, cross-country per worker income, cross-sectional and panel estimation, country heterogeneity.

JEL Classification: O30, O40, O47

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1 Introduction

The World Heath Organization (WHO) estimated that in December 2002, 42 million people were living with the human immunodeficiency virus (HIV) or the acquired immune deficiency syndrome (AIDS). The newly infected with HIV in 2002 totaled 5 million and AIDS related deaths in 2002 were 3.1 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] It is feared that AIDS will soon surpass malaria, which has been around for at least a millennium, and considered as the most deadly infectious disease. AIDS may be a relatively new infectious disease, only quarter of a century old, but its negative impact is felt most profoundly in sub-Saharan Africa in which it is erasing decades of progress made in extending quantity and improving quality of life.[2]

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. 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, concluded that AIDS, via its impact on morbidity and mortality rates, would likely 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 simulated the impact of AIDS on the Malawian economy and found 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 (2003) constructed and fully studied a model that exhibited substantial negative growth effects of the AIDS epidemic, mainly through

[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/*.

[2] Average life expectancy at birth in sub-Saharan countries is now 47 years, when according to experts it could have been as high as 62 without AIDS.

the detrimental impact of lower life expectancy on investment combined with a sizable number of orphans created by AIDS. Even though the above papers have contributed to our understanding of the problem, they are based on theoretical models that are taken to the data by means of numerical simulation exercises and do not utilize the full information that potentially exists in existing AIDS data.[3]

At the empirical side, the little work that exists has focused on the use of mirco data – at the village or country level; see e.g. Wachter, Knodel and VanLandingham (2003), de Walque (2004), and Young (2004).[4,5] An exception is an important contribution by Bloom and Mahal (1997). These authors use standard epidemiological models to estimate the number of AIDS incidents from information on HIV prevalence at a point in time. Utilizing their rather scarce cross-country estimates of AIDS incidents and using novel econometric techniques these authors arrive to the conclusion that the AIDS epidemic has had an insignificant effect on the growth rate of per capita income.

The main goal of this paper is to provide new evidence on the potential effect of AIDS on cross-country income. In principle this paper follows the lead of Bloom and Mahal (1997) and makes a contribution to the embryonic literature that studies empirically the potential impact of AIDS on economic aggregates. There are two main differences between our work and that of Bloom and Mahal relating to the focus of the analysis and the data used in estimation. 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.[6] Second, we use an alternative more comprehensive dataset on officially reported AIDS cases compiled by WHO and UNAIDS for the period 1979-2000 across 116 countries. This enables us to consider both cross-sectional regression and panel techniques to study the impact of the disease on the level of income.

In particular, our empirical analysis is based on the extended (for human capital) Solow spec-

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[3]Other recent notable theoretical papers include Levy (2002), Auld (2003), Clark and Vencatachellum, and Oster (2004).

[4]In his interesting and highly controversial paper, Young (2004) attempts to calculate the impact of the AIDS epidemic on future living standards in South Africa. He concludes that from the perspective of per capita living standards, the AIDS epidemic endows society with additional resources which in turn could be used to care for the afflicted and provide higher living standards to future generations.

[5]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/*.

[6]For this and other arguments in favor of using levels rather than growth regressions, see Hall and Jones (1999, pp. 85-86). Others 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.

ification. Making use of Penn World Table version 6.1 we extend the Mankiw, Romer and Weil (1992) (MRW hereafter) dataset until the year 2000 and consequently merge this dataset with our AIDS dataset. We obtain results using cross-sectional and panel techniques based on the extended Solow model with AIDS as an additional explanatory variable. In addition, we employ the data splitting methodology proposed by Hansen (2000) to examine whether AIDS is a valid threshold variable that can cluster countries into groups obeying different statistical models.

Our main findings are as follows: First, we show that AIDS incidents has a negative and significant effect on the level of income for the full sample in both the cross-sectional and panel estimations. When we arbitrary split our full sample into OECD and non-OECD countries, we find that the AIDS coefficient continues to be negative and significant for the non-OECD subsample, but not for the OECD subsample. Second, exploiting a nice feature of our dataset that allows us to disaggregate the data in four different age groups, we find that only the AIDS coefficient corresponding to the age group 16-34 is negative and significant. Third, when we use Hansen's (2000) endogenous splitting methodology, we find that AIDS is a threshold variable that can split countries into regimes that obey different statistical models. Finally, robustness analysis shows that our results are quite robust to different subsamples and regression specifications.

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 baseline cross-sectional and panel estimation results for the full sample and various exogenously and endogenously determined subsamples of countries. Section 4 examines the robustness of our baseline results by considering alternative subsamples and regression specifications. Section 5 discusses of our main results with particular emphasis in interpretation, and potential caveats of our analysis. Section 6 concludes.

2 A Look at the Data

We begin by describing the AIDS data used in our estimation. Later on,we explain how we update the MRW original dataset to obtain the rest of the data needed for our analysis. The datasets used in this paper (cross-section, panel and age-specific) are available in their entirety from the authors upon request.

2.1 The AIDS dataset

We constructed the AIDS dataset which includes 116 countries over 1979-2000 using the officially reported cases from the UNAIDS/WHO Global Surveillance fact sheets.[7] The WHO "case" definition for AIDS surveillance is as specified in "Weekly Epidemiological Record," WHO, Geneva (1994).[8] For each country in the sample we start from the year during which a case was reported. We multiply the number of reported incidents by 100,000 and divide by total population in each year (data on population is from the *World Development Indicators* (2002)) to obtain incidence per 100,000 per country per year. The officially reported AIDS cases represent the number of new AIDS infections, occurring each year. Thus, we obtain AIDS incidence, which is a flow measure. Due to data constraints associated with explanatory variables necessary for our empirical analysis other than AIDS, our sample is reduced from 116 countries to 89.[9] Regarding the cross-sectional estimation, for each country in the sample we average AIDS incidents, starting from the year in which a case was reported (usually 1979) up to the year 2000. For the panel estimation, we average the data into 5 year periods for which the disturbance terms are less likely to be influenced by business cycle fluctuations. Thus, we construct three non-overlapping five-year time intervals 1985-1990, 1990-1995 and 1995-2000.

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 disaggregate our data into AIDS incidents by four age groups (0-4, 5-15, 16-34, 35-60+). 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.[10] The main reason for grouping countries into

[7] 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.

[8] For a detailed description of the definition, see Appendix B.

[9] More on the sample used in our empirical estimation later on. For more information about the sample of countries and relevant variables used in the estimation, see Appendix A, Table A1.

[10] **Africa:** Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, C. African Rep., Chad, Comoros, Congo, Egypt, Gabon, Gambia, Ghana, Guinea, Guinea-Bis., Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, 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, Cyprus, 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

Table 1: Regional descriptive statistic

Regions	Variable	Mean	Stand. Dev.	Min.	Max.
Africa	GDP per worker ($)	2195	2395	461	10294
	AIDS cases per 100,000	22.317	37.632	0.021	173.043
Americas	GDP per worker ($)	6192	5234	1075	22934
	AIDS cases per 100,000	6.326	6.734	0.217	26.818
Asia	GDP per worker ($)	7951	6799	1004	21205
	AIDS cases per 100,000	1.129	3.596	0.001	17.047
Europe	GDP per worker ($)	15322	5595	4424	29274
	AIDS cases per 100,000	2.046	2.127	0.022	8.412
Oceania	GDP per worker ($)	10566	7855	3152	19424
	AIDS cases per 100,000	1.433	1.120	0.162	2.872
World	**GDP per worker ($)**	**7153**	**6888**	**461**	**29274**
	AIDS cases per 100,000	**9.938**	**24.355**	**0.001**	**173.043**

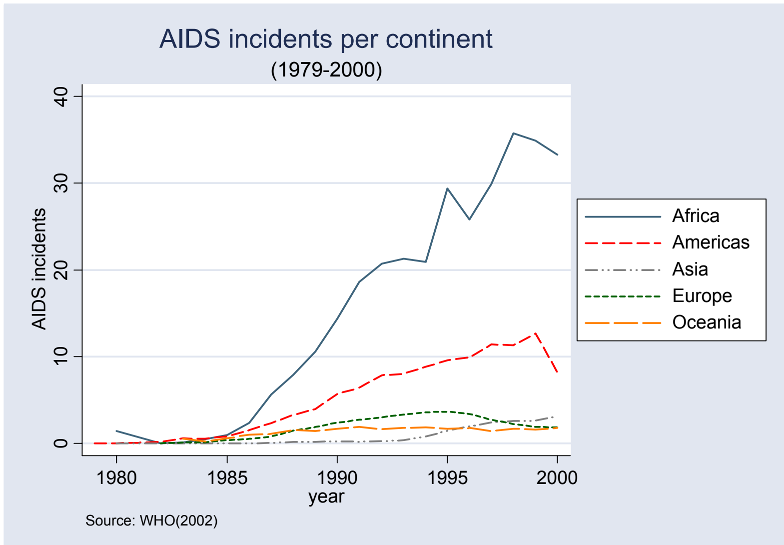
Notes: The mean, standard deviation, minimum and maximum values presented above are computed for 41 countries in Africa, 25 countries in the Americas, 22 countries in Asia, 24 countries in Europe, 4 countries in Oceania. GDP per worker and AIDS incidents represent averages since an AIDS case was reported annually from 1979 until 2000.

regions is to examine whether geographical location matters. We note that the mean for AIDS in Africa (22.317) is much higher than in all other regions/continents. Another interesting observation is the quite high incidence of AIDS in the Americas (with mean 6.326). It is much higher than in Europe, where the mean incidence of AIDS is 2.016. Finally, it is readily seen that Asia and Oceania are experiencing considerably lower AIDS incidents 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 incidents is quite large at 9.938 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, is the observed reversal of AIDS spread

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: Mean AIDS incidents in 5 regions across time



Notes: This plot illustrates the evolution of AIDS in 5 regions over the period 1979-2000.

rate in Africa and Latin America after 1997, and in Europe after 1995. A plausible explanation for this slowdown is that policies and educational programs for promoting AIDS awareness initiated by many local, national and international agencies may have started to pay off. Third, is the recent increase in AIDS incidence in Asia. This is a major concern because AIDS in particular South Asian countries (i.e. Thailand and China) have increased at an alarming rate over the last few years.

Next, we present AIDS incidents 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 116 countries. Among the countries with highest AIDS incidents 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., Germany and the U.S.[11] 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

[11]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 incidents

Top 25

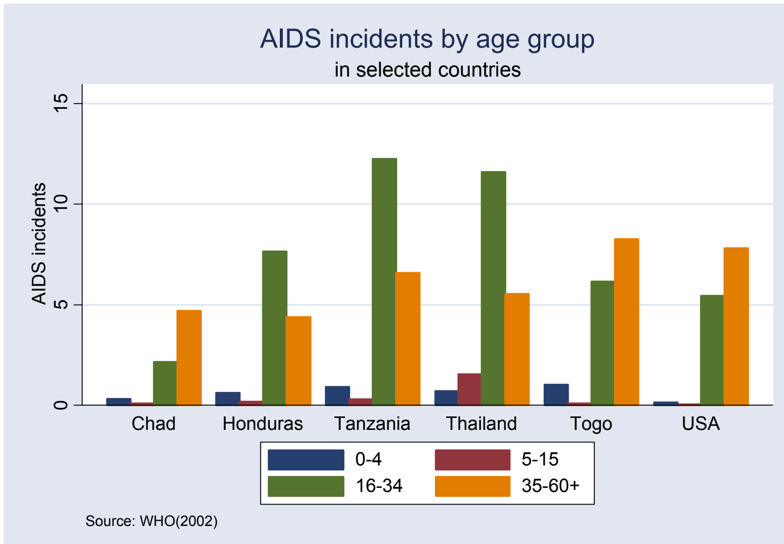
Country	Rank	AIDS incidents Mean (1979-2000)
Namibia*	1	173.043
Congo	2	168.600
Botswana	3	57.084
Zimbabwe	4	55.472
Lesotho*	5	49.333
Malawi	6	40.971
Zambia	7	39.767
Swaziland*	8	38.525
Burundi	9	27.484
Barbados*	10	26.818
Tanzania	11	26.060
Kenya	12	24.953
Gabon*	13	22.013
Togo	14	21.910
C.African Rep.	15	20.396
Uganda	16	19.119
Rwanda	17	18.540
Guyana*	18	17.806
Thailand	19	17.047
Ghana	20	16.679
Tri.&Tobago	21	15.906
USA	22	14.809
Honduras	23	13.256
Chad	24	12.769
Burkina Faco	25	13.589

Bottom 25

Country	Rank	AIDS incidents Mean (1979-2000)
Bolivia	92	0.217
Morocco	93	0.207
Poland*	94	0.164
Fiji*	95	0.162
S. Arabia*	96	0.158
Jordan	97	0.147
Algeria	98	0.116
Yemen*	99	0.109
Czech Rep.*	100	0.096
Japan	101	0.095
India	102	0.073
Sri Lanka	103	0.047
Philippines	104	0.042
Turkey	105	0.038
Iran*	106	0.037
Syria	107	0.036
Korea	108	0.031
Egypt	109	0.029
Slovakia	110	0.028
Russian Fed.*	111	0.022
Madagascar	112	0.021
Indonesia	113	0.016
Pakistan	114	0.012
China*	115	0.004
Bangladesh	116	0.001

Notes: (*) denotes countries not in our estimation sample.

Figure 2: AIDS incidents by four age groups in sellected countries



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

the list with the bottom 25 countries as many developing and less developed countries experience very low AIDS incidents. A notable feature of the low-AIDS-incidence 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 incidents very low.

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

2.2 Extending the MRW dataset

Since our empirical analysis is based on the Solow specification, we have extended the MRW original dataset (PWT version 4.0) until the year 2000 for their non-oil sample. Our data sources are the World Development Indicators (WDI-2002) for working age population growth, Barro and

Lee (2001) and Bernanke and Gürkaynak (2001) for human capital, and PWT version 6.1 for the remaining variables. Due to data constraints with variables necessary for our estimation other than AIDS, our sample was reduced from 116 to 89 countries (our sample is reduced further to 81 countries in the panel estimation).

It is important to clarify that for human capital we use the Bernanke and Gürkaynak datatset[12] for our cross-sectional estimation and the Barro and Lee dataset for our panel estimation. We do that because the former dataset offers more observations for our cross-sectional estimation, whereas the latter dataset offers more entries for our panel estimation.

3 Estimation and Results

In this section we present our baseline results. First, we present the cross-sectional results for the full sample and arbitrarily chosen subsamples as well as endogenously chosen subsamples.

3.1 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:

$$\ln y_{i,2000} = a_0 + a_1 \ln s_{ik} + a_2 \ln(n_i + g + \delta) + a_3 \ln s_{ih} + a_4 \mathrm{AIDS}_i + \varepsilon_i, \tag{1}$$

where $y_{i,2000}$ is output per working age person in country i in 2000,[13] s_{ik} is the ratio of average investment to GDP over 1979-2000, s_{ih} is secondary school enrollment of working-age population, n_i is average population growth, $g + \delta = 0.05$ as in MRW, AIDS_i is the AIDS incidence per 100,000 people averaged for the period 1979-2000, and ε is an error term.[14]

Table 3 presents estimates for the *extended Solow model* for the period 1979-2000 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 parameter.

[12] 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 1970-1995.

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

[14] Following Gallup and Sachs (2000) and McCarthy, Wolf and Wu (2002), AIDS_i enters the regressions in levels.

Table 3: Cross-country regressions for the full sample and OECD and non-OECD subsamples

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	4.7111***	10.2405***	5.9796***	4.8387***	10.0434***	6.1577***
	(0.9751)	(2.0989)	(1.6396)	(0.9673)	(2.0069)	(1.6224)
$\ln s_{ik}$	0.6190***	0.4973	0.5893***	0.6040***	0.5142	0.5732***
	(0.1276)	(0.3342)	(0.1396)	(0.1281)	(0.3173)	(0.1401)
$\ln(n_i + g + \delta)$	−2.7775***	−1.3014*	−2.2274***	−2.7292***	−1.3294**	−2.1595***
	(0.3094)	(0.6683)	(0.6366)	(0.3062)	(0.5799)	(0.6290)
$\ln s_{ih}$	0.6283***	1.2455***	0.6060***	0.6289***	1.2162***	0.6067***
	(0.0789)	(0.3071)	(0.0832)	(0.0755)	(0.2401)	(0.0801)
AIDS				−0.0031*	0.0247	−0.0032*
				(0.0019)	(0.0174)	(0.0020)
Adj. R^2	0.849	0.584	0.724	0.852	0.653	0.731
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 1979-2000. s_h is the average percentage of the working-age population in secondary school for the period 1970-1995.

When we reestimate the MRW specification using PWT 6.1 for the full sample of 89 countries, we find that the model explains 84.9% of the overall variation in per worker income (column 2). Adding AIDS into the regression improves Adj. R^2 slightly to 85.2% (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 0.6190 in the model without AIDS to 0.6040 in the model with AIDS, keeping the same significance level at 1%. The coefficient for human capital remains almost identical in magnitude at 0.63 in both models and significant at 1%. The estimated coefficient for $\ln(n_i + g + \delta)$ is −2.7775 in the model without AIDS and increases to −2.7292 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 (−0.0031) and significantly different from zero at the 10% level. This result suggests that each additional AIDS incident per 100,000 people per year is associated with a 0.0031 percentage point reduction in per worker income. This is first evidence that AIDS has a negative impact on cross-country income.

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 $\ln(s_{ik})$, 0.5893, a positive and highly significant coefficient for $\ln(s_{ih})$, 0.6060, and a negative and significant coefficient for $\ln(n_i + g + \delta)$, -2.2274 (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 (-0.0032) 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 0.4973 to 0.5142, 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 -1.3014 and significant at the 10% level in the model without AIDS, and decreases to -1.3294 and significant at the 5% level when we include AIDS. 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.[15]

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.[16] 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

[15] We have also reestimated all of the specifications in Table 3 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 D1 in Appendix D. 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.

[16] 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.

less education facing a high probability of getting infected with AIDS.

3.2 Panel estimation

This section extends our baseline cross-sectional results to consider estimation of the extended Solow equation using panel data techniques. Even thought AIDS data since 1979 exists for some countries in our sample, we consider the period 1985-2000 because for most countries 1985 was the starting year for reporting AIDS incidents. This enables us to evaluate the impact of the epidemic across different countries and over time. Following much of the literature on cross-country panel estimation, we average the data in five-year time intervals; 1985-1990, 1990-1995 and 1995-2000. Due to data constraints our full sample is now reduced to 81 countries with a maximum of three and a minimum of one time observations for each country. Our panel dataset is therefore unbalanced with a total of 238 observations.

Our regression equation is:

$$\ln y_{it} = a_0 + a_1 \ln s_{itk} + a_2 \ln(n_{it} + g + \delta) + a_3 \ln s_{ith} + a_4 \mathrm{AIDS}_{it} + \varepsilon_{it}, \tag{2}$$

where $\ln y_{it}$ is income per worker and $i = 1, 2, ..., 81$ indexes each country and $t = 0, 1, 2$ indexes time-year periods, s_{itk} is the ratio of average investment to GDP, s_{ith} is investment in human,[17] n_{it} is the average population growth of the working age population, and $g + \delta$ is assumed as previously to be 0.05. As in the cross-country regressions, we add AIDS in the panel regressions.

Table 4 presents results from the panel data analysis for the full sample under different specifications. First we consider the Between Estimator (BE).[18] In a recent paper Hauk and Wacziarg (2004) argue that using an OLS estimator applied to a single cross-section of variables averaged over time (BE) performs best in terms of the extent of bias on each of the estimated coefficients. Consistent with the cross-sectional analysis, the coefficient on AIDS is -0.0050 and significant at the 5% level (column 2). The remaining estimated coefficients for $\ln(s_{itk})$, $\ln(n_{it}+g+\delta)$ and $\ln(s_{ith})$ have the expected signs and are significant at the 1% level.

To allow for the possibility of time effects, we have also estimated the model by adding $(T - 1)$

[17] Our measure of human capital is taken from Barro and Lee (2001) and is the percentage of secondary school attained in the total population. We use the Barro and Lee (2001) human capital dataset (instead of the Bernanke-Gürkaynak (2001) dataset) which provides data for five-year periods from 1960-2000 for most (81) of the countries in our sample.

[18] We refer the interested reader to Green (2000, Ch.14, pp. 562-565) for further information on the Between Estimator.

Table 4: Panel regressions

Dependent variable: ln(GDP per worker for 1985-1990, 1990-1995 and 1995-2000)					
Specification	Extended Solow Model with AIDS (*PWT 6.1 – WHO 2002*)				
	Non-oil with Between Estimator	Non-oil with time effects	Non-oil with time effects & country effects	Non-oil with dOECD & interaction term	Non-oil with time effects, dOECD & interaction term
Constant	6.0352***	6.6639***	7.9758***	8.8015***	8.7002***
	(1.0192)	(0.5649)	(0.3246)	(0.6604)	(0.6330)
$\ln s_{itk}$	0.6714***	0.6524***	−0.0710	0.5462***	0.5592***
	(0.1113)	(0.0664)	(0.0505)	(0.0666)	(0.0638)
$\ln(n_i + g + \delta)$	−1.9045***	−1.5976***	−0.0375	−0.7212***	−0.6996***
	(0.3462)	(0.1920)	(0.1051)	(0.2480)	(0.2374)
$\ln s_{ith}$	0.5218***	0.5318***	−0.3727***	0.5350***	0.5161***
	(0.0795)	(0.0514)	(0.0943)	(0.0498)	(0.0479)
AIDS_{it}	−0.0050**	−0.0045***	−0.0008	−0.0040***	−0.0046***
	(0.0022)	(0.0013)	(0.0006)	(0.0013)	(0.0012)
d91		0.1808**			0.1653**
		(0.0723)			(0.0675)
d96		0.3243***			0.3229***
		(0.0723)			(0.0672)
IT				0.0273**	0.0253**
				(0.0114)	(0.0110)
dOECD				0.4566***	0.4694***
				(0.1120)	(0.1073)
Adj. R^2	0.84	0.81	0.45	0.82	0.84
Obs.	81	238	238	238	238

Notes: d91 and d96 denote time dummies for 1991 and 1996 respectively, IT denotes an interaction term between AIDS and an OECD dummy variable, and dOECD denotes an OECD dummy variable. 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.

time dummies, where d91 and d96 are dummy indicators for the years 1991 and 1996, respectively.[19] These dummies are meant to captures exogenous shocks specific to each five-year period. The results (column 3) are similar in terms of the magnitude and significance level to those obtained from estimating the model with BE. There is a slight decrease in the magnitude of the AIDS coefficient (-0.0047) but significance increase to the 1% level.

To account for the possibility of country-specific effects as well as time effects, we estimate a two-way fixed-effect specification that involves the addition of 80 country-specific dummy variables and 2 time dummy variables. However, as there are more coefficients to estimate, we lose a large number of degrees of freedom which clearly biases our estimates. This is obvious from the results presented in column 4 as there is a stark change in terms of the magnitude and significance of the coefficient estimates. In particular, the estimate on $\ln(s_{itk})$ becomes insignificant, and the estimate on $\ln(s_{ith})$ changes from positive and significant into negative and significant. The coefficient on AIDS is still negative (-0.0008) but not significantly different from zero. We believe that these radical changes in the estimates is due to the substantial loss of degrees of freedom. In addition, as Griliches and Hausman (1986) note, in regressions using panel data with fixed effects specifications, measurement error in the explanatory variables can lead to coefficient estimates that are "too low" and therefore insignificant; in controlling for the various fixed effects, the relative importance of measurement errors in the explanatory variables becomes greatly exacerbated, biasing coefficient estimates.

In order to allow for the effect of AIDS to differ among OECD and non-OECD countries, we add an interaction term (IT) between AIDS and an OECD dummy variable (column 5). All of the estimates are significant and have the expected signs. In particular the key coefficient estimate for AIDS is -0.0040 and is significant at the 5% level which corresponds with our cross-sectional results. Finally, in addition to the interaction term, we include time specific dummies (d91 and d96) to allow for the effect of AIDS to differ across time (column 6). The coefficient estimate for AIDS continues to be negative (-0.0046) but is now significant only at the 10% level, whereas the IT coefficient estimate is positive and significant at the 5% level and the dummy for OECD is positive and significant at the 1% level.

In summary, our panel estimation is generally supportive of our cross-sectional results. In particular, with the exception of the model with fixed and time effects the impact of AIDS on

[19] In order to avoid perfect collinearity we drop the dummy variable on the first five-year period.

income obtained from the panel estimation is shown to be negative and similar in magnitude to that obtained from our cross-sectional estimation.

4 Robustness

This section examines the robustness of our baseline results to alternative subsamples of AIDS incidents by age group, and panel estimation that consider the problem of endogeneity.

4.1 AIDS by age groups

In addition to obtaining data on annual AIDS incidents, we were also able to assemble data on the officially reported AIDS incidents 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*). Due to data constraints our original sample was reduced from 89 to 63 countries.[20]

Some interesting observations become apparent from exploiting this dimension of our data. Two of the four groups, AIDS[16-34] and AIDS[35-60+], are affected most by the disease. More precisely, the most affected group in Africa is AIDS[16-34] which can have disastrous economic consequences since it affects people in their most productive stage of their lives. The same occurs in Europe and Latin American countries like Argentina, Brazil and Mexico. Interestingly, and in contrast to most countries, in the US the most affected group is AIDS[35-60+].

Due to the high correlation between AIDS[0-4] and AIDS[16-34], 0.825, and AIDS[0-4] and AIDS[16-34], 0.812, we decided to exclude AIDS[0-4] from our regression to reduce the possibility of multicolinearity.[21] Table 5 presents regression results using AIDS incidents by the three age groups. The estimates on $\ln(s_{ik})$, $\ln(s_{ih})$ and $\ln(n_i + g + \delta)$, are all significant at the 1% level of significance with the expected sign. The main result from this exercise is that only the coefficient on AIDS[16-34] is significant (albeit marginally at the 7% level) with a negative sign. It is also important to notice that the magnitude of the AIDS[16-34] coefficient estimate (-0.0961) has more than doubled compared to respective cross-sectional estimate. This finding is quite intriguing as

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

[21] 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 regression using AIDS by age group

Dep. var.: ln(GDP per worker in 2000)	
Specification	AIDS by age group
Constant	5.2621***
	(1.0457)
$\ln s_{ik}$	0.7231***
	(0.1461)
$\ln(n_i + g + \delta)$	−2.5612***
	(0.3184)
$\ln s_{ih}$	0.4986***
	(0.0880)
AIDS[5-15]	−0.0230
	(0.2010)
AIDS[16-34]	−0.0961*
	(0.0030)
AIDS[35-60+]	0.0584
	(0.0782)
Adj. R^2	0.85
Obs.	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.

it promotes the idea that the negative impact of AIDS on income is primarily due to arguably the most productive age group, AIDS[16-34], being infected by AIDS.

4.2 Panel-IV estimation

Our regression model is potentially subject to the well-known endogeneity problem. A common way to correct the endogeneity problem in much of the existing literature is to use instrumental variables. However, as Islam (1995) and many subsequent papers have pointed out, it is difficult to come up with a set of "good" instruments that will be correlated with the potentially endogenous variable (in our case AIDS) but not correlated with other regressors.[22] An alternative solution to

[22]Nevertheless, we have considered instrumenting AIDS with initial AIDS in our cross-sectional analysis. However, since initial AIDS is very likely measured with very large errors (especially due to under-reporting), this can substantially bias our estimates toward zero.

the endogeneity problem is the use of panel data and in particular the use of lags of the right-hand side variables as predetermined or weakly exogenous instruments in panel-data regressions.[23,24]

In this section we extend our panel data results presented in the previous section by using instrumental variables (a panel-IV approach) to correct for the potential endogeneity of AIDS. In particular, we use the first lag of AIDS and schooling (s_{ih}) as instrumental variables for AIDS. We use schooling because there are empirical and theoretical grounds to expect that past values of human capital play an important role in explaining the effect of AIDS on economic performance.[25] The downside of this analysis is that our sample is reduced from 238 to 157 observations.

To examine the validity of our instruments we test the overidentifying restrictions for every regression specification considered in our panel-IV estimation. Results are presented in Panels A and B in Table 6. For the specifications in column 2 and 3, the endogenous variable, AIDS, is explained with two instruments; the first lag of AIDS and the first lag of schooling. This results in one over-identifying restriction. For the next two specifications, presented in columns 4 and 5, in addition to AIDS we allow for another potentially endogenous variable; the interaction term between AIDS and a dummy variable for OECD (IT). Therefore, as suggested by Woolridge (2002), we include in our set of instruments an interaction term between a dummy variable for OECD and the first lag of AIDS.[26] This, once again, results in one over-identifying restriction.

The first row of Panel B in Table 6 reports the p-values from χ^2 Sargan's (1958) test. This is a test of the joint null hypothesis that the excluded instruments are valid instruments. A rejection casts doubt on the validity of the instruments. In all the specifications considered we fail to reject the null of no correlation between the instruments and the error term, indicating that our over-identifying instruments are satisfactory. In the bottom row of Panel B in Table 6 we use the Hausman test to determine whether AIDS should be treated as exogenous or endogenous. In two of the specifications, with dOECD and interaction term (column 4), and with dOECD, interaction term and time effects, we are able to reject the null at the 10% level of significance that AIDS and

[23] The first paper that examined cross-country regressions adjusting for both the fixed-effects problem as well as for the endogeneity problem is Caselli et al. (1996).

[24] Despite these advantages, panel data with instrumental variable techniques have also been criticized for obtaining estimates that are quite biased. For further discussion on these issues see Durlauf and Quah (1999), and Hauk and Wacziarg (2004).

[25] See e.g., Corrigan, Glomm and Mendez (forthcoming), and Kalemli-Ozcan (2004).

[26] We thank Carter Hill who suggested to us this instrument. Ressler et al. (2002) use a similar instrument in an attempt to test their hypothesis of a positive relationship between the size of welfare payments per recipient and the heterosexual HIV infection rate in the United States.

Table 6: Panel with Instrumental-Variable regressions

IV Regressions of ln(GDP per worker for 1985-1990, 1990-1995 and 1995-2000)				
Specification	Panel A: Two Stage Least Squares			
	Non-oil with time effects	Non-oil with time effects & country effects	Non-oil with dOECD & interaction term	Non-oil with time effects, dOECD & interaction term
Constant	7.1240***	10.4529***	9.3990***	9.3595***
	(0.6595)	(3.4310)	(0.8114)	(0.8043)
$\ln s_{itk}$	0.5965***	-0.2999	0.5206***	0.5202**
	(0.0853)	(0.2956)	(0.0843)	(0.0836)
$\ln(n_{it}+g+\delta)$	-1.4968 ***	-0.2396	-0.5341*	-0.5212*
	(0.2174)	(0.5187)	(0.3016)	(0.2989)
$\ln s_{ith}$	0.5862*	1.6255	0.5575***	0.5556***
	(0.0696)	(2.8414)	(0.0676)	(0.0670)
AIDS_{it}	-0.0081***	-0.0333	-0.0083***	-0.0088***
	(0.0035)	(0.0482)	(0.0019)	(0.0019)
d96	0.1359*	0.1580***		0.1543***
	(0.0771)	(0.0537)		(0.0715)
IT			0.0404**	0.0363**
			(0.0173)	(0.0168)
dOECD			0.4423***	0.4599***
			(0.1495)	(0.1476)
Adj. R^2	0.79	0.51	0.82	0.82
Obs.	157	157	157	157
	Panel B: Specification Tests (p-values)			
Overidetifying Restrictions	0.304	0.875	0.462	0.788
Hausman Test	0.177	0.993	0.064	0.052

Notes: d96 denotes a time dummy for 1996, IT denotes an interaction term between AIDS and an OECD dummy variable, and dOECD denotes an OECD dummy variable. 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.

the potentially endogenous interaction term are correlated with the error term. This implies that we can apply Two Stage Least Squares (2SLS) and correct for endogeneity. For the specifications in columns 2 and 3 we are not able to reject the null.

To evaluate the quality of our instruments, we further test their validity by estimating reduced form regressions of AIDS on the explanatory instrumental variables. Subsequently we test the joint significance of the coefficients on the instruments in each of our specifications. In all the regressions, we reject the null hypothesis of zero coefficients at the 1% level of significance. This shows that our instruments provide useful information in addition to that provided by the explanatory variables.

The panel-IV results are presented in Panel A of Table 6. In all specifications, the coefficients on $\ln(s_{itk}), \ln(s_{ith})$ and $\ln(n_{it} + g + \delta)$, as well as the 1996 dummy variable (d96), the interaction term (IT), and the OECD dummy variable (dOECD) are qualitatively similar to those obtained in the panel estimation without instrumental variables. With the exception of the model with country and time specific effects (column 3), the coefficient estimates for AIDS are negative and highly significant, and in fact larger in magnitude than previous results. Therefore these results provide evidence suggesting that our baseline results are robust to correcting for potential endogeneity.

4.3 Endogenous sample splitting

Following the emerging literature on *parameter heterogeneity* in cross-country regressions we are able to examine whether AIDS is a threshold variable.[27] In particular, we employ Hansen's (2000) splitting methodology and allow the data to endogenously select regimes using AIDS as a potential threshold variable.[28] The advantage of Hansen's methodology over the regression-tree methodology used in Durlauf and Johnson (1995) is that it is based on an asymptotic distribution theory. Our threshold estimation uses the Solow level regression equation (1).[29]

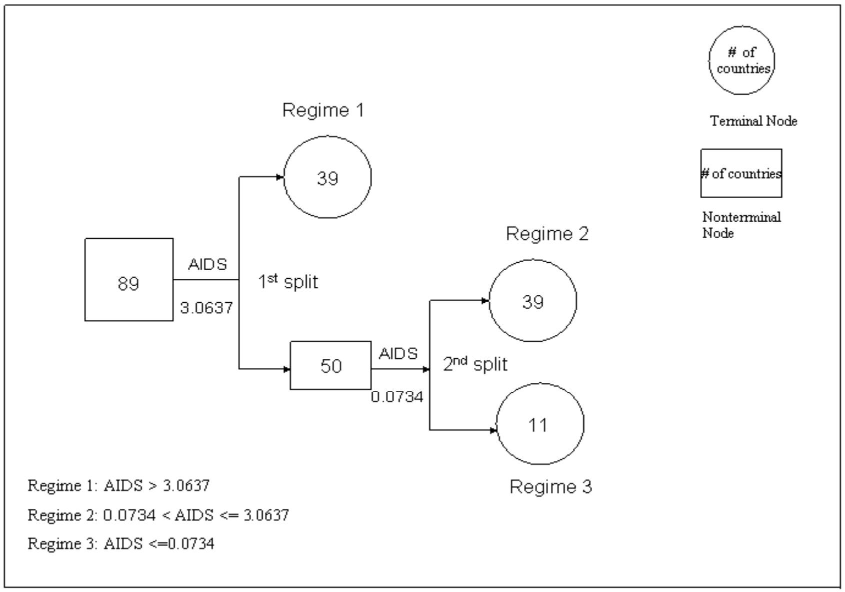
In the first round of splitting the bootstrap p-value was 0.008, implying that there may be a sample split based on AIDS. The threshold estimate was $\gamma = 3.0637$ with asymptotic 95% confidence set $[0.0734, 7.4395]$. AIDS as a threshold divided the full sample (89 countries) into two subsamples: one, containing 50 countries (AIDS ≤ 3.0637) and another, with 39 countries (AIDS

[27] Papers in this literature include, Durlauf and Johnson (1995), Liu and Stengos (1999), Durlauf, Kourtellos and Minkin (2001), Kalaitzidakis et al. (2001), and Masanjala and Papageorgiou (2004), just to name a few. For a more comprehensive discussion on parameter heterogeneity see Durlauf and Quah (1999, Vol. 1, Ch. 4), and Durlauf, Johnson and Temple (forthcoming, Part II, Ch. 7), and references therein.

[28] We use average AIDS (1979-2000) rather than initial AIDS because we expect initial AIDS data to be much more prone to measurement error than subsequent periods.

[29] The GAUSS programs used for threshold estimation are available from the authors upon request.

Figure 3: Regression tree diagram



> 3.0637).

We tried to further split the group with the higher AIDS incidence (AIDS > 3.0637), but the bootstrap test statistic was insignificant. However, the bootstrap test statistic for the sample with 50 countries with AIDS ≤ 3.0637 was significant (0.035), showing a possible sample split. More precisely, $\gamma = 0.0734$ and the confidence set is $[0.0360, 0.4024]$. This implies that AIDS further splits our subsample into two additional regimes: one, with 11 countries (AIDS ≤ 0.0734) and another, with 39 countries (AIDS > 0.0734). No more splits were possible using the new regimes as we obtained bootstrap test statistics that were insignificant.

Figure 3 presents a regression tree diagram that illustrates these results. Non-terminal nodes are illustrated by squares whereas terminal nodes are illustrated by circles. The numbers inside the squares and circles show the number of countries in each node. The point estimates for the threshold variable are presented on the rays connecting the nodes. Table E1 in Appendix E presents the countries included in each of the three regimes.

In general we interpret our threshold estimation results as further evidence of parameter heterogeneity; countries can be grouped according to different statistical models. More importantly, we have shown evidence supporting the idea that AIDS is a threshold variable.

Table 7: Cost of AIDS in selected countries

Country	AIDS	GDP/worker	Cost/GDP	Cost per worker	Cost per capita	Cost per case
	Severe					
Botswana	57.084	$14,769.7	0.22834%	$33.73	$18.57	32,530.70
Thailand	17.047	$9,858.3	0.06819%	$6.72	$4.58	26,861.10
Honduras	13.256	$3,947.2	0.05302%	$2.09	$1.15	8,657.80
	Medium					
Nigeria	3.148	$1,592.5	0.01259%	$0.20	$0.10	3,305.80
Venezuela	2.647	$11,757.8	0.01059%	$1.25	$0.77	28,930.10
Hong Kong	0.494	$38,179.1	0.00198%	$0.75	$0.55	111,570.50
	Low					
Bolivia	0.217	$5,205.1	0.00087%	$0.05	$0.03	11,735.50
India	0.073	$4,360.6	0.00029%	$0.01	$0.01	10,734.40
Korea	0.031	$20,719.5	0.00012%	$0.03	$0.02	59,747.10

Notes: All of the values are for the year 2000.

5 Discussion

Summary of results: Our results can be summarized as follows: a) When using the full sample of 89 countries we find a negative and statistically significant effect of AIDS on cross-country per worker income. b) When we arbitrarily split our entire sample into OECD and non-OECD subsamples the negative relationship continues to exist when using the non-OECD subsample but vanishes in the OECD subsample. c) When using AIDS incidents by age group we find that there exists quantifiable negative impact of AIDS on income only for people in the ages 16-34. d) Panel estimation results (without or with instrumental variables) are consistent with those obtained in the cross-sectional analysis. e) Using Hansen (2000) we also find that AIDS is a threshold variable that can split our full sample into four regimes obeying different statistical models.

Interpretation of results: Beyond the negative impact of AIDS on income that emerges from our estimation results it is important to examine the magnitude of this impact. It works out that the coefficient estimates for AIDS from various alternative estimation specifications (cross-sectional, panel) and samples (full, non-OECD) are surprisingly quite stable at around -0.003 to -0.004. This implies that for the period 1979-2000 each additional AIDS incident per 100,000 people per year was associated with a 0.003 to 0.004 percentage point reduction income per worker income.

Using the most conservative AIDS estimate of -0.003 we are able to back out "lower bound" cost estimates for the epidemic. Table 7 reports total cost to GDP ratio, cost per worker, cost per capita, and cost per new case in year 2000 for nine non-OECD countries grouped in three categories by AIDS severity. As expected the total cost to GDP ratio varies with the epidemic's severity across countries (column 4). In particular, total cost to GDP ratio was 0.23% for Botswana with the second highest incidence rate in our sample, whereas the same ratio was only 0.0001% for South Korea. Cost per worker and cost per capita (columns 5-6) indicate the difference in individual welfare loss in countries with a range of AIDS incidence. Finally, the last column reports estimates of the cost per case in selected countries. Cost per case calculated using our estimates increases with AIDS incidence but also with per capita income. For example even though AIDS incidence is much lower in Hong Kong ($0.0494/100,000$) than in Botswana ($57.084/100,000$), the cost per case is more than three times higher in the former than the later country. Of course, thinking about these estimates in relation to individual welfare would be the appropriate metric for this exercise. Overall, these calculations show that the impact of AIDS vary dramatically across countries in our sample and can have devastating effects especially in those countries with high incidence but low per capita income.

Reconciling our results with those of Bloom and Mahal (1997): 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.

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 F1 in Appendix F. 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).

This then leads us to the key question: How can it be that the Bloom and Mahal results hold, indicating an insignificant impact of AIDS on growth, yet in our host of level regressions AIDS is robustly negatively related with income? The difference in the two results comes down to the central question asked; on the one hand, we are interested in the effect of AIDS on income, thinking that income is a good proxy for welfare. On the other hand Bloom and Mahal were interested in the effect of AIDS on growth, thinking that growth is a good proxy for the development process. Our analysis suggests that the only criticism that Bloom and Mahal (1997) may be subject to is that by using per worker income growth as the dependent variable the potential effect of AIDS on aggregate output may be masked (see Hall and Jones (1999, p.85)).

Limitations: Our work is certainly not without limitations. Even though one can point to other caveats we want to focus on limitations due to quality and quantity of our AIDS dataset. We recognize that the quality of the UNAIDS/WHO data is questionable on the grounds of cross-country comparability, variable under-reporting and other methodological issues relating to data collection and the definition of AIDS. In addition, we admit that AIDS epidemic is still a transitory phenomenon and therefore as more data become available we will be in a better position to reach more definite conclusions about its effect on income.

6 Conclusion

In this paper, we investigate the impact of AIDS on cross-country income levels. Contrary to previous work on AIDS, we make use of the officially reported AIDS incidents from UNAIDS/WHO on 89 countries for the period 1979-2000, during which the AIDS epidemic has spread across the world.

Using the extended Solow model as the basis of our empirical analysis we first show that in the full sample and non-OECD subsample, the coefficient estimate for AIDS is negative and marginally significant. For the OECD countries, we obtain an insignificant coefficient estimate, which implies that AIDS has no quantifiable effect on the income level for these countries. We also utilize the time dimension of our data and employ panel-data techniques on the extended Solow model with AIDS as a regressor. AIDS enters negative and highly significant in all of the specifications considered except from the specification with country and time effects, where the estimate is insignificant.

Regression analysis using AIDS 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. Finally, we employ Hansen's (2000) threshold methodology that attempts to endogenously split countries in different regimes. This methodology successfully identifies AIDS as a threshold variable. An extensive robustness analysis establishes robustness of our baseline results to various alternative specifications and subsamples.

Obviously, we do not claim to have the last word on the effect of the AIDS epidemic on income but merely to have shed new light on the effects of an unraveling epidemic.

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Appendix A

Table A1: Data used in the extended Solow model

Country	PWT Code	Mean values for relevant variables				
		Y/L	I/Y	SCHOOL	$n+g+\delta$	AIDS
Algeria*	DZA	10005.4	13.65	0.0825	0.0811	0.1165
Angola	AGO	4360.1	6.35	0.0241	0.0759	3.5434
Argentina*	ARG	18742.5	15.89	0.0859	0.0647	2.6654
Australia	AUS	40452.0	23.98	0.1108	0.0633	2.8723
Austria*	AUT	36615.7	25.61	0.1075	0.0556	1.4293
Bangladesh	BGD	3046.7	10.30	0.0381	0.0709	0.0009
Belgium*	BEL	38061.8	23.13	0.1094	0.0515	1.6902
Benin	BEN	2406.2	7.19	0.0252	0.0795	5.4167
Bolivia*	BOL	5205.1	9.01	0.0646	0.0739	0.2169
Botswana	BWA	14769.7	17.38	0.0635	0.0790	57.0842
Brazil*	BRA	11723.9	17.34	0.0587	0.0716	7.4395
Burkina Faso*	BFA	2051.0	11.25	0.0073	0.0725	11.2315
Burundi	BDI	1248.1	6.07	0.0066	0.0698	27.4842
Cameroon	CMR	4321.1	6.64	0.0345	0.0772	10.8619
Canada*	CAN	42080.2	24.97	0.1155	0.0614	3.0637
C.African Rep.	CAF	2357.0	5.11	0.0191	0.0708	20.3963
Chad*	TCD	1903.4	6.63	0.0108	0.0745	12.7695
Chile*	CHL	16137.4	18.79	0.0941	0.0657	1.7143
Colombia*	COL	9276.3	12.14	0.0834	0.0733	1.5264
Congo	COG	5024.4	7.48	0.1059	0.0771	168.5997
Costa Rica*	CRI	9391.8	16.04	0.0806	0.0776	3.4051
Denmark*	DNK	42759.9	22.52	0.1151	0.0532	2.4675
Dom. Rep.*	DOM	9089.1	13.43	0.0764	0.0731	4.2897
Ecuador*	ECU	6051.4	15.90	0.0917	0.0785	0.7835
Egypt*	EGY	7282.9	6.06	0.1082	0.0756	0.0295
El Salvador*	SLU	7778.1	7.85	0.0525	0.0732	3.2685
Ethiopia	ETH	1388.1	4.27	0.0179	0.0733	7.1639
Finland*	FIN	36433.6	24.42	0.1164	0.0525	0.3876
France*	FRA	36165.8	24.60	0.1065	0.0549	4.8720
Ghana*	GHA	2464.5	6.08	0.0678	0.0826	16.6795
Greece*	GRC	23087.6	21.53	0.0968	0.0556	1.2263
Guatemala*	GTM	8202.7	7.40	0.0350	0.0768	2.2228
Haiti	HTI	6235.0	5.31	0.0256	0.0724	8.1973
Honduras*	HND	3947.2	14.48	0.0503	0.0820	13.2563
Hong Kong*	HKG	38179.1	25.05	0.0859	0.0674	0.4939
India	IND	4360.6	12.35	0.0609	0.0710	0.0734
Indonesia*	IDN	6263.5	17.76	0.0629	0.0717	0.0159
Ireland*	IRL	40520.7	19.79	0.1453	0.0616	1.0947
Israel*	ISR	30942.5	26.60	0.1163	0.0794	0.8832
Italy*	ITA	33816.6	22.27	0.0836	0.0528	4.5305
Jamaica*	JAM	5648.5	17.72	0.1233	0.0660	11.1127
Japan*	JPN	38057.5	32.56	0.1038	0.0531	0.0950
Jordan*	JOR	7490.8	15.15	0.1548	0.0998	0.1469
Kenya	KEN	2451.1	8.07	0.0417	0.0853	24.9535
Korea*	KOR	20719.5	36.29	0.1261	0.0644	0.0306

Notes: The sources for these data are Bernanke and Gürkaynak (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 used in the extended Solow model (cont.)

Country	PWT Code	Mean values for relevant variables				
		Y/L	I/Y	SCHOOL	$n+g+\delta$	AIDS
Madagascar*	MDG	1677.6	3.03	0.0383	0.0769	0.0211
Malawi	MWI	1591.9	7.92	0.0147	0.0735	40.9708
Malaysia	MYS	15251.6	26.56	0.0906	0.0777	1.6425
Mali	MLI	1995.9	8.23	0.0162	0.0730	3.7066
Mauritania	MRT	2984.3	8.70	0.0201	0.0779	2.0821
Mauritius*	MUS	21132.0	12.52	0.0808	0.0643	0.4024
Mexico*	MEX	15629.6	17.49	0.0953	0.0759	2.9271
Morocco*	MAR	7024.9	11.95	0.0547	0.0746	0.2073
Mozambique	MOZ	2107.5	3.41	0.0112	0.0672	9.8234
Netherlands*	NLD	37847.2	22.58	0.1226	0.0564	1.8466
New Zealand*	NZL	30608.2	22.20	0.1223	0.0605	1.1704
Nicaragua*	NIC	3584.3	12.41	0.0775	0.0810	0.4314
Niger*	NER	1875.0	4.61	0.0091	0.0816	4.2395
Nigeria	NGA	1592.5	9.39	0.0330	0.0778	3.1480
Norway*	NOR	49423.1	28.65	0.1129	0.0555	0.9070
Pakistan*	PAK	3956.5	11.14	0.0359	0.0736	0.0112
Panama*	PAN	10528.0	18.78	0.1079	0.0736	7.7935
Papua N.G.*	PNG	5778.8	10.35	0.0218	0.0762	1.5274
Paraguay*	PRY	8423.9	12.70	0.0558	0.0800	0.6948
Peru*	PER	7767.1	17.62	0.1068	0.0747	2.3352
Philippines	PHL	6896.7	14.36	0.1239	0.0754	0.0420
Portugal*	PRT	25241.1	23.10	0.0836	0.0538	4.8888
Rwanda	RWA	1839.0	4.64	0.0101	0.0773	18.5401
Senegal	SEN	3161.3	6.71	0.0258	0.0766	2.5547
Sierra Leone	SLE	1388.0	4.85	0.0258	0.0701	0.5959
Singapore*	SGP	40393.7	42.45	0.0971	0.0741	1.3665
Spain*	ESP	27861.2	24.47	0.1157	0.0553	8.4116
Sri Lanka*	LKA	5695.3	12.34	0.1030	0.0677	0.0467
Sweden*	SWE	38254.8	21.12	0.0960	0.0535	1.1200
Switzerland*	CHE	41885.1	27.79	0.0946	0.0562	5.6556
Syria*	SYR	7742.7	9.17	0.1052	0.0875	0.0360
Tanzania*	TZA	932.4	16.46	0.0079	0.0815	26.0605
Thailand*	THA	9858.3	32.98	0.0570	0.0685	17.0469
Togo*	TGO	1760.4	8.12	0.0425	0.0782	21.9104
Tri.&Tobago*	TTO	20072.5	9.39	0.1175	0.0642	21.9104
Tunisia	TUN	11064.1	13.26	0.0695	0.0758	0.4423
Turkey*	TUR	11548.5	18.80	0.0740	0.0716	0.0376
Uganda	UGA	2132.7	13.65	0.0172	0.0753	19.1190
UK*	GBR	37153.1	18.77	0.0998	0.0531	1.6040
Uruguay*	URY	16503.9	10.76	0.0907	0.0565	2.8308
USA*	USA	53979.1	21.29	0.1163	0.0603	14.8092
Venezuela	VEN	11757.8	14.30	0.0686	0.0771	2.6470
Zambia	ZMB	1664.6	8.94	0.0367	0.0774	39.7673
Zimbabwe	ZWE	5053.0	13.49	0.0577	0.0752	55.4721

Notes: The sources for these data are Bernanke and Gürkaynak (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

In a meeting convened in Geneva by the WHO Global Programme on AIDS (1994) was suggested the following: the 1985 provisional WHO clinical case definition for AIDS ("Bangui definition") to be referred to as the WHO AIDS surveillance case definition and it was introduced an expanded WHO AIDS surveillance case definition. (Weekly Epidemiological Record, 1994, issue 69, pp. 273-280).

1. WHO case definition for AIDS surveillance

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 wit hat 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.

2. Expended WHO case definition for AIDS surveillance

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 the 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/unknown cases" (NS).

- Although the data in the OECD countries have very few NS cases, the data in many low-income countries like sub-Saharan Africa countries contain a lot of NS cases.

- 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*).

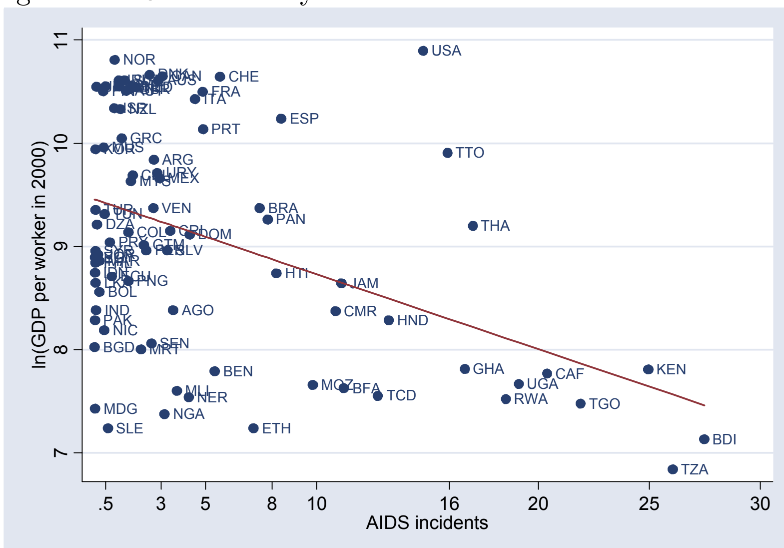
- We divide the total number of reported AIDS cases in each age group by the number of years cases are reported and multiply by 100,000 and divide by average population. This the mean AIDS cases reported per 100,000 people by each of the four age groups.

- Data on population are taken for the WDI (2002). We start from the year, during which an AIDS case was reported till 2000.

Appendix D

Excluding potential outliers

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.

Table D1: Cross-country regressions

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.

Appendix E

Table E1: Countries in three regimes

Regime 1		Regime 2		Regime 3
Angola	Kenya	Algeria	Mauritania	Bangladesh
Benin	Malawi	Argentina	Mauritius	Egypt
Botswana	Mali	Australia	Mexico	India
Brazil	Mozambique	Austria	Morocco	Indonesia
Burkina Faso	Niger	Belgium	Netherlands	Korea
Burundi	Nigeria	Bolivia	New Zealand	Madagascar
Cameroon	Panama	Chile	Nicaragua	Pakistan
C. Afr. Rep.	Portugal	Canada	Norway	Philippines
Chad	Rwanda	Columbia	Papua N.G.	Sri Lanka
Congo	Spain	Denmark	Paraguya	Syria
Costa Rica	Switzerland	Ecuador	Peru	Turkey
Dom. Rep.	Tanzania	Finland	Senegal	
El Salvador	Thailand	Greece	Sierra Leone	
Ethiopia	Togo	Guatemala	Singapore	
France	Tri.&Tobago	Hong Kong	Sweden	
Ghana	Uganda	Ireland	Tunisia	
Haiti	USA	Israel	UK	
Honduras	Zambia	Japan	Uruguay	
Italy	Zimbabwe	Jordan	Venezuela	
Jamaica		Malaysia		
(39)		(39)		(11)

Appendix F

Growth Regressions

Table F1: 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

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 1979-2000. s_h is the average percentage of the working-age population in secondary school for the period 1970-1995.