The Patterns of AIDS' Effects on Growth and Human Capital : Evidence from Africa and Theory

Paul CAHU and Falilou FALL[1]

DGTPE

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Abstract

The paper presents empirical evidence of AIDS epidemic effects on demography variables and accumulable factors. Using a panel of 47 Sub-Saharan African countries, we show that AIDS has negative and significant effect on life expectancy and fertility rate. Thus, a one percent increase in AIDS prevalence rate leads to a decrease of one month every year of the life expectancy in average. We also show that AIDS has a negative effect on investment rate, capital intensity and primary and secondary enrollment rate. However, we cannot find a global effect of AIDS on GDP per capita. This outline the difference between the short run and direct effect of AIDS and the long run indirect effect of the epidemic.

Then, we propose a model that exhibits the poverty trap property the epidemic have. Our model is an OLG economy which highlight the effect of AIDS related health expenditures on life expectancy.

Key words : health, AIDS epidemic, human capital, growth, inequalities,
JEL Classification : ...

[1] Authors contact : paul.cahu@dgtpe.fr and falilou.fall@dgtpe.fr

1 Introduction

The UNAIDS has released its 2008 "Report on the global AIDS epidemic" showing that there were an estimated 33 million people living with AIDS in 2007 in the World. Sub-Saharan Africa remains most heavily affected by HIV, accounting for 67% of all people living with HIV and for 72% of AIDS deaths in 2007. In some countries, as Botswana, Lesotho and south Africa, the HIV prevalence rate among pregnant women attending clinics is more than 30%.

The social and economic consequences of such epidemic are huge. Families are broken, sometimes with an important number of orphans. The burden in family incumbering to provide health care for infected people is heavy and, has consequences on savings and investment. It also have important effect on national public policies directing finance to health care from others non satisfied needs. None has a doubt on the economic consequences of AIDS on hit countries. However, first estimation by Bloom and Mahal (1997) in a cross-country perspective found no evidence that AIDS impedes growth. These estimates have been criticized for the lack of appropriate data, since they were based on data for the period 1980-1992, when AIDS prevalence were low. Others estimates, in this first wave of tentative to assess the macroeconomic effects of HIV/AIDS were by Cuddington (1993) and, Cuddington and Hancock (1994). They examined the impact of AIDS on individual countries showing that the negative effects on Malawi and Botswana GDP per capita or growth rate were important.

A second wave of studies aiming to assess the impact of AIDS on growth find more evidence of the negative effects of the epidemic. Bonnel (2000) concluded from a cross-country study that AIDS on average reduced Africa's per capita growth by 0.7% points. McDonald and Roberts (2006), departing from studies that use cross-country cross-section method, estimate the AIDS' effects on growth in a cross-country panel data. They found that, in Africa, the marginal impact on income per capita of a 1% increase in HIV prevalence rate is minus 0.59%. Thus, at least, there is still debates on the magnitude of the AIDS impact on growth.

This paper has two goal. The first one is to assess and separate the empirical effects of AIDS on variables that matters for growth, namely demographic and factors accumulable variables, from the effects on GDP per capita and growth. Doing so, we expect to differentiate the long run and short run effects of the epidemic. The second goal is to derive a theoretical model, focusing on the effect of the disease on life expectancy and human capital investment, to outline the poverty trap the epidemic potentially have.

Our estimates, based on data from the UNAIDS for 47 Sub-Saharan Africa, indicate that AIDS reduce life expectancy by one month every year for a 1% increase of the epidemics. It also have substantial negative effect on fertility rate. These results differs from the findings of Kalemli-Ozcan (2006) who depict a positive effect of AIDS on fertility. The effect on capital intensity and on investment rate are also negative. The impacts of AIDS in education are also negative. We the estimate the global effect on GDP per capital and find no significant evidence of AIDS effect on it. The one way to reconcile these findings is that the long run effects of AIDS have not already completely occurred.

We then build a model in which AIDS epidemic can influence long-run growth. It is an OLG economy where individuals live potentially for three periods : youth, adulthood and old age. Every individual is a member of a family household. In each household there is a constant exogenous share of the member who are HIV positive. There are two factors of production : physical capital and Labor, which is a sum of efficient unit of human capital.

The physical capital is not accumulable, it is completely consumed during the process of production. This assumption ease the resolution of the model and is not completely at odds with some patterns of African economies.

The accumulation of human capital depends on three inputs, education expenses, time and parental human capital. Each child is endowed with one unit of time which can be devoted to learning or to working on the behalf of their parents to increase income. Adults make time allocation decisions for their children. They also make decisions on how to allocate family income between consumption, savings and AIDS related medical expenditures.

Our approach differs from earlier theoretical research in this area. Corrigan, Glomm and Mendez (2005) model is the closest to our approach. However, we differ in some important aspect that is, they model health expenditures as utility enhancing goods, while we consider that health expenditures improve the life expectancy of HIV positive people. This specification allow us to show that AIDS epidemic can generate a poverty trap for the economy. The occurrence of such poverty trap depends on the degree of which the epidemics had spread into the economy. A huge number of people contaminated in the country can settle the economy in a poverty trap. We show that, in such case, subsidizing education is not efficient to escape the economy from the poverty trap. Either, subsidizing health care expenditures is efficient only for some degree of expansion of the epidemics.

The next section presents the econometric analysis. Section 3 set up the model. In section 4 we develop the policy analysis.

2 Econometric Analysis

2.1 The data

The data are from several international institutions and cover 47 countries of Sub-Saharan Africa on a yearly basis from 1970 to 2006[2]. Data on HIV/AIDS epidemic are from the UNAIDS fact sheets, which detail the spread of HIV infection on each UN country using several sources. The most reliable and comparable variable, both in time and space are HIV/AID prevalence rate among pregnant women in both rural and urban areas and reported AIDS cases. We mainly use HIV/AID prevalence rate among pregnant women. Missing data have been extrapolated using reported AIDS cases. HIV prevalence rate among total population is calculated as a weighting average of HIV prevalence rate among rural and urban population. The prevalence rate is a good measure of the progression of the epidemics. Urbanization data are from United Nations World Urbanization Prospects (2007) (UNWUP)[3]. In African countries the rate of education enrolment is correlated with the level of urbanization and the latter is also linked to HIV/AID progression. Infant mortality data are available on a five-year average basis in the UNWUP. We compute the annual data with an algorithm that minimizes the yearly variation of the annual growth rate of data taking the value of the series in the years 1970, 1975, 1980, 1985 and 1990 as given. This procedure is therefore very similar to an Hodrick-Prescott filter. Fertility and life expectancy data are published by the World Bank every two or three years since 1960. We compute the annual data with the same procedure as before. Demographic data, such as working age population are from UN data. Estimates of GDP and net formation of fixed capital (in constant US$) are provided by the United Nations

[2] A sum up of available data by country can be found in appendix.

[3] The 2007 Revision Population Database

Statistics Division. Education data including primary and secondary enrolment rate and the ratio of the number of pupil per teacher on the primary level are from UNESCO data. These data are available yearly since 1990 and every five year from 1960 to 1990. Missing years are extrapolated from five-year data using our smoothing algorithm. The data on conflicts are extracted from the third version of the Armed Conflict Dataset of the Uppsala Conflict Data Program, Uppsala University (UCDP) and International Peace Research Institute (Oslo) (UCDP/PRIO, December 2007). This dataset contains annual observations of conflicts about all members of the international system, as defined by Gleditsch & Ward (1999), between 1946 and 2006.

Table 1 : Descriptive statistics

Variable	Numb. of obs.	Mean	Std. Dev.	Min	Max
GDP per worker ($)	1 662	1 482.78	1 933.45	98.41	19 375.93
Pop. (in work age)	1 702	5 714.5	8 960.32	35.662	76 655.7
Fertility	1 726	6.03	1.26	1.91	8.50
Life expectancy	1 727	50.71	7.64	23.64	73.17
Infant Mortality (%)	1 610	109.60	36.84	14.59	206.40
AIDS Prevalence (%)	1 545	3.40	6.61	0	41.73
Primary school	1 562	76.98	33.19	8.00	179.56
Secondary school	1 536	21.58	18.40	1.11	114.01
Urbanization (%)	1 739	28.99	14.31	2.4	84.09

Notes : Variables are averaged over 1970-2006. GDP per worker is the GDP over the population in working age, which is thousands. Fertility is the total fertility rate per woman. Life expectancy is at birth. Infant mortality is the infant mortality per 1000 births. AIDS prevalence rate is the reported prevalence rate among pregnant woman. Primary school is the total gross primary school enrollment. Secondary school is he total gross primary school enrollment. Urbanization is the percentage of population in urban areas.

2.2 Results

2.2.1 AIDS and demography

HIV\AIDS is likely to affect a country through different mechanisms and variables. HIV\AIDS disease is not a one shot shock that decrease the population level of a country. On the contrary, it is a long lasting disease, which can affect demographic figures as life expectancy, fertility rate and therefore the population level. We consider Sub-Saharan African countries because it is the region most affected by AIDS in terms of death. Our estimation recover the 47 Sub-Saharan African countries from 1970 to 2006. Our concern is whether and in which scale AIDS had an effect on demographic variables.

AIDS reduces life expectancy in two ways. First, it is likely to increase infant mortality by its impact on pregnant women and, secondly, it causes a huge number of death in African countries due to the absence of the needed health care. To assess this effect we run the following panel regression with country fixed effects and a time trend :

$$\text{LifeExp}_{it} = \alpha_i + \beta_1 Year + \beta_2 AIDS_{it} + \beta_3 CONTROL_{1it} + \beta_4 CONTROL_{2it} + ... + \varepsilon_{it} \quad (1)$$

where α_i is the cross country fixed effect and "CONTROL" represent the additional control variables. The fixed effects take into account the heterogeneity between countries in terms of infrastructure, wealth or religion.

Results are given in Table 2. In the two regressions, AIDS has a significant negative effect on life expectancy. A 1% increase in AIDS prevalence rate implies 0.07 years of decrease in life expectance. The time trend (Year) captures the climbing trend in life expectancy in the absence of AIDS. It shows a very slow progress on life expectancy in the period. The variable Civdeath, indicating wether a country had experienced several wars, has a strong negative effect on life expectancy. Schooling does not seem to have a strong effect on life expectancy ; an increase in primary enrollment rate has a limited positive effect, while the effect of secondary enrollment rate is not significant.

We also analyze the impact of AIDS on fertility rate. Some theoretical models (see Kalemli-Ozcan (2003)) predict that increased education of women reduces fertility due to the raise in the cost of childbearing. In the same line, the higher cost of childbearing in urban zone is associated with a decrease in fertility. The coefficients of correlation between the different variables (see appendix) show that GDP, urbanization, AIDS and education are negatively correlated to fertility.

We run regression (1) with fertility rate as dependent variable. The results in table 2 show in column (3) and (4) that AIDS has a significant negative effect on fertility and that an increase in secondary education reduce also the fertility rate. A 1% increase in AIDS lessen the number of births by 0.03 in average per year. For a disease lasting more than twenty years from now, it is a huge cumulated effect. The time trend variable depict a decreasing trend in fertility and urbanization also has a negative effect on fertility. A one percent increase of the urban population decreases the number of birth by 0.01.

Another important effect of AIDS already emphasized in the literature is its impact on working people. By its nature, AIDS is more likely to affect young adult and therefore hit the working population. However, our estimation of equation (1) with the working population as dependent variable give a very little effect of AIDS on working age population. In estimation (6), AIDS have a negative effect on working age population. While, in estimation (7), when we remove the lagged variable of the working age population, the effect of AIDS on working population is positive and the coefficient of the effect of life expectancy is much higher. It seems that the life expectancy variable reverse the effect of AIDS.

Table 2 : The effects of AIDS on demographic figures

Dependent variable	Life expectancy		Fertility		working age pop.	
	(1)	(2)	(3)	(4)	(5)	(6)
AIDS_1	-0.074	-0.069	-0.047	-0.032	-0.0003	0.0002
.	(-19.24)	(-16.88)	(-21.67)	(-13.9)	(-5.64)	(3.33)
LogGDP_1	-0.026*	-0.111*	-	-0.122	-	-
.	(-0.52)	(-1.78)		(-2.75)		
LifeExp_1	0.94	0.94	-	-	-	0.0013
.	(189.37)	(181.6)				(12.27)
Year	0.018	0.018	-	-0.031	0.001	0.001
.	(7.78)	(7.45)		(-12.6)	(9.14)	(8.13)
Civdeath	-0.17	-0.18	-	-	-0.008	-0.006
.	(-2.82)	(-2.81)			(-6.15)	(-4.95)
Primary	-	0.003	-	0.001	-	-
.		(3.22)		(2.56)		
Secondary	-	-0.003*	-0.007	-0.007	-	-
.		(-1.48)	(-4.65)	(-4.40)		
Mortality_1	-	-	0.010	0.002	-	-
.			(12.42)	(1.97)		
Urbanization_1	-	-	-0.026	-0.01	-	-
.			(-10.42)	(-3.54)		
LogWPOP_1	-	-	-	-	0.964	-
.					(203.02)	
Civconflict	-	-	-	-	-0.005	-0.003
.					(-4.60)	(-3.50)
R^2 (within)	0.98	0.98	0.68	0.72	0.99	0.99
Observations	1523	1411	1421	1373	1545	1545
Numb. of groups	44	44	44	44	44	44

Notes : This is a fixed-effects within regression with countries panel data. t values are in parentheses. LogWPOP variable is the log of working age population. Civconflict is the war inside a specific country. * denotes not significant at 5%. In the regression (4), it is Log GDP per capita instead of Log GDP. The sign (_1) denotes that the variable is lagged one period.

2.2.2 AIDS and macroeconomic variables

In order to capture the economic effect of AIDS, we investigate whether there have been any impact on macroeconomic variables. To this end, we run the same estimation regression described in equation (1) with macroeconomic variable as dependent variable. The literature has emphasized the different mechanism through which AIDS affect the economy[4]. One aspect of AIDS, by its long lasting time, is to increase health expenditures or to reduce the earnings of a household and, therefore decrease the saving capacity. Thus, AIDS may induce a reduction in capital accumulation and investment and, then a decrease in GDP growth.

Estimations of the impact of AIDS on those variables are given in table 3. The effect of AIDS on GDP per capita is negative and significant once the effects of civil conflict are

[4] See Boucekkine, Diene and Azomahou (2007) for a survey.

taken into account, though that it is very limited. The impact on GDP (in log) is also negative. The conflicts in the different countries appear to have strong negative impact on GDP and GDP per capita.

AIDS has a positive and significant effect on capital intensity. This is due, in the short run, to the capital deepening effect of AIDS through its negative impact on working age population. The time trend is negative showing a decreasing trend in capital intensity in the absence of AIDS.

AIDS also have a negative and significant affect on the investment rate. A 1% increase in AIDS prevalence rate leads to a decrease of the investment rate of 0.5% in average per year. Civil death due to the conflict has a negative impact on the investment rate. But, an increase in the population reduce also the investment rate. In the African context, this is from the necessity to address first of all the consumption needs.

Table 3 : AIDS's effects on macroeconomic variables

Dependent variable	LogGDP per capita		Log GDP	Capital intensity		LogInvest. rate
	(7)	(8)	(9)	(10)	(11)	(12)
AIDS_1	-0.0004*	-0.0009	-0.0012	0.0004	0.0003	-0.005
.	(-1.27)	(-2.32)	(-3.31)	(6.05)	(4.97)	(-2.54)
LogGDP_1	0.978	0.974	0.975	-0.0010*	-0.0013*	0.49
.	(138.32)	(139.63)	(140.04)	(-0.87)	(-1.16)	(11.39)
Civdeath	-	-0.064	-0.074	-	-	-0.131
.		(-7.16)	(-8.04)			(-2.99)
Civconflict	-	-0.026	-0.031	-	-	-
.		(-3.87)	(-4.52)			
Year	-	0.0004*	0.0013	-	-0.0037	-
.		(1.78)	(4.56)		(-8.54)	
Cap. intensity_1	-	-	-	1.001	0.973	-
.				(2659.08)	(294.22)	
Log Pop_1	-	-	-	-	-	-0.562
.						(-9.86)
Primary_1	-	-	-	-	-	0.002
.						(2.87)
Secondary	-	-	-	-	-	-0.003
.						(-2.23)
R^2 (within)	0.92	0.93	0.96	0.99	0.99	0.12
Nb of observ.	1523	1523	1523	1523	1523	1411
Nb of groups	44	44	44	44	44	44

Notes : This is a fixed-effects within regression with countries panel data. t values are in parentheses. * denotes not significant at 5%. For estimation (7) and (8), it is Log GDP per capita_1 instead of Log GDP_1. Capital intensity variables are in log.

2.2.3 AIDS, growth and education

Several studies have tried to estimate the global effect of AIDS on growth. Early estimates by Over (1992) and Cuddington and Hancock (1994) found evidence of a negative important effect of AIDS on growth. These estimates based of a country specific effects suffer a lack of appropriate data. One of the first estimates in a cross-country basis is by

Bloom and Mahal (1997) who found no evidence of negative effect of AIDS on growth. However, their studies have been criticized for the limitations in the data they used. Indeed, the time period of their estimates (1980-1992) is characterized by a growing, but still limited, AIDS epidemic. More recently, McDonald and Roberts (2005) provide a new estimation of the effect of AIDS on growth through its impact on health capital. Their studies, based on more recent data from 1984 to 1999, is an estimation of a Solow-augmented model, following Mankiw and al. (1992). They introduce health capital as a accumulable factor as human and physical capital. Another difference is that they use panel estimation method applied to cross-country economic growth instead of cross-section method. They found strong and significant negative effect of AIDS on growth.

We estimate a Solow augmented model-type by introducing AIDS variable, it appears to have no effect significantly different from zero. Moreover, the estimation have a very limited explicative power of the variation of GDP per capita. We run another regression more structural with GDP in log as dependent variable and different variables of control. We found that AIDS has no significant effect on GDP. Schooling at primary and secondary level has a positive effect on growth.

The impact of AIDS on education is more likely negative. In our estimation, the impact of AIDS on primary school enrollment rate is negative when others variables as civil conflict are taken into account. Its effect on secondary enrollment is also negative, however non significant. Kalemli-Ozcan (2005) found the same negative effect of AIDS on education in Sub-Saharan Africa.

Table 4 : The effects of AIDS on growth and education

Dependent variable	GDP per capita	LogGDP	Primary		Secondary	
	(13)	(14)	(15)	(16)	(17)	(18)
Capital intens_1	0.058	-	-	-	-	-
.	(8.93)					
AIDS_1	0.0018*	0.002*	-0.032*	-0.07	-0.004*	-0.015*
.	(1.33)	(1.62)	(-1.47)	(-2.82)	(-0.39)	(-1.37)
Secondary_1	0.010	0.010	-	-	0.93	0.92
.	(10.12)	(10.08)			(112.98)	(101.77)
Primary_1	0.0018	0.001	0.97	0.96	0.02	0.026
.	(4.04)	(4.19)	(131.93)	(118.73)	(8.43)	(7.27)
Civdeath	-0.127	-	-	-2.95	-0.19*	-0.22*
.	(-4.60)			(-5.23)	(-0.89)	(-0.96)
CivConflict	-	-	-	-1.41	-0.24*	-0.33*
.				(-3.17)	(-1.37)	(-1.75)
LogCapital_1	-	0.044*	-	-	-	-
.		(1.72)				
LogPopW	-	0.88	-	-	-	-
.		(9.39)				
GDP per capita_1	-	-	-	-	-	0.55
.						(2.50)
Year	-	-	-	0.04	-	0.02
.				(2.43)		(2.78)
R^2 (within)	0.14	0.64	0.92	0.92	0.95	0.95
Nb of observations	1411	1411	1455	1455	1410	1390
Nb. of groups	44	44	44	44	44	44

Notes : This is a fixed-effects within regression with countries panel data. t values are in parentheses. * denotes not significant at 5% level. GDP per capita variables are in log.

Therofe, AIDS had limited consequences on growth in the short run in Sub-Saharan Africa. However indirect effects on factors accumulation indicate that AIDS may have strong long-run effects on growth. In the following, we present a theoretical model aiming to describe and analyze this prediction.

3 The model

3.1 Background and main hypothesis

Epidemic have been model as sudden decreases of life expectancy or a destruction of part of the labor supply in an hit economy. Classical OLG models show that a reduction of life expectancy have steady state effects on investment levels, both in physical and human capital due to sharp decrease of the saving and investment rate. Our estimations suggest that AIDS may have decrease in the long run the level of investment for Sub-Saharan Africa. However AIDS[5] differs strongly from other major epidemics for at least three reasons :

[5]It can be pointed out that the paludism epidemic exhibits the same properties than the AIDS epidemic. Consequently, the properties of the model might be extended to paludism, which is also endemic in Subsaharian countries since several generations.

– HIV-positive people do not always die right after been contaminated. They can survive several years and still participate to the economy, although their productivity is reduced ;
– family incurring health expenditures may undergo income loss and therefore reduce their investment in physical capital and education ;
– current AIDS treatments can increase significantly life expectancy of HIV-positive people and also treatments against HIV have no significant effects if they are not completely taken by patients.

The first property is a good explanation for the fact that AIDS tends to become endemic in many countries. As this disease spreads out and stabilizes in an economy, it is likely that the epidemic has not only short-term consequences. The epidemic may modify the behavior of several generations and have long-term effects on economic growth. The second property is also a channel through which AIDS have economic short and long run consequences. The third property suggests that the ability of an economy to provide massive access to treatment may be a key factor of long-run growth. Whereas a country is rich or poor when hit by the epidemic, it is able to invest in health and prevent the life expectancy to fall dramatically. It also implies that there may appear a threshold level of investment or expenditures in health and AIDS treatments so as to prevent the epidemic to affect potential growth.

We develop a simple OLG model where each individual belongs to a household and lives, at most, three periods. In the first period of life agents are young and they receive education or work at home for their parents. Therefore, learning has an opportunity cost given by the forgone income by not producing at home. In the second period of life, the individual inelastically supplies labor to the firm. However, ill people see there working time reduced. The share of HIV- ill people is exogenously given and in every household there is a part of adults who are ill. Only healthy people survive in the third period, so they have to save for their old age consumption. The model in that settings look like that of Corrigan and al. (2005). But it differs in some important respect, that are in their model health expenditures enters in the utility function. While we consider health expenditures have a positive effect on life expectancy. However, the effects of treatments are insignificant on life expectancy when the quantity of drugs taken by the patients remain below a threshold.

3.2 Model features

A representative household is considered, whose members are both HIV-positive and healthy. Life is divided into three periods : childhood denoted (0), adult life, denoted (1) and retirement, denoted (2). Only healthy people enjoy the third period of life. Each adult people has one child. Utility of adult people is assumed to be logarithmic and depends on consumption in the adult life c_1 and in the retirement period c_2 and the human capital level of the elder h_{+1}. Adults are altruistic and they invest in their children's education. Hence the utility of a healthy individual can be written as follows, where ρ and β are exogenous preference parameters :

$$U_H = \ln(c_1) + \rho \ln h_{+1} + \beta \ln c_2 \tag{2}$$

And the utility of an HIV-positive adult can be written as :

$$U_A = \ln(c_1) + \rho \ln h_{+1} \tag{3}$$

The head of household takes decisions regarding savings, investment in the children education, consumption during adult life and retirement and health expenditure so as to maximize the average utility of the adults of the household. For reasons of simplicity, it is supposed that a fraction a of each household is HIV-positive. Then the utility to be maximize is :

$$U = U_H (1-a) + aU_A = \ln(c_1) + \rho \ln h_{+1} + \beta (1-a) \ln c_2 \tag{4}$$

The expenditure devoted to education of the children is denoted ewh. We suppose that ill people can only work a time $l < 1$. Therefore in each household, the duration of adult work is $1 - a + al - e$. Children are supposed to work during a time b in the behalf of their parents. Therefore, their productivity only depends on the human capital of their parents. Denoting S the savings of the household, m the health expenditure, w the wage and r the physical capital returns, the budget constraints of adult period (1) and retirement period (2) are :

$$c_1 + S + m + ewh = wh (1 - a + al + b) \tag{5}$$

$$c_2 = (1+r) S \tag{6}$$

Human capital is accumulated by children according to a standard function. Human capital of the children depends of parental human capital h and time devoted to education e. We suppose that HIV-positive adults are less efficient to educate children, they can only spent a fraction l of their time educating their children. Therefore, human capital of the children is assumed to be an increasing function of the share of healthy adults in the household. Given θ, γ, δ and ζ exogenous parameters, the human capital accumulation process is :

$$h_{+1} = \theta h^{\gamma} e^{\delta} (1 - a + al)^{\zeta} \tag{7}$$

For matter of simplicity, we assume that the time l can be interpreted as an indicator of life expectancy of HIV-positive people. Eventually, we assume that health expenditure has a positive effects on life expectancy and if it is strictly above an exogenous threshold $\overline{m}$. Life expectancy of healthy people is supposed to be 1. As life expectancy is bounded when health expenditure goes toward infinity, we assume that life expectancy of HIV-positive people belongs to $\left[l_0, \overline{l}\right]$. We assume that health expenditure has no effect when it is below an exogenous amount per capita $\overline{m}$. Moreover, we assume that health expenditure has increasing returns on life expectancy, to be consistent with this hypothesis :

$$l = \begin{cases} l_0 \left(1 + \left(\frac{m}{am_0}\right)^{1+\varepsilon}\right) & if \quad m \leq a\overline{m} \\ l_0 \left(1 + \left(\frac{\overline{m}}{m_0}\right)^{1+\varepsilon}\right) \equiv \overline{l} & if \quad m > a\overline{m} \end{cases} \tag{8}$$

On the production side, we assume that the production function is Cobb-Douglas, using aggregated human capital N, physical capital K. Average human capital H have a positive external effect on the productivity.

$$Y = AK^{\alpha} H^{\xi} N^{1-\alpha} \tag{9}$$

We suppose that there exist a continuum of households $i, I = \{i\}$,which may differ by their level of human capital but not by there share of HIV-positive people, which remains equal to a among each household. The density of i is denoted dG_i.

The aggregated human capital is defined as :

$$N = \int_I h_i q_i dG_i \tag{10}$$

where q denotes the efficient time available for work (see below). The average human capital in the economy is :

$$H = \int_I h_i dG_i \tag{11}$$

The physical capital stock equals the adult savings :

$$K = \int_I S_i dG_i \tag{12}$$

3.2.1 The household decisions

We make the assumption that the head of household does not take into account the impact of medical expenditure on the utility. The weight of consumption during the second period is assumed as exogenous and denoted a. It is convenient to define the efficient time q of the household as the time available for work and education. Equations (7) and (8) become :

$$\begin{gathered} h_{+1} = \theta h^{\gamma} eq\,(a,m)^{\zeta} \\ N = q\,(a,m) + b \\ q = \begin{cases} 1 - a + al_0 \left(1 + \left(\frac{m}{am_0}\right)^{1+\varepsilon}\right) & if \quad m \leq a\overline{m} \\ 1 - a + a\bar{l} \equiv \overline{q} & if \quad m > a\overline{m} \end{cases} \end{gathered} \tag{13}$$

The household utility can be rewritten using the budget constraints as a function $\widetilde{U}$ of investment in education e, savings S and health expenditure m :

$$\widetilde{U}\,(e,m,S) = \ln\left(wh\,(q\,(m) - e + b) - S - m\right) + \rho\delta \ln e + \beta(1-a)\ln S \tag{14}$$

To ease the notations, we introduce the labour income per time unit of labour $y = wh$ and the smallest value of efficient time $q_0 \equiv 1 - a + al_0$.

Proposition 1 *There is a single threshold level of labor income $\widehat{y}$ such that households whose labor income is below $\widehat{y}$ do not invest in health and other households invest a constant expenditure by HIV-positive member of the household $\overline{m}$.*

Proof. *For every value of m, the utility function tends toward minus infinity when e or S tends toward 0. As the utility is well defined for strictly positive values of e and S, and for every value of m, it is maximized for a couple of strictly positive value of e and S.Partial derivatives of the utility function with e and S are C^1 for every value of m. Hence for* *every value of m, the utility is maximized considering e and S when the following first order conditions are fulfilled :*

$$\frac{wh}{c_1} = \frac{\rho\delta}{\widehat{e}} = 0 \tag{15}$$

$$\frac{1}{c_1} = \frac{\beta(1-a)}{\widehat{S}} \tag{16}$$

Replacing $\widehat{e}$ and $\widehat{S}$ by there expressions given by (13) and (14) in the first period budget constraint (4) gives

$$c_1 = \frac{yq(m) - m}{1 + \rho\delta + \beta(1-a)} \tag{17}$$

Therefore the maximization of $\widetilde{U}(e, m, S)$ is equivalent to the maximization of c_1 given the conditions (13), (14) and (15). Let us note the function $\kappa(m) = yq(m) - m$. The maximization of c_1 is equivalent to the maximization of the function $\kappa(m)$. This function is continuous on $[0, \infty[$. It is strictly decreasing on $]a\overline{m}, \infty[$. On $[0, a\overline{m}]$, its variations are given by $\kappa'_m = y(1+\varepsilon)\frac{l_0}{m_0}\left(\frac{m}{am_0}\right)^{\varepsilon} - 1$. Therefore, the function κ has two potential local maxima, which are 0 and $a\overline{m}$. Thus the optimal health expenditure is 0 or $a\overline{m}$ whether $\kappa(0) > \kappa(a\overline{m})$. This condition is equivalent to

$$y > \widehat{y} = \frac{a\overline{m}}{a\left(\overline{l} - l_0\right)} = \frac{\overline{m}}{l_0\left(\frac{\overline{m}}{m_0}\right)^{1+\varepsilon}} \tag{18}$$

■

Household choices when the needed medical expenditure is too high
When the labor income is insufficient to invest in health, the education expenditure is

$$e = \frac{\rho\delta}{1 + \rho\delta + \beta(1-a)}(q_0 + b) \equiv e_0 \tag{19}$$

The investment in physical capital is :

$$S = \frac{\beta(1-a)}{1 + \rho\delta + \beta(1-a)}(q_0 + b)\, y_0 \equiv S_0 \tag{20}$$

Household choices when the needed medical expenditure is too high
When the household income is sufficient, the medical expenditure is :

$$m = a\overline{m} \tag{21}$$

The life expectancy l becomes :

$$l = \overline{l} \tag{22}$$

The education investment depends of the labour income y

$$e(y) = \frac{\rho\delta}{1 + \rho\delta + \beta(1-a)}\left(\overline{q} + b - \frac{a\overline{m}}{y}\right) \tag{23}$$

The investment in physical capital is :

$$S\left(y\right)=\frac{\beta\left(1-a\right)}{1+\rho\delta+\beta\left(1-a\right)}y_{\infty}\left(\overline{q}+b-\frac{a\overline{m}}{y_{\infty}}\right) \tag{24}$$

To solve the model, it is necessary to study the behavior of the firm to obtain the value of the real wage. To do so, it is necessary to know the distribution of human capital in the economy. We will study three different cases :

1. In the first case, we consider a representative household. Thus, there is only one type of household in the economy and the distribution degenerates in a single point.
2. In the second case, we consider that there are two different households in the economy and we assume that their relative weight in the total population is exogenous and constant over time. We denote μ the share of the poorest household, that is the household which is less endowed with human capital.
3. In the last case, we suppose that health care are provided by the government. The government taxes household income at an exogenous rate σ and use all the collected resources to invest in health.

3.2.2 Decisions of the firm

The firm demands physical capital and labor in order to maximize its benefits. This leads to two first orders condition, on human and physical capital. The condition on human capital allows to set the wage and the condition on physical capital gives capital returns rate. In a perfect competition equilibrium, marginal productivity of labour equals remuneration. This leads to :

$$w=\left(1-\alpha\right)\frac{Y}{N}=\left(1-\alpha\right)\left(\frac{S}{N}\right)^{\alpha}H^{\xi} \tag{25}$$

1. In the first case, the value of capital stock, labour force and human capital can be replaced directly using (22) and (23).

$$w=\left(1-\alpha\right)\left(\frac{\beta\left(1-a\right)}{1+\rho\delta+\beta\left(1-a\right)}\frac{y\left(q+b-\frac{m}{y}\right)}{\left(q+b\right)h}\right)^{\alpha}h^{\xi} \tag{26}$$

When the representative household has a low income, it does not invest in health and the equilibrium value of wage degenerates to :

$$w_0^{1-\alpha}=\left(1-\alpha\right)\left(\frac{\beta\left(1-a\right)}{1+\rho\delta+\beta\left(1-a\right)}\right)^{\alpha}h_0^{\xi} \tag{27}$$

When the representative household has a higher income, the wage becomes :

$$w^{1-\alpha}=\left(1-\alpha\right)\left(\frac{\beta\left(1-a\right)}{1+\rho\delta+\beta\left(1-a\right)}\left(1-\frac{a\overline{m}}{y_{\infty}\left(\overline{q}+b\right)}\right)\right)^{\alpha}h_{\infty}^{\xi} \tag{28}$$

2. In the second case, the wage is given by :

$$w^{1-\alpha}=\left(1-\alpha\right)\left(\frac{\beta\left(1-a\right)}{1+\rho\delta+\beta\left(1-a\right)}\left(1-\left(1-\mu\right)\frac{a\overline{m}}{w\left(\mu\left(q_0+b\right)h_0+\left(1-\mu\right)\left(\overline{q}+b\right)h_{\infty}\right)}\right)\right)^{\alpha}\left(\mu h_0+(1- \tag{29}$$

3. In the third case, there are no private health expenditure. The investment rate in education and the life expenditure become identical for every type of households.

$$e = (1 - \sigma) \frac{\rho\delta}{1 + \rho\delta + \beta(1 - a)} (q(\sigma) + b) \tag{30}$$

Therefore, there is only one type of household in the equilibrium. The wage becomes then :

$$w^{1-\alpha} = (1 - \alpha) \left(\frac{\beta(1 - a)}{1 + \rho\delta + \beta(1 - a)} \right)^{\alpha} h^{\xi} \tag{31}$$

3.3 Equilibria

In the long run, the economy is completely described by the distribution of human capital. This distribution is degenerated into one or two mass points, which are called low and high equilibria. In this section, we study the existence of this equilibria and therefore the form of the stationary distribution. We make the following assumptions to ensure the further propositions.

Assumption 2 *The efficient time of an HIV-infected agent which is not under medication, l_0 is small.*

Assumption 3 *The health expenditure of the rich household compared to its labour income is limited $\frac{a\overline{m}}{wh_{\infty}(\overline{q}+b)}$.*

Assumption 4 *The level of externality of human capital ξ is small.*

3.3.1 Low equilibrium

We name "low equilibrium" the stationary level of human capital of a dynasty such that health expenditures in this dynasty are always null. In this case, the stationary level of human capital is unique and simply defined :

$$h_0 \equiv \theta^{1/1-\gamma} \left(\frac{\rho\delta}{1 + \rho\delta + \beta(1 - a)} (q_0 + b) \right)^{\delta/1-\gamma} q_0^{\zeta/1-\gamma} \tag{32}$$

The labour income is therefore :

$$y_0 \equiv wh_0 \tag{33}$$

The condition of existence of a stable low equilibrium is thus given by the condition :

$$wh_0 < \widehat{y} \tag{34}$$

Proposition 5 *In a private health system (case 1 and 2), for a sufficiently small q_0 and for sufficiently large b, there exist for μ and $\overline{m}$ given a threshold value of the HIV prevalence rate in the population $\widehat{a}(\mu, \overline{m})$ such that the low equilibrium exists, if and only if $a > \widehat{a}$.*

Proof. *The steady state of the economy is described by two equations : the equilibrium on the labour market and the stationary of human capital. The stationary human capital of the richest household is given by a function of HIV prevalence rate a, the human capital* *of the richest household itself h_∞, and the equilibrium wage per unit of human capital and time work, w, H. The equilibrium wage is a function of a, w, h_∞ and h_0 also, as given by (NN) :*

$$w \equiv \Omega\left(a, w, h_\infty, h_0\right)$$

Differentiating equations (NN), we can determine the sign of $\frac{dw}{da}$:

$$\frac{dw}{da} = \frac{\frac{\partial\Omega}{\partial a} + \frac{\partial\Omega}{\partial h_0}\frac{dh_0}{da} + \frac{\partial\Omega}{\partial h_\infty}\frac{\partial H}{\partial a} / \left(1 - \frac{\partial H}{\partial h_\infty}\right)}{1 - \frac{\partial\Omega}{\partial w} - \frac{\partial\Omega}{\partial h_\infty}\frac{\partial H}{\partial w} / \left(1 - \frac{\partial H}{\partial h_\infty}\right)} \tag{35}$$

For sufficiently low l_0, the following condition is verified :

$$\frac{dh_0}{h_0 da} = -\frac{\zeta}{1-\gamma}\left(1 - l_0\right)\frac{1}{q_0} - \frac{\delta}{1-\gamma}\left(\frac{1-l_0}{q_0+b} + \frac{\beta}{1+\rho\delta+\beta\left(1-a\right)}\right) < 0$$

In addition to that, we have directly, $\frac{\partial\Omega}{\partial a} < 0$ and $\frac{\partial\Omega}{\partial h_\infty} > 0$. Using the previous property, $\frac{\partial H}{\partial h_\infty} < 0$. Moreover, a simple calculus shows that $\frac{\partial H}{\partial h_\infty} < 1$. Thus, the numerator of (NN) is positive. To determine the sign of the denominator, let us note :

$$\begin{aligned} z &= (1-\mu)\frac{a\overline{m}}{w\left(\mu\left(q_0+b\right)h_0 + (1-\mu)\left(\overline{q}+b\right)h_\infty\right)} \\ x &= \frac{a\overline{m}}{wh_\infty\left(\overline{q}+b\right)} \end{aligned} \tag{36}$$

The terms of denominators become :

$$\begin{aligned} \frac{\partial\Omega}{\partial w} &= \frac{\alpha}{1-\alpha}\frac{z}{1-z} \\ \frac{\partial\Omega}{\partial h_\infty} &= \frac{\alpha}{1-\alpha}\frac{z}{1-z}\frac{w}{h_\infty}\frac{(1-\mu)\left(\overline{q}+b\right)h_\infty}{\left(\mu\left(q_0+b\right)h_0 + (1-\mu)\left(\overline{q}+b\right)h_\infty\right)} \\ \frac{\partial H}{\partial w} &= \frac{\delta}{1-\gamma}\frac{x}{1-x}\frac{h_\infty}{w} \\ \frac{\partial H}{\partial h_\infty} &= \frac{\delta}{1-\gamma}\frac{x}{1-x} + \frac{\xi}{1-\alpha}\frac{1-\mu}{\mu h_0 + (1-\mu)h_\infty} \end{aligned} \tag{37}$$

The denominator Δ becomes then :

$$\Delta = 1 - \frac{\alpha}{1-\alpha}\frac{z}{1-z}\left(1 + \frac{\frac{\delta}{1-\gamma}\frac{x}{1-x}}{1 - \frac{\delta}{1-\gamma}\frac{x}{1-x}}\frac{(1-\mu)\left(\overline{q}+b\right)h_\infty}{\left(\mu\left(q_0+b\right)h_0 + (1-\mu)\left(\overline{q}+b\right)h_\infty\right)}\right) \tag{38}$$

The denominator is consequently positive for x sufficiently small as $z < x$. Taking $\alpha = 0,2$ and $\delta + \gamma < 1$, the condition $\Delta > 0$ is verified for $x < \frac{4}{7}$ which seems to be a good compromise. Making this assumption, we obtain $\frac{dw}{da} < 0$. As $\frac{dh_0}{da} < 0$, we can conclude that the labour income of the poor household is a decreasing function of HIV-prevalence in the economy. Therefore for other parameters given, there is an unique threshold value of a such that $wh_0 < \widehat{y}$. High equilibrium ■

Proposition 6 *In a private health system, there is a threshold value of maximal AIDS treatments $\widehat{m}$, such that the low equilibrium exists, if and only if $\overline{m} > \widehat{m}$.*
Proof. *Making the same assumption than in the previous proof, we get :*

$$\frac{dw}{d\overline{m}} = \frac{\frac{\partial\Omega}{\partial\overline{m}} + \frac{\partial\Omega}{\partial h_\infty}\frac{\partial H}{\partial\overline{m}} / \left(1 - \frac{\partial H}{\partial h_\infty}\right)}{\Delta} < 0$$

For other parameters given, there is therefore a single value of $\overline{m}$ such that $wh_0 = \widehat{y}$. ■

3.3.2 High equilibrium

We name "high equilibrium" the stationary level of human capital of a dynasty such that health expenditure are not null. Using the condition (NN), we obtain a relation between the stationary level of human capital h_∞.

$$h_\infty = \theta^{1/1-\gamma}\left(\frac{\rho\delta}{1+\rho\delta+\beta(1-a)}\right)^{\delta/1-\gamma}\left(1-\frac{a\overline{m}}{wh_\infty(\overline{q}+b)}\right)^{\delta/1-\gamma}(\overline{q}+b)^{\delta/1-\gamma}\,\overline{q}^{\zeta/1-\gamma} \equiv H(a,w,h_\infty) \tag{39}$$

Proposition 7 *Making the same assumption as before on the parameters, there is an unique stationary value of the human capital such that the health expenditure of the dynasty is not null.*

Proof. We have already proven that when there are two type of households, $\frac{dw}{da} > 0$ As the function $w(a,\cdot)$ is continuous, there is at most one equilibrium for μ give. ■

In the steady state, the distribution of human capital in the economy corresponds to one or two mass points, h_0 and h_∞.The stability of the low equilibrium has already been studied.

Proposition 8 *Making the same assumptions than previously, for given values of parameters μ and $\overline{m}$, there is a threshold value of a,such that the high equilibrium is stable if and only if $a < \widetilde{a}$,with $\widetilde{a} < \widehat{a}$*

Proof. With the same kind of thinking, we show that:

$$\frac{dh_\infty}{da} = \frac{\frac{\partial H}{\partial a} + \frac{\partial H}{\partial w}\frac{dw}{da}}{1-\frac{\partial H}{\partial h_\infty}} < 0$$

Consequently, the stationary labour income of the richest household is a decreasing function of HIV-prevalence. Therefore, there exists an unique threshold value of a such that $wh_\infty = \widehat{y}$. Moreover, this threshold is greater than $\widehat{a}$ if and onlu if $h_\infty > h_0$ which is likely. ■

When the low equilibrium is stable, there exists a poverty trap : some households which have not accumulated enough human capital when the epidemic spreads out will not be able to invest in health and, the human capital of the dynasty will converge to the low equilibrium.

Definition 9 *A poverty trap is defined as the set $A = [\widehat{a}, 1]$, such that for any $a \in A$, the human capital of dynasties whose initial human capital is near to zero converges to the low equilibrium.*

4 Policy analysis

4.1 Influence of human capital distribution on the poverty trap

We know that for any initial distribution of human capital in the economy, the stationary distribution is a two or a one mass point, located in h_0 and $h_\infty(\mu)$. The relative weight of the two mass points, described by the parameters μ depends obviously on the initial distribution. But to simplify the problem, we suppose that the economy is initially constituted of only two types of households, one which is poorer than the other. We assume that the relative weight of the poorest household in the economy is μ. Due to the interaction on the labour market, the stationary position of the two households depends of their own initial position but also of the initial position of the other household. Three configurations are possible. First, the initial position of both households may be low. In this case, both households converge to the low equilibrium. The opposite case is also possible, where both households converge to the high equilibrium. Eventually, there can be at the steady state a household in the low equilibrium and another in the high equilibrium. In the case where both equilibria are stable, we can wonder what could be the consequences of an increase of the aggregated human capital in the economy, that is a decrease of μ, on the poverty trap.

Proposition 10 *When human capital externalities on the labour market (ξ) are small, an increase of initial aggregated human capital in the economy has a negative effect on the lower bound of the poverty trap.*
Proof. *For low ξ, the derivative of wage according to μ is positive, using the system (NN).Therefore, the threshold value $\widehat{a}$ is an decreasing function of μ.* ■

To reduce the size of the poverty trap, one can think to subsidy education or health. As we just saw it, subsidizing education, that is a greater μ is not good. Let us study the case of a public health system.

4.2 Effects of public health expenditure on the poverty trap

Proposition 11 *When there is only one type of household in the economy, and when both low and high equilibrium are stable, there is a threshold level of human capital $\widehat{h}$ such that the human capital of a household converges toward h_0 or h_∞ whether their initial human capital is below or above $\widehat{h}$.*
Proof. *Let us assume that both equilibrium are stable. The threshold value of human capital is given by the following condition :*

$$\begin{aligned} w(h)\,h &= \widehat{y} \Longleftrightarrow (1-\alpha)^{\frac{1}{1-\alpha}} \left(\frac{\beta(1-a)}{1+\rho\delta+\beta(1-a)}\right)^{\frac{\alpha}{1-\alpha}} h^{1+\xi/1-\alpha} \left(1-\frac{a\overline{m}}{w(h)\,h\,(\overline{q}+b)}\right)^{\frac{\alpha}{1-\alpha}} \quad (40) \\ \Longleftrightarrow \quad \widehat{h}^{1-\alpha+\xi} &= \frac{\widehat{y}}{(1-\alpha)} \left(1-\frac{a\overline{m}}{\widehat{y}\,(\overline{q}+b)}\right)^{\alpha} \left(\frac{1+\rho\delta+\beta(1-a)}{\beta(1-a)}\right)^{\alpha} \end{aligned}$$

Using Taylor development at order 1 of the following system allows to show that for any $h > \widehat{h}$, the economy converges to the high equilibrium.

$$\begin{cases} h_{+1} = \theta h_t^{\gamma} e_0^{\delta} \left(1-\frac{a\overline{m}}{w_t h_t(\overline{q}+b)}\right)^{\delta} \overline{q}^{\zeta} \\ w_t = (1-\alpha)^{\frac{1}{1-\alpha}} \left(\frac{\beta(1-a)}{1+\rho\delta+\beta(1-a)}\right)^{\frac{\alpha}{1-\alpha}} h_t^{\xi/1-\alpha} \left(1-\frac{a\overline{m}}{w_t h_t(\overline{q}+b)}\right)^{\frac{\alpha}{1-\alpha}} \end{cases}$$

■

Proposition 12 *When health expenditure are financed through a tax on labour income, there is only one type of households in the steady state.*
Proof. *This corresponds to the third case. As health expenditure are similar for every households, the life expectancy and consequently the investment in education are similar among all dynasties. Therefore, the human capital of dynasties converges to the same value in all the economy.* ■

Proposition 13 *There is a value of $a' > \widehat{a}$, such that for any $a < a'$, subsidizing health expenditure allows the overall dynasties of the economy to escape the poverty trap.*
Proof. *For a given rate of tax σ, the stationary human capital becomes :*

$$h_{\sigma} \propto q(\sigma)^{\zeta/1-\gamma} \left(\left(q(\sigma) + b \right) (1-\sigma) \right)^{\delta/1-\gamma}$$

This function is defined and bounded in $\sigma \in [0,1]$. Therefore, there exists a value σ^* of σ which maximizes h_{σ}. In the long run, if $h_{\sigma*} > \widehat{h}$, the overall economy would converge to the high equilibrium when the tax is removed. Public health expenditure allows to reduce the poverty trap. ■

Therefore, when the country is not heavily affected by AIDS, a fiscal response may be sufficient to put the economy on the high growth path. In the other case however, there is no other choice than reducing the price of HIV treatments $\overline{m}$ to make the poverty trap disappear.

5 Concluding remarks

Our estimation suggests that AIDS epidemics is having strong negative effects on demographic variables as fertility rate and life expectancy on Sub-Saharan Africa. It is also decreasing the working age population. We also find some negative effects on macroeconomic variables, namely capital intensity and investment rate. It is also damaging investment in education. However, we found in our estimation no significant evidence of a negative AIDS' effects on growth. The epidemics may have positive effect on growth in the short run by a capital deepening effect. But, in the long run, due to its negative effects on accumulable factors, AIDS is more likely to have strong negative effect on growth.

In our model we show that AIDS epidemic may induce a poverty trap for some countries. The occurrence of such poverty trap depends on the degree of which the epidemics had spread into the economy. A huge number of people contaminated in the country can settle the economy in a poverty trap. We show that, in such case, subsidizing education is not efficient to escape the economy from the poverty trap. Either, subsidizing health care expenditures is efficient only for some degree of expansion of the epidemics. One remain solution, we haven't check, is to deal with the price of drugs.

Appendix

Country	urb	wars	ptpr	gdp	inv	pop	fert	lifex	mort	pge	sge	AI
Angola	37	37	29	37	37	37	37	37	37	30	33	3
Burundi	37	37	37	37	37	37	37	37	37	37	37	3
Benin	37	37	37	37	37	37	37	37	37	37	36	3
Burkina Faso	37	37	37	37	37	37	37	37	37	37	37	3
Botswana	37	37	36	37	37	37	37	37	37	36	36	3
Central African Republic	37	37	22	37	37	37	37	37	37	37	33	3
Cote d'Ivoire	37	37	37	37	37	37	37	37	37	37	33	3
Cameroon	37	37	37	37	37	37	37	37	37	37	37	3
Congo,Rep.	37	37	37	37	37	37	37	37	37	37	35	3
Comoros	37	37	36	37	37	37	30	37	37	36	36	3
Cape Verde	37	37	37	37	37	37	37	37	37	37	37	3
Eritrea	37	37	16	17	17	37	37	37	37	17	15	3
Ethiopia	37	37	30	17	17	37	37	37	37	37	37	3
Gabon	37	37	35	37	37	37	37	37	37	15	22	3
Ghana	37	37	37	37	37	37	37	37	37	37	37	3
Guinea	37	37	37	37	37	37	37	37	37	37	37	3
Gambia,The	37	37	37	37	37	37	37	37	37	37	37	3
Guinea-Bissau	37	37	32	37	37	37	37	37	37	32	32	3
Equatorial Guinea	37	37	24	37	37	37	37	37	37	16	21	3
Kenya	37	37	36	37	37	37	37	37	37	37	37	3
Liberia	37	37	37	37	37	37	37	37	37	32	31	2
Lesotho	37	37	37	37	37	37	37	37	37	37	37	3
Madagascar	37	37	37	37	37	37	37	37	37	37	37	3
Mali	37	37	37	37	37	37	37	37	37	37	37	3
Mozambique	37	37	37	37	37	37	37	37	37	37	37	3
Mauritania	37	37	37	37	37	37	37	37	37	37	37	3
Mauritius	37	37	37	37	37	37	37	37	37	37	36	3
Malawi	37	37	26	37	37	37	37	37	37	37	37	3
Namibia	37	37	15	37	37	37	37	37	37	17	21	3
Niger	37	37	37	37	37	37	37	37	37	37	37	3
Nigeria	37	37	36	37	37	37	37	37	37	36	36	3
Rwanda	37	37	37	37	37	37	37	37	37	37	36	3
Sudan	37	37	37	37	37	37	37	37	37	37	37	3
Senegal	37	37	37	37	37	37	37	37	37	37	37	3
SierraLeone	37	37	37	37	37	37	37	37	37	37	37	3
Somalia	37	37	16	37	37	37	37	37	37	27	27	3
Sao Tome and Principe	37	37	37	37	37	37	37	37	37	8	5	3
Swaziland	37	37	36	37	37	37	37	37	37	36	36	3
Seychelles	37	37	37	37	37	0	31	25	0	9	9	3
Chad	37	37	36	37	37	37	37	37	37	36	36	3
Togo	37	37	37	37	37	37	37	37	37	37	36	3
Tanzania	37	37	37	37	37	37	37	37	37	37	30	3
Uganda	37	37	37	37	37	37	37	37	37	37	36	3
South Africa	37	37	25	37	37	37	37	37	37	35	19	3
Congo, Dem.Rep.	37	37	34	37	37	37	37	37	37	34	34	3
Zambia	37	37	37	37	37	37	37	37	37	37	36	3
Zimbabwe	37	37	32	37	37	37	37	37	37	37	37	3

Références

[1] Bibliography