The Relationship between HIV Infection Rates and GDP Per Capita in African Countries

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Abstract:

This paper examines the relationship between GDP per capita and HIV prevalence in African countries. Our hypothesis is that as HIV infections increase within a nation, its GDP per capita will decrease due to the disease's harm to human capital. First, we created a simple regression model using data of 2005 GDP per capita along with number of adults and children living with HIV as the independent variable. After resulting in a negative but weak correlation, we further alter this model by adding multiple independent variables including HIV/AIDS deaths, arable land per capita, labor force, Foreign Direct Investment (FDI) percentage, life expectancy, exports, imports, and people living with HIV. By using multiple regression, our results indicate that both the number of people living with HIV and HIV related deaths in a country negatively affects its economy.

1. Introduction

As one of several life-threatening diseases, HIV/AIDS has uniquely created detrimental harm on development through its spread in Africa and other parts of the world. Human Immunodeficiency Virus (HIV) impairs the function of the immune system and progresses to Acquired Immunodeficiency Syndrome (AIDS). The first case of AIDS was diagnosed in 1981. According to the World Health Organization, 78 million people have been infected with HIV and about 39 million people have died of the virus since its discovery. While the infection rates of HIV/AIDS vary considerably between countries and regions, Sub-Saharan Africa carries the greatest burden of the disease with about 5% of its adults currently living with an HIV diagnosis. In addition, this region accounts for about 70% of the worldwide population living with HIV (2004 Report).

The inversely proportional relation between HIV infection rate and economic wealth of countries is a long-held belief. The World Bank's 1997 report claims that both widespread poverty and unequal income distribution stimulates HIV prevalence (Ainsworth et al., 1997). Similarly, the United Nations Joint Programme on HIV/AIDS (UNAIDS) states "poverty, underdevelopment, and the lack of choices and the inability to determine one's own destiny fuel the [HIV] epidemic" (Global Strategy, 2001).

However, relating only the GDP growth or economic wealth of countries with HIV infection rate may contain bias. According to recent research by Justin Parkhurst, Senior Lecturer in Global Health Policy, "the relationship between wealth and HIV infection is not direct, nor does it always act in the same direction in every setting." Trying to correlate relative wealth directly with prevalence of HIV does not accurately reflect the dynamics that characterize the way in which underlying social drivers and structural factors manifest themselves as risk of HIV infection, or how these factors change with time. (Parkhurst et al., 2010).

In this paper, we will expound on two different regression models in order to discover more on the relationship between the HIV/AIDS epidemic and economic prosperity. In our first model we will find a correlation between GDP per capita and HIV prevalence in African countries which support reports of the World Bank and UNAIDS. In addition to our simple analysis, with a multiple regression model we intend to discover more on Parkhurst's findings in his recent analysis, that the relationship between wealth and HIV prevalence is not correlated directly by adding multiple independent variables.

2. Literature Review

2.1 HIV/AIDS and Economic Growth: A Global Perspective

Contained in this article from 2000, Bonnel explains that the HIV/AIDS epidemic slows a nation's development because it harms physical, human, and social capital. In nations where the disease is prevalent, both local and national institutions are being overtaken as impeding its spread must be prioritized above provision of basic social and legal needs. Bonnel's hypothesis is that presence of HIV/AIDS in a nation decreases its per capita income growth rate due to a lessened expansion in labor and capital as well as decline in institutions and policy enforcements necessary to continue to spur a country's production and economic growth. The model constructed within this paper calculates a Sub-Saharan African nation with 20% HIV prevalence to experience a 2.6% decline in GDP growth per year.

2.2 AIDS and Economic Growth in Africa: A Panel Data Analysis

This 2001 publication uses data from 41 African countries collected from 1960 through 1988 to model a relation between HIV prevalence and GDP growth. Dixon, McDonald, and Roberts work to do this by creating a production function to calculate output, and in turn the growth in calculated output throughout the years. They find that the nations with low levels of HIV prevalence have normal levels of GDP growth throughout the time period. However, those with relatively high HIV prevalence yield inconclusive results on GDP growth.

2.3 The Impact of HIV/AIDS on Economic Growth in Sub-Saharan Africa

In this 2009 study by Lovasz and Schipp, they confirm a hypothesis that the HIV/AIDS epidemic of sub-Saharan Africa has produced a negative effect on growth rates of GDP per capita. This model was constructed with panel data of 41 African nations spanning from 1997 through 2005. Through use of an augmented Solow model including physical, educational, and health capital stocks, a production function is created to capture the effect of HIV/AIDS prevalence on human capital and therein the nation's output. In their results, countries with 5% HIV prevalence saw a 2% decrease in growth rate of GDP per capita. As the percentage of HIV infection increases to 30%, the growth rate of GDP per capita decreases even further to about 4%. Even as some studies argue that as HIV/AIDS decreases population and therefore leads to increased income per capita, this model demonstrates that the negative effect of HIV infection on human capital stock has potential to overtake the effect of population decrease.

2.4 Welfare Implications of HIV/AIDS

In this working paper of the IMF, rather than measuring the epidemic's effects on economic indicators such as GDP, the authors attempt to represent its possible changes on quality of life and living standard in HIV prevalent countries. Craft and Haacker do this by generating a utility function in which they include income and life expectancy. While their methodology creates much uncertainty from some and is subject to much limitation, their findings show some African nations with 80% in welfare losses due to HIV's eventual result of increased mortality.

2.5 The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations

Written by Alwyn Young in 2004, this study is a common reference in the topic of HIV/AIDS and its economic effects. By focusing on only South Africa, Young explains that even while the epidemic of this disease harms human capital development, the welfare of future South Africans is improved due to lower fertility rates. Without the epidemic, the population would have grown immensely more than it has as it caused increased mortality rates for both HIV infected infants and adults. Because of this, income per capita is projected to increase for future generations. While the HIV/AIDS epidemic is certainly cause for concern and a major social issue, it does not constitute as an economic downturn for Africa.

In comparison with the research summarized above, our analysis in unique in that while we also attempt to capture the effects of HIV/AIDS on human capital development, we also control for many other determinants of economic output. Through adding additional independent variables such as presence of arable land, foreign direct investment, imports, exports, and others, we hope to account for majority of the variability in economic output between African nations. Doing so will allow us to more adequately capture the sole effect of HIV prevalence on GDP per capita with fairly recent data.

3. Data

In order to evaluate the impact of HIV prevalence on African GDP, we utilized data sets containing financial information and HIV rates found in African countries. The year 2005 was selected to avoid major market events and shocks occurring in the early and later parts of the decade, in an attempt to minimize potential sources of error and maximize the potential visibility of a country's HIV prevalence rate specifically on GDP per capita. The data sets we utilized were

provided by the *World Bank Group* and the *World Health Organization*. Table 1 lists the 44 countries we used for this study as not all African nations reported data needed for our analysis.

3.1 Explanation of Variables:

- **Arable Land in hectares per capita (D)** - The amount of arable land per capita in hectares. This is a good measure of the distribution of natural resources among the African countries. (Source: World Bank)
- **Labor Force (L)** - The total number of unemployed seeking work as well as employed persons in a given country. The labor force is directly correlated with the population of a country therefore diluting the per capita rate of the GDP of a country. Combining this further with the positive correlation between birth rate and poverty rate, we should see a negative overall correlation between this variable and the GDP per capita rate of a country. (Source: World Bank)
- **Gross Domestic Savings as a % of GDP (S)** - This variable shows the savings rate of a country. It is a calculated value of GDP less consumption expenditure. This is a standard variable found in the equation for calculating GDP making it an important independent variable to include for the model. (Source: World Bank)
- **Foreign Direct Investment (I)** - This variable shows the foreign investment levels towards a country's economy. High levels of investment look towards an optimistic future and faster growth of GDP. This is a standard variable found in the equation for calculating GDP making it an important independent variable to include for the model. (Source: World Bank)
- **Life Expectancy (LE)** - This variable represents the average lifespan of an individual from birth to death. Human capital is an important factor in determining the GDP of a country, and life expectancy can be used to represent the health capital portion of human capital. (Source: World Bank)
- **Exports as a Percentage of GDP (E)** - This variable shows how much of the economy is based on exports. Strong economic growth is representative of a high percentage of exports. It is expected that high HIV prevalence will lead to lowered levels of exports. (Source: World Bank)
- **Imports as a Percentage of GDP (IM)** - This variable shows much an economy relies on imports. A weaker economy is associated with higher levels of imports. High HIV prevalence in a country is expected to cause an increase on reliance of imports, as internal

production levels fall while also causing increased demand for imported medical goods. (Source: World Bank)

- **Number of Adults and Children Living with HIV (K)** - This is the number of adults and children with HIV. We expect this variable to negatively influence a country's exports and life expectancy. We also expect this variable to increase imports. (Source: World Health Organization)
- **Number of HIV Related Fatalities (X)** - The number of HIV related deaths in a given year. We expect this variable to negatively influence a country's life expectancy rates. (Source: World Health Organization)
- **Gross Domestic Product Per Capita (Y)** - The Gross Domestic Product of a country divided by the country's population. (Source: World Bank)

Simple Regression Model:

For the simple regression model we took the natural log of the HIV prevalence in all adults and children within a country, and regressed it against the natural log of the GDP per capita of the country.

$$\log(Y) = \beta_0 + \beta_1(\log(K))$$

Where $\beta 1$ is the natural log of the 2005 HIV prevalence in all adults and children in correlation with the natural log of the 2005 GDP per capita.

Multiple Regression Model:

We build the multiple regression model:

$$Y = \beta_0 + \beta_1(D) + \beta_2(L) + \beta_3 I + \beta_4(LE) + \beta_5(E) + \beta_6(IM) + \beta_7(K) + \beta_8(X) + \beta_9(S)$$

Because we want to determine the relative effects of each of these variables on the gross domestic product per capita and achieve homoskedasticity for our regression we form the log-log model:

$$\log(Y) = \beta_0 + \beta_1\log(D) + \beta_2\log(L) + \beta_3\log(I) + \beta_4\log(LE) + \beta_5\log(E) + \beta_6\log(IM) + \beta_7\log(K) + \beta_8\log(X) + \beta_9\log(S)$$

Where *Y* represents the 2005 GDP per capita of an African country, *β1* represents the correlation between the log of the hectares of arable land per capita and GDP per capita. *β2* represents the correlation between log of the total labor force and GDP per capita, *β3* represents the correlation between foreign direct investments and GDP per capita, *β4* represents the correlation between the log of the life expectancy of a person and GDP per capita, *β5* represents the correlation between the log of exports as a percentage of GDP and GDP per capita, *β6* represents the correlation between the log of imports as a percentage of GDP and GDP per capita, *β7* represents the correlation between the number of adults and children living with HIV and GDP per capita, *β8* represents the correlation between the number of HIV related deaths and GDP per capita, and *β9* represents the correlation between the gross domestic savings rate and GDP per capita.

Table 1. List of Countries

Algeria	**Burundi**	**Congo, Rep.**	**Ethiopia**	**Kenya**	**Mali**	**Niger**	**Sierra Leone**	**Tunisia**
Angola	**Cameroon**	**Cote d'Ivoire**	**Gabon**	**Lesotho**	**Mauritius**	**Nigeria**	**South Africa**	**Uganda**
Benin	**Cape Verde**	**Djibouti**	**The Gambia**	**Liberia**	**Morocco**	**Rwanda**	**Sudan**	**Zambia**
Botswana	**Central African Republic**	**Egypt, Arab Rep.**	**Ghana**	**Madagascar**	**Mozambique**	**Sao Tome and Principe**	**Swaziland**	**Zimbabwe**
Burkina Faso	**Chad**	**Eritrea**	**Guinea**	**Malawi**	**Namibia**	**Senegal**	**Togo**	

3.2 Descriptive Statistics

We compiled data over 44 African countries from the year 2005 to accurately represent our hypothesis. Table 2 contains summary statistics for each of the 10 variables surveyed for this study.

Table 2. Descriptive Statistics of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Arableland	44	.2520704	.1795373	.0012371	1.08882
Laborforce	44	6,749,566	8,765,044	51,622.48	43,700,000
Foreigndir	44	3.27836	3.823385	-4.618017	15.27714
Lifeexpect	44	54.92835	8.518145	43.86159	73.50244
Exportsofg	44	34.82985	20.14534	6.166469	87.06688
Importsofg	44	43.55649	19.36077	20.77384	120.8668
GDPPerC	44	1319.308	1597	154.07	6321.991
Grossdomesav	44	11.01447	22.09817	-50.02009	58.34813
EstimatedHIV	44	478088.6	977233.9	1000	5600000
NumberofdeathsHIV	44	37834.09	71311.78	100	380000

3.3 Gauss Markov Assumptions

The following are the Gauss Markov Assumptions that we have satisfied for our linear regression models.

- **Assumption 1 (Linear in Parameters)**

  The model must be linear in parameters and written as such $Y = \beta_0 + \beta_1 X_1 + \ldots + \beta_k X_k$.
- **Assumption 2 (Random Sampling)**

  A random sample of 44 observations was used for our regressions.
- **Assumption 3 (No Perfect Collinearity)**

  In the sample, none of the independent variables are constant, and there are no exact linear relationships among our independent variables in question.
- **Assumption 4 (Zero Conditional Mean)**

  The error *u* has an expected value of zero given any values of the independent variables.
- **Assumption 5 (Homoskedasticity)**

The error *u* has the same variance given any value of the explanatory variables.

4. Results

Table 3. Regression Model Results

Variable	Model 1	Model 2	Model 3
Arableland		0.013 (0.104)	0.028 (0.084)
Laborforce		-0.401*** (0.104)	-0.345*** (0.085)
Lifeexpect		4.549*** (1.120)	3.991*** (0.964)
Exportsofg		2.666*** (0.743)	2.606*** (0.603)
Importsofg		-02.591 (1.620)	-1.774 (1.327)
Grossdomesav		0.002 (0.003)	0.002 (0.002)
EstimatedHIV	-.120 (.078)	1.033** (0.491)	0.814* (0.407)
NumberofdeathsHIV		-0.820* (0.465)	-0.696* (0.381)
Foreigndir		-0.018 (0.011)	-0.022** (0.009)
Constant	3.476*** (.395)	-4.236* (2.136)	-3.161* (1.861)
N	44	44	42

R-Squared	0.0543	0.7371	0.8186

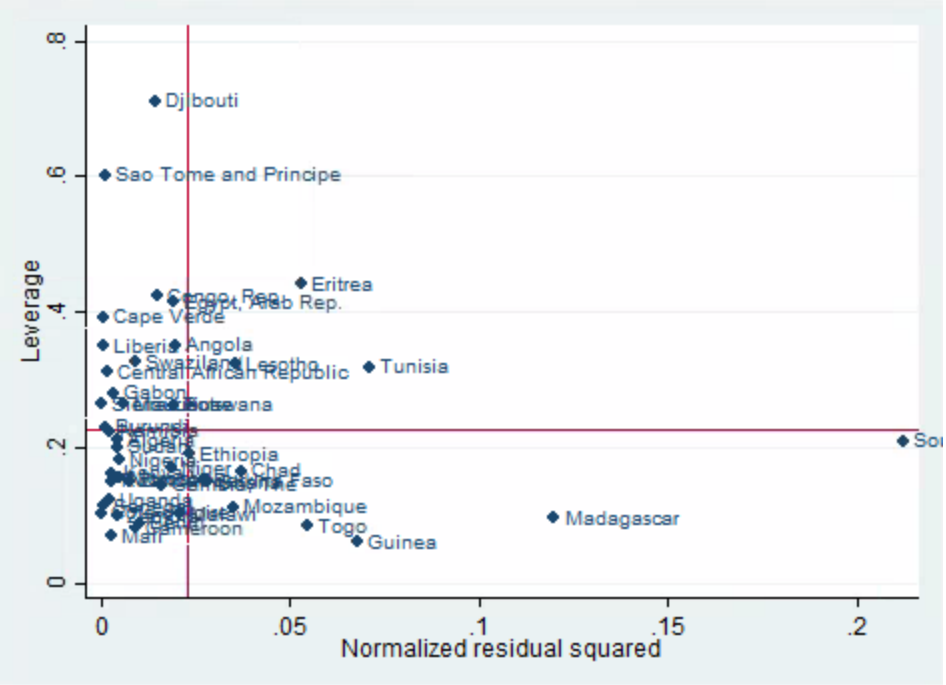
For the simple regression model, model 1, we have significance at 1% only for the constant. The value for the coefficient of HIV prevalence is -0.120. This means that a 1% increase in HIV prevalence will result in a 0.12% decrease in per capita GDP.

From the multiple regression model, model 2, we see significance at 1% for labor force, life expectancy, and exports. We see significance at 5% for HIV prevalence, and significance at 10% for HIV related deaths. We observe a constant of -4.501 and an R-squared of 0.7536. Going from the simple regression model to the multiple regression model we see the coefficient for HIV prevalence swap from negative to positive.

In order to test for outliers, we ran a robust regression analysis and plotted the leverage versus the normalized residual squared shown in figure 1. Looking specifically at the normalized residual squared, we are left with two distinct outliers: Madagascar and South Africa. We then ran a regression analysis omitting these two observations as model 3. This model left us with significance at 1% for labor force, life expectancy, and exports, significance at 5% for foreign direct investment, and significance at 10% for HIV prevalence and number of HIV related deaths.

Using model 3, we can see that HIV prevalence and HIV death rates significantly affect the GDP per capita of African countries. A 1% increase in HIV prevalence is associated with a 0.84% increase in GDP per capita. A 1% increase in the number of HIV related deaths is associated with a 0.696% decrease in GDP per capita. This looks to point towards HIV being a net positive for the economy, but we can infer that this is not the case for many reasons. First, our simple regression model shows a negative coefficient in relation to the HIV prevalence variable. Second, we believe to have gotten this result due to the behavior of more developed economies with higher rates of social interaction leading to greater infection rates throughout the country. These effects further exasperate themselves in the sense that countries with better health care are able to allow HIV infected individuals a longer lifespan, further inflating the prevalence rates within the country, while countries with worse health care end up with unproportionally high death rates.

Figure 1. Leverage vs Squared Residuals



Note: The data point title partially cut off to the far right is South Africa.

Conclusion:

Africa is currently facing an HIV epidemic wherein more than nearly 20% of some nations people are infected. It is imperative that research be done to understand and mitigate the negative effects of this disease. In the future we may find ourselves facing similar situations within our own borders, and so we need to learn as much about every aspect of the current situation in Africa.

Although it is obvious to many in the fact that HIV has massive negative economic consequences associated with it, it is affecting the least developed continent of the world the hardest, Africa. Difficulties come in determining the direct economic consequences in this region due to an overall lack of data reporting and weak, unstable economies. Furthermore, political turmoil and internally fractured states, and arbitrarily drawn state borders can limit available data even further, along with causing problems in determining which state to attribute specific data.

Even with the limitations we faced, using our log-log models we are able to conclude that HIV prevalence and HIV related deaths are significantly related to the economies of African

nations. There is considerable evidence pointing towards a relationship between HIV related deaths and a decline in a country's GDP per capita.

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Appendix (Stata Output)

Model 1

```
. regress GDPPerCapitaUS2005 EstimatedHIVNumbersfromWHOf
```

Source	SS	df	MS		
Model	.475643435	1	.475643435	Number of obs	= 44
Residual	8.28929293	42	.197364117	F(1, 42)	= 2.41
				Prob > F	= 0.1281
Total	8.76493637	43	.20383573	R-squared	= 0.0543
				Adj R-squared	= 0.0317
				Root MSE	= .44426

GDPPerCapitaUS2005	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
EstimatedHIVNumbersfromWHOf	-.1203387	.0775173	-1.55	0.128	-.2767749	.0360976
_cons	3.476418	.3945287	8.81	0.000	2.680227	4.272609

Model 2

Source	SS	df	MS		
Model	6.46041901	9	.717824334	Number of obs	= 44
Residual	2.30451736	34	.067779922	F(9, 34)	= 10.59
				Prob > F	= 0.0000
Total	8.76493637	43	.20383573	R-squared	= 0.7371
				Adj R-squared	= 0.6675
				Root MSE	= .26035

GDPPerCapitaUS2005	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Arablelandhectaresperperson	.0131036	.1036766	0.13	0.900	-.1975926	.2237997
Laborforcetotal	-.401021	.1037488	-3.87	0.000	-.611864	-.190178
Foreigndirectinvestmentneti	-.0180224	.0115099	-1.57	0.127	-.0414134	.0053686
Lifeexpectancyatbirthtotal	4.549495	1.119867	4.06	0.000	2.273651	6.825339
GrossdomesticsavingsofGDP	.0019846	.0028378	0.70	0.489	-.0037824	.0077517
EstimatedHIVNumbersfromWHOf	1.033412	.4912229	2.10	0.043	.0351267	2.031697
NumberofdeathsduetoHIVAIDS	-.8196959	.4652285	-1.76	0.087	-1.765154	.1257621
logexports	2.665705	.7427329	3.59	0.001	1.15629	4.17512
logimports	-2.591161	1.620393	-1.60	0.119	-5.884196	.7018748
_cons	-4.235818	2.136035	-1.98	0.055	-8.576762	.1051267

Model 3

Source	SS	df	MS		
Model	6.43926475	9	.715473861	Number of obs	= 42
Residual	1.42669301	32	.044584157	F(9, 32)	= 16.05
				Prob > F	= 0.0000
Total	7.86595776	41	.191852628	R-squared	= 0.8186
				Adj R-squared	= 0.7676
				Root MSE	= .21115

GDPPerCapitaUS2005	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Arablelandhectaresperperson	.0278725	.084219	0.33	0.743	-.1436761	.199421
Laborforcetotal	-.345332	.0851719	-4.05	0.000	-.5188215	-.1718426
Foreigndirectinvestmentneti	-.021912	.0093784	-2.34	0.026	-.0410151	-.0028089
Lifeexpectancyatbirthtotal	3.991286	.963922	4.14	0.000	2.027842	5.954731
GrossdomesticsavingsofGDP	.0024237	.002314	1.05	0.303	-.0022897	.0071371
EstimatedHIVNumbersfromWHOf	.8141347	.4069931	2.00	0.054	-.0148831	1.643152
NumberofdeathsduetoHIVAIDS	-.6956308	.3809136	-1.83	0.077	-1.471526	.0802648
logexports	2.606418	.6027255	4.32	0.000	1.378707	3.83413
logimports	-1.774342	1.327349	-1.34	0.191	-4.478063	.9293786
_cons	-3.160666	1.861275	-1.70	0.099	-6.951959	.6306279