The relationship between economics, public health, and education and HIV transmission

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Keywords: AIDS/HIV, Education, Health Expenditure, GDP, Regression Model.

Abstract: Acquired immune deficiency syndrome (AIDS) is a very dangerous infectious disease caused by infection with human immunodeficiency virus (HIV), a virus that attacks the body's immune system and causes the body to lose its immune function. As a result, people with AIDS are susceptible to a variety of diseases, and patients often die from other infections with other diseases. AIDS is of great concern worldwide as an infectious disease with no effective cure. There are many researchers around the world who are studying how to prevent and treat AIDS. Currently, pre-infection prophylaxis has been used to reduce the rate of HIV infection. Antiretroviral therapy (ART) is one of the most effective treatments to extend the life expectancy and quality of life of people with HIV, and ART is also effective in reducing the risk of HIV transmission. However, because of the high cost of ART drugs, many families and individuals cannot afford to pay for them, so national medical subsidies are important for people with HIV. It is well known that national gross domestic product (GDP) per capita, government health spending, and other factors have a significant impact on whether or not a country can adequately subsidize medical care for people/families living with HIV. Not only in terms of money, but education also has a significant impact on AIDS. Education educates people about HIV prevention and strengthens the ability of people to cope with HIV infection. At the same time, national GDP per capita also influences government spending on education and government spending on public health, and these three are closely related. Therefore, in this paper, we compare national GDP per capita, health expenditure per capita, and government expenditure on education with the estimated number of HIV infections in each country, integrate the data, and build regression models to investigate how these factors affect the transmission of HIV. These results are useful in helping countries to control the spread of HIV through the rational allocation of resources, and perhaps we can look forward to eradicating AIDS by means of prevention and making AIDS a thing of the past.

1. Introduction

With the gradual improvement of living standards, people's demand for health is getting higher and higher. Acquired immune deficiency syndrome (AIDS) is widely concerned as an infectious disease with no effective cure. AIDS is a very dangerous infectious disease caused by infection with the human immunodeficiency virus (HIV), a virus that attacks the body's immune system and causes the body to lose its immune function. There are many researchers around the world who are studying how to prevent and treat AIDS (Brik & Wong, 2003). Currently, people are trying to reduce the rate of HIV infection mainly through pre-infection prevention (Kelly, 2000). Antiretroviral therapy (ART) is currently the most effective treatment for extending the life span and quality of life of people with HIV and can also be effective in reducing the risk of HIV transmission. However, due to the high cost of ART drugs, the high cost of medication is a burden for many families of AIDS patients, and even the unaffordable cost of medication leads to death (Greener, 2002). Most economically developed countries provide subsidies to AIDS patients, which effectively prolongs the life span of the patient and reduces the rate of transmission of HIV. Therefore, whether or not the state subsidizes medical expenses for AIDS patients, the amount of government health spending, the availability of various medical benefits, and the effective promotion of methods to prevent the spread of HIV have an important impact on controlling the spread of HIV.

In terms of money, factors such as national gross domestic product (GDP) per capita and government health expenditure have a big impact on whether the country can provide adequate medical subsidies to AIDS patients/families. Not only medical subsidies, but increased government public health expenditure can provide better treatment and care services for people living with HIV, more widespread dissemination of HIV prevention information, and expanded health care spending, all of which contribute to reduce HIV infection rates (Osemwengie & Shaibu, 2020).

Beyond money, education has an important impact on HIV prevention. In the long run, education plays a key role in creating conditions that reduce the likelihood of HIV transmission. Education can help people learn to better protect themselves, reduce the incidence of risky behaviors and increase the likelihood of using protection such as condoms, as well as strengthen the ability of individuals or families to cope with HIV infection and reduce discrimination and stigma. Strengthening education can also reduce the pathways that promote the transmission of HIV through conditions such as poverty reduction, individual empowerment, and the promotion of gender equality (Kelly, 2000).

In general, national revenue, public health spending, and education have an important impact on HIV prevention, and they are inextricably linked to each other. An increase in national revenue will increase national spending on public health and education, and an increase in education spending will bring more talented people to the country, expand the national talent market, and have a positive impact on national finance (Wolfe & Haveman, 2002). Therefore, studying how national revenues, public health expenditures, and education affect the transmission of HIV in a country not only promotes government control of HIV transmission but also plays an important role in how a country should allocate its revenues appropriately, which has an important impact on the development of a country.

This paper selects national GDP per capita, health expenditure per capita, and government expenditure on education to reflect the national revenue, public health expenditure, and education expenditure, respectively. By comparing these factors with the estimated number of people with HIV in each country, the data were integrated, and regression models were built to examine how these factors affect the transmission of HIV.

2. Method

We will build regression models from the data and determine if the regression models built are statistically significant by analyzing these models through p-value. Regression modeling is a predictive modeling technique that studies the relationship between the dependent variable (target) and the independent variable (influencing factor) and is an important tool for modeling and analyzing data, which is why we chose this model (Ter Braak & Looman, 1995).

Regarding the data, we let the national GDP per capita, health expenditure per capita, and government expenditure on education in 2018 reflect the national revenue, public health expenditure, and education expenditure, respectively, and organized these data by removing some outliers. The relationship between government expenditure on education and the estimated number of people with HIV was not obvious, so I divided the estimated number of people with HIV by the total population of each country to obtain the proportion of people living with HIV, and using the proportion of people living with HIV and the government expenditure on education data for the next modeling step.

In the model-building phase, we build a regression model on our processed data by using the function, lm (), in RStudio (RStudio Team, 2021). At first, we were using a linear regression model, but we found that the linear regression model did not match my data very well. We found by observation that the scatter plot of the data seemed similar to the logarithmic function and used the following regression model:

$$Y = \beta \log(x) + \epsilon \tag{1}$$

where ϵ denotes the y-intercept, β denotes the slope, Y denotes the dependent variable, and x denotes the independent variable. In this model, as the independent variable increases, if the slope is positive, then the dependent variable also increases, indicating that the independent and dependent variables are positively correlated; if the slope is negative, then the dependent variable also becomes smaller, and the independent and dependent variables are negatively correlated.

In validation studies, the null hypothesis is formulated. p-value is a probability that expresses the probability of obtaining a result that is at least as extreme as the observed result of the alternative hypothesis test, assuming the null hypothesis is correct (Ciubotaru, 2021). This probability reflects the measure of evidence against the null hypothesis. When a p-value less than 0.05 indicates that this hypothesis is statistically significant, we should reject the null hypothesis and accept the alternative hypothesis. Therefore, when the P-value is less than 0.05, it means that the regression model is statistically significant.

After building the regression model, we used the p-value to verify that the model was statistically significant. In the validation study, the null hypothesis was formulated. The p-value is a probability that expresses the probability of obtaining a result that is at least as extreme as the observed result of the alternative hypothesis test, assuming that the null hypothesis is correct (Dahiru, 2008). This probability reflects the measure of evidence against the null hypothesis. When a p-value less than 0.05 indicates that this hypothesis is statistically significant, we should reject the null hypothesis and accept the alternative hypothesis. Therefore, when the p-value is less than 0.05, it means that the regression model is statistically significant.

3. Results

Based on the above rationale, various data were processed by RStudio software, and the following conclusions were obtained.

By creating a regression model between the estimated number of people living with HIV in each country and the GDP per capita, the slope of the regression equation was found to be negative. This means that as the GDP per capita increases, the population of people living with HIV decreases. The regression model is as follows:

$$Y = -3208.9 \log(x) + 50947.7 \tag{2}$$

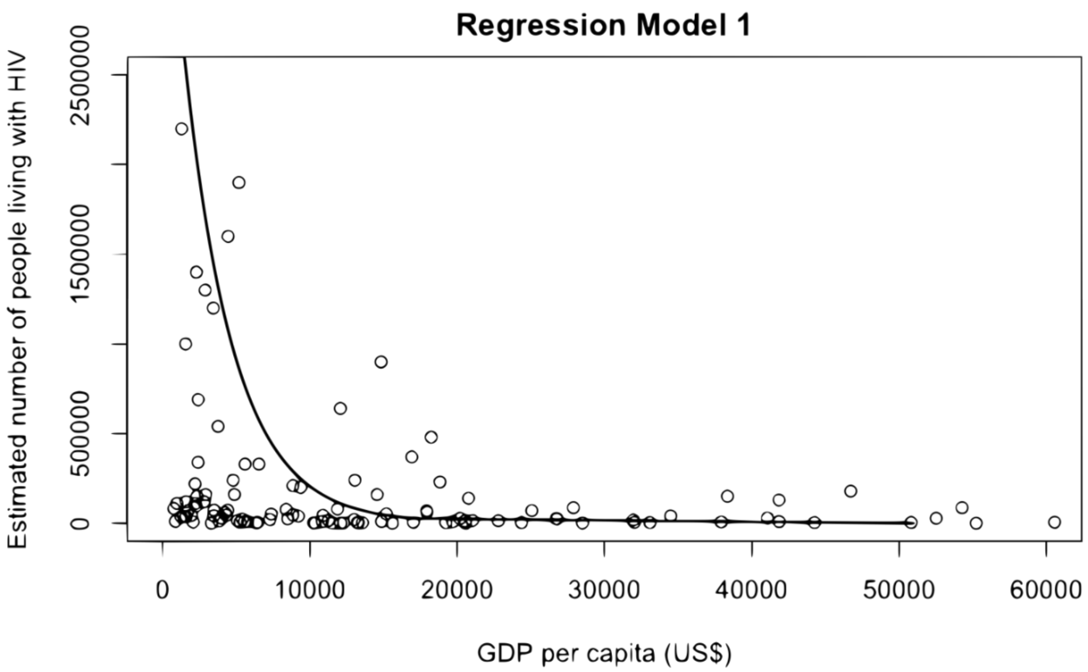

Fig. 1 The regression model between the estimated number of people living with HIV in each country and the GDP per capita in US dollars. The blank circles therein indicate the processed data, and the smoothed curves represent the predicted curve obtained after visualization of Equation 2.

We can easily see from Figure 1 that the number of countries with the estimated number of people living with HIV greater than 500,000 decreases sharply with increasing GDP per capita in the range of GDP per capita less than $20,000. This suggests that growth in GDP per capita has a positive impact on controlling HIV transmission, which is also consistent with the prediction of the regression model we developed.

Also, we can see in Figure 1 that the GDP per capita is less than $10,000 and the predicted number of people living with HIV is less than 500,000 are distributed with many data that do not match the regression curve perfectly, these data indicate countries that do not have high GDP per capita and the predicted number of people living with HIV is not very high either. We believe that the reason these countries do not fit the model is that they have a small number of people living with HIV to have a small impact on the model when it is built, so the model is then influenced by data from countries with a lot of people living with HIV but not high GDP per capita leading to this phenomenon. Although these data have some impact on the model's fit, we can still see that most countries with estimated HIV populations greater than 500,000 have a GDP per capita of less than $20,000, which suggests that the result that we get a positive impact of GDP per capita growth on the prevention of HIV transmission is still relevant.

By then creating a regression model between the estimated number of people living with HIV and health expenditure per capita (US$) for each country, we find that the slope of the model is negative, implying that as GDP per capita increases, the population of people living with HIV decreases. The regression model is as follows:

$$Y = -212.5\log(x) + 3153.7 \tag{3}$$

Fig. 2 The regression model between the estimated number of people living with HIV in each country and the health expenditure per capita in US dollars. The blank circles therein indicate the processed data, and the smoothed curves represent the predicted curve obtained after visualization of Equation 3.

As shown in Figure 2, the estimated number of people living with HIV greater than 500,000 has decreased sharply as government spending on health has increased in the range of health expenditure per capita less than $1,000. This suggests that as health spending grows, governments can have a positive impact on preventing the spread of HIV by increasing medical subsidies for people with HIV, expanding awareness of AIDS prevention, and providing better treatment and care services for people with HIV.

We also found that, like model 1, model 2 had some data that did not match the model perfectly in areas where the health expenditure per capita was less than $1,000 and the estimated number of people living with HIV was less than 500,000. Again, we believe that these non-perfect matches have less impact on the model because they are too small, leading the model to prefer to match larger values. As in Model 1, although there are some data that do not fit our model perfectly, we can see that most of the countries with the estimated number of people living with HIV greater than 500,000 in the range of the health expenditure per capita less than $1,000, suggesting that our conclusion that increased government spending on health has a positive effect on preventing the spread of HIV still holds true.

Finally, we modeled the regression between the proportion of people living with HIV and government expenditure on education in each country and found that the slope of the regression equation was negative, implying that as the government expenditure on education increases, the population of people living with HIV decreases. The regression model is as follows:

$$Y = -0.003654 \log(x) + 0.010309 \tag{4}$$

Fig. 3 The regression model between the proportion of people living with HIV in each country and the proportion of government expenditure on education in GDP. The blank circles therein indicate the processed data, and the smoothed curves represent the predicted curve obtained after visualization of Equation 4.

As shown in Figure 3, as government spending on education increases, we can see that the more money the government spends on education as a percentage of GDP, the percentage of the country's population with HIV decreases significantly, which is in line with the model's prediction. This indicates that as government spending on education increases, the government can better help people learn to better protect themselves through education and reduce the occurrence of risky behaviors, thus reducing the number of HIV infections.

We can see that most of the data in this model fit the model, but the data for government expenditure on education greater than 0.015% do not fit our model very well. We believe that this is because there are too little data for government expenditure on education greater than 0.015%, and we also have a relatively low proportion of people living with HIV in each country, which causes these data to have less impact on the model than those with a high proportion of people living with HIV. However, we can still see that in the range of the proportion of government expenditure on education in GDP greater than 0.015%, the proportion of people living with HIV in most countries is less than 4%, which suggests that our result that the increase in government expenditure on education has a positive effect on reducing the number of HIV infections is meaningful.

4. Summary/Discussion

This paper examines the relationship between the GDP per capita, health expenditure per capita, and government expenditure on education and the number of people living with HIV in each country. Overall, all three variables were negatively associated with the number of people living with HIV in each country. This suggests that when a country's GDP per capita, health expenditure per capita, and government expenditure on education increase, it has a positive impact on reducing the number of people living with HIV. By increasing GDP per capita through economic development, the government can increase public health expenditure and education expenditure, promote HIV prevention, provide better treatment and health care services for people with HIV, promote HIV prevention knowledge more widely, expand health care expenditure, and reduce the spread of HIV. The promotion of education not only reduces the spread of HIV by strengthening the ability of individuals or families to cope with HIV infection, helping people learn to better protect themselves, reducing discrimination and stigma, reducing poverty, empowering individuals, and promoting gender equality, but also promotes domestic economic development by increasing the pool of teachers, training talent, and returning talent, creating a virtuous cycle. (Greener, 2002)

During our data analysis, we found that our model did not fit all the data perfectly. We suspect that these data represent countries that have small populations and therefore have low GDP per capita and low numbers of people living with HIV. Because they have small populations of people living with HIV, these countries are influenced by countries with large populations of people living with HIV and low GDP per capita, which does not fit our model perfectly. This can be seen in Models 1 and 2. In Model 3, we model the regression between the proportion of people living with HIV and the proportion of government expenditure on education in GDP of each country, and unlike Models 1 and 2, in Model 3, we use the number of people living with HIV as a proportion of the total national population, which helps us to eliminate some of the model's influence of over-or undersized data. But even though some of the data do not exactly match our models, our conclusions are still relevant because we can easily see the trends in HIV transmission.

In future work, we can upgrade our model and try to improve the model to match the data. We can consider using more complex models or increasing the number of restrictive factors, such as WHO regional divisions, differentiating the age of people living with HIV, or national population size classes, to be added to our model as some constraints to avoid the influence of extreme values on the model. We can also consider changing the estimated people living with HIV variable in Model 1 and Model 2 to the proportion of people living with HIV, because the difference in population size of each country may have a greater impact on the estimated number of people living with HIV, and such a change can eliminate the impact of extreme values on the estimated number of HIV-infected people due to the difference in population size of each country.

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Overall, this paper found that three factors, national revenues, public health expenditures, and education expenditures, affect the number of HIV infections in each country. Therefore, when a country wants to control the AIDS population in the country, it can start from the economy, public health, and education. By studying the impact of each factor on the spread of HIV, the government can allocate resources more rationally and maximize the use of all resources to control the spread of HIV. More work needs to be done in the future to determine a precise model to determine the impact of each factor on HIV transmission, but this gives us hope that controlling HIV transmission may lead to the complete elimination of AIDS and make AIDS history.

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