The recent evolution of the HIV rates in Sub-Saharan Africa: Do differences still persist?

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Abstract

Background This paper studies the evolution of the human immunodeficiency virus (HIV) prevalence and incidence rates in Sub-Saharan African countries, paying special attention to the possible presence of a unique pattern of behavior of these variables across the mentioned countries during the 1990-2016 period. Methods We employ time series methods designed to analyze the hypothesis of convergence. We apply these tests to prevalence and incidence rates of the Sub-Saharan African countries for the 1990-2016 period. Results We cannot reject the null hypothesis of convergence for male prevalence rates and total incidence rates. By contrast, we can observe divergence in female prevalence rates. Conclusion The evolution of the male prevalence rates and incidence rates is quite similar for the Sub-Saharan countries. But, we can still find different patterns of behavior for female prevalence rates. Therefore, the recent HIV-oriented policies have not been able to control its transmission yet. We can also appreciate that some socioeconomic variables play a crucial role to explain the different behaviors of female prevalence rates, especially the level of female education. So, focusing on this variable is crucial to control this pandemia.

1. Background

According to United Nations Development Programme (2005), the human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS) epidemic is the disease that has inflicted the single greatest reversal in human development in modern history. It has claimed more than 35 million lives so far, with 1.0 million people dying from HIV-related causes in 2016. Whilst this is a global problem, we should note that Sub-Saharan Africa is the most affected region, with 25.6 million people living with HIV in 2016, while it accounts for almost two thirds of the global total of new HIV infections. The
situation was so complicated at the end of the XX century, with some prevalence rates close to 30% and incidence rates above 5%, that the United Nations specifically included the combat against the spread of HIV as target 6 of its Millennium Development Goals (MDGs) in the Millennium Declaration. This document was signed in September 2000, with the aim of halting and beginning to reverse the spread of HIV by 2015. These MDGs were subsequently substituted by the Sustainable Development Goals (SDGs) and, again, the reduction of the spread of HIV/AIDS explicitly appears in the set of 17 goals included the 2030 Development Agenda signed by the 193 countries of the United Nations General Assembly on 25 September 2015.

The application of the different United Nations’ HIV-oriented policies has been relatively successful and there is a general consensus that they are closely related to the decline of the spread of HIV/AIDS during the XXI century. New HIV infections fell by 39% during 2000-2016 and the development of new effective antiretroviral drugs have helped to control the virus and prevent the transmission of the virus. The consequences are a remarkable reduction in HIV-related deaths[1] and a more healthy life for HIV-infected people.

However, this does not mean that the battle against this epidemic is over. We can still appreciate unacceptably high values of HIV prevalence and, to lesser extent, incidence rates in some Sub-Saharan countries. This leads us to consider that the effect of the different international and local policies has not had the same effect in all the Sub-Saharan countries, although they share similar social, cultural and economic conditions. It also suggest the possible existence of different patterns of behavior, which could be caused by the presence of zones where HIV transmission is not controlled and where, as a consequence, more resources and efforts should be dedicated to end its resistance.

We can interpret the existence of these different patterns of behavior from a convergence
perspective. If the values of the largest prevalence/incidence rates move towards the smallest, there is a single pattern of behavior between all of them. By contrast, if the rates diverge, then multiple patterns of behaviors can be found. In our context, this result would imply a lack of control of the epidemic and, as a consequence, that the HIV-oriented policies have not been successful as was expected according to the MDG and SDG agendas.

Against this background, the purpose of the present paper is to analyze the null hypothesis of convergence for the abovementioned prevalence/incidence HIV rates. If we cannot reject this null hypothesis, it means that there is a single pattern of behavior for these rates across the Sub-Saharan countries and the HIV epidemic could be considered as controlled, although not eradicated. By contrast, if we can reject the null hypothesis of convergence, then multiple patterns of behaviors exist and, consequently, we should conclude that more efforts are necessary to reduce the HIV rates before we can consider this epidemic to be controlled.

The rest of the paper is organized as follows. We first describe the database employed, paying attention to the recent evolution of the two measures that we will employ in the paper, namely, the prevalence and the incidence rates. Later, we test for the null hypothesis of convergence in order to verify the existence of a single pattern of behavior in the evolution of these rates. If we can reject this hypothesis, we will try to determine the possible presence of convergence clubs or groups of countries with similar trend profiles of prevalence or incidence rates. If these clubs are found, we will analyze their characteristics and, additionally, explain why these different behaviors coexist. In particular, the role played by female education may help us to explain them and, furthermore, to establish some policies that could help to combat the HIV/AIDS epidemic in Sub-Saharan countries. The paper ends with a review of the most important
According to the World Health Organization (WHO) data, the use of the antiretroviral therapy (ART) has saved the lives of 13.1 million people during 2000-2016.

2. Methods

2.1. Database description

In order to assess the evolution of HIV infection in the Sub-Saharan countries, we will use two different indicators, namely, the prevalence and the incidence of HIV. Incidence is defined as the number of new HIV infections among uninfected populations aged 15-49, expressed per 100 uninfected population in the year before the period, whilst prevalence refers to the percentage of people aged 15-49 who are infected with HIV. We also disaggregate prevalence by gender. We have selected the countries that have full data for 1990-2016, the data having been collected from the World Health Organization database. Table 1 reports the values of the female/male prevalence and the total incidence rates for the Sub-Saharan countries for different years. We can observe a great heterogeneity in the data. For instance, considering the data of 1990, Comoros, Gambia, Guinea-Bissau, Madagascar, Mauritania, Somalia and South Sudan showed female prevalence levels close to 0, whilst the rates of Zimbabwe and Uganda were around 15. If we take into account the data at the end of the sample, we can observe that half of the countries included in the sample exhibit a female prevalence rate lower than (or equal to) 1, whilst Swaziland, Lesotho, South Africa and Botswana present rates greater than 10. The highest recorded value is 32.1, corresponding to Swaziland in 1999. If we now consider the male prevalence rates, we can first observe that the values are generally lower than those observed for the female case, with more than two thirds of the countries showing male prevalence rates lower than 1. The highest historic value is 10.8 and it again corresponds to Swaziland, but
in 1997. The countries with the highest male prevalence rates at the end of the sample are Lesotho (6.3), Botswana (5.4), Zambia (4.1) and South Africa (4.0). Finally, we should analyze the total incidence prevalence rates. These rates are lower than the prevalence rates. The highest value (6.3) is recorded in Swaziland in 1996. We can also observe that 29 countries never show incidence rates greater than 1, whilst only Swaziland presents incidence rates greater than 1 for all the years considered. Swaziland (4.2), Lesotho (3.4), Botswana (3.2), South Africa (2.3), Zimbabwe (2.1), Namibia (2.1), Mozambique (2.0), Malawi (1.5) and Zambia (1.4) exhibited incidence rates greater than 1, with Lesotho (2.3) and Swaziland (1.7) presenting the highest rates at the end of the sample.

A clear conclusion can be drawn from the previous descriptive analysis: HIV spread is far from being homogenous across the Sub-Saharan African countries. To support this idea, Figure 1 presents the evolution of the dispersion of the data, providing some useful initial insights about convergence for the different HIV measures considered. We can observe a very clear hump-shaped evolution in the female prevalence rates, whose maximum value was in 1998. The dispersion remains relatively constant up to 2000, when a very clear decline begins. However, the dispersion value at the end of the data is still greater than the initial one. So, this figure leads us to cast some doubts about convergence, in spite of appreciating an evident effort to reduce the HIV female prevalence rates in the countries especially affected by this problem.

The evolution of the standard deviation of both the HIV male prevalence rates (MPHIV) and total incidence rates (TIHIV) is somewhat different. The curves also exhibit a humped shape, less markedly than that of the female prevalence rates. The maximum values are in 1997 and 1996, respectively, for male and incidence rates, with these maximum values taking more modest values (2.7 and 1.6) if we compare them with the maximum value of the dispersion of the female prevalence rate (6.9). Finally, if we compare the initial and
the final dispersion values, we observe that the MPHIV rates hardly vary, whilst the TIHIV rates reduce from 1.0 to 0.5. So, we have some evidence in favor of the convergence hypothesis, in the sense that the countries with the highest MPHIV and TIHIV rates at the beginning of the sample have reduced these rates so a catching-up process may have occurred.

These results lead us to conclude that the TIHIV and MPHIV rates may exhibit convergence, which would involve the existence of a single pattern of behavior for these two variables. By contrast, the total and the female prevalence rates may diverge and, consequently, different patterns of behavior may co-exist.

In any event, these results are simply descriptive and, therefore, we should confirm this initial evidence by using more appropriate methods that directly test for the convergence null hypothesis. This is the aim of the next section.

2.2. Testing for convergence in HIV

The previous analysis has shown the disparities that exist between the evolution of the prevalence and the incidence HIV rates across Sub-Saharan countries, which offer some support to the existence of convergence and can be interpreted as a first and very important step towards the real possibility of ending this epidemic. However, it seems to be more appropriate to test for the null hypothesis of convergence instead of analyzing some figures to determine whether this phenomenon has happened. To do so, we have followed the recent papers of Phillips and Sul (2007, 2009) (PS hereafter) where they develop a framework that allows us, first, to test for the convergence hypothesis and, if this hypothesis is rejected, to determine the composition of the different convergence clubs, if they exist.

Following these authors, let us consider that $X_{it}$ represents the different HIV measures considered in this paper, with $i=1, 2, \ldots, 45$ (the 45 sub-Saharan countries) and $t$ is the
sample size that covers the period 1990-2016. Following PS, this variable can be decomposed as $X_{it} = d_{it} m_{t}$, where $m_{t}$ and $d_{it}$ are the common and the idiosyncratic component, respectively. PS suggest testing for convergence by analyzing whether $d_{it}$ converges towards $d$. To do so, they first define the relative transition component:

$$
(eq\ 1\ in\ Supplementary\ Files)
$$

In the presence of convergence, $h_{it}$ should converge towards unity, whilst its cross-sectional variation ($H_{it}$) should go to 0 when $T$ goes toward infinity,

$$
(eq\ 2\ in\ Supplementary\ Files)
$$

PS test for convergence by estimating the following equation:

$$
(eq\ 3\ in\ Supplementary\ Files)
$$

with $r$ taking values in the (0.2, 0.3) interval, following the results of PS. Equation (3) is commonly known as the log-t regression. The null of convergence is tested by way of a standard $t$-statistic and, according to PS, the null hypothesis is rejected whenever this $t$-statistic takes values lower than -1.65. If we reject convergence, we can use the PS algorithm to consider the existence of clubs[1].

[1] See Phillips and Sul (2007, 2009) or Panopoulou and Pantelidis (2013) for a description of the use of this algorithm.

3. Results

3.1 Testing for convergence

The results that we have obtained are presented in Table 2. This table reports the results for the female HIV prevalence rates (FPHIV) and male HIV prevalence rates (MPHIV), as well as for the total HIV incidence rates (TIHIV). The results obtained are mixed. We can first observe that the convergence null hypothesis is not rejected for either the TIHI or the
MPHIV, as was suggested by the analysis of Figure 1. This result could be interpreted as a successful implantation of the health policies in the recent years, especially those related to the MDGs and, to lesser extent, the SDGs. In order to explore the influence of these two agendas on HIV evolution, we have additionally analyzed the null hypothesis of convergence for several periods of time. As we can observe, the FPHIV quickly converge, given that we cannot reject the convergence null hypothesis since 2005, whilst the convergence of the TIHIV occurred later. Thus, we can affirm that it took longer to control the evolution of the TIHIV rates than the evolution of the MPHIV rates. Similarly, the non-rejection of the convergence null hypothesis implies that the two rates show a unique pattern of behavior across the countries included in our sample. Consequently, it could be considered that the measures recommended in both MGG and SDG agendas have been useful to control the HIV epidemic, at least as far as the FPHIV and the TIHIV rates are concerned.

If we now analyze the behavior of the FPHIV rates, the results are not so positive. The results reported in Table 2 show that we can clearly reject the convergence null hypothesis for this rate. It is true that the evidence against this hypothesis is now smaller than it was in 2004, but it still is large enough to allow us to reject the presence of a single pattern of behavior among the Sub-Saharan countries. This implies that more efforts are necessary to control the evolution of the FPHIV rates, making it very difficult to adopt similar policies in all the countries. Rather, it would seem to be sensible to consider adopting country-specific policies or, at least, different policies for some groups of countries, if we can group some of them by the similar evolution of their FPHIV rates. In this regard, we should note that, once we have found divergence, it is advisable to analyze whether convergence clubs exist, showing the presence of groups of countries whose FPHIV rates share a similar pattern of behavior. To that end, we can employ the PS
algorithm. The results that we have obtained from the use of the cluster algorithm proposed by these authors, lead us to conclude in favor of the existence of two clubs with statistically different behaviors. The first club, which will be referred to as club 1, is composed of the rates of the following countries: Botswana, Equatorial Guinea, Lesotho, Malawi, Mozambique, Namibia, Sierra Leone, South Africa, Swaziland, Uganda, Zimbabwe and Zambia, whilst the rest of the countries are included in the second club, which will be referred to as club 2. This result is quite understandable given that club 1 includes the 10 countries with the highest female prevalence rate in 2016 plus Equatorial Guinea, the 12th country in 2016 and with a relatively important growth in the recent years, and Sierra Leone, with a small prevalence rate but showing a final value very close to its maximum, which was in 2005. Additionally, Equatorial Guinea and Sierra Leone are the only two countries that have increased their FPHIV rates since 2000. In any event, their inclusion in club 1 should be interpreted with some caution, given that these results are reflecting the relatively bad behavior of the female prevalence rates in recent years, which could originate a problem in the future, more than the current situation.

In order to reflect the evolution of the two groups, Figure 2 reflects the evolution of the average values of the FPHIV rates of the countries in the estimated clubs. Once again, we can appreciate a hump-shaped curve for both of them, although a much sharper one for the countries included in club 1. We can also see that the initial distance between the two curves is around 4 points. It grew to 11 points in 1999, when it attains its maximum, and has decreased since then to 6.2 points in 2016, the minimum distance since 1992. So, our data again reflects the positive effects of the UN recommendations and the local policies to control the evolution of the FPHIV rates. However, the important differences that emerged at the end of the last century have not disappeared yet and, as a consequence, more efforts are still necessary, first, to move the club 1 FPHIV rates towards those of club
2 and, second, to reduce all of them towards 0, finally eradicating this painful pandemic. To that end, the use of appropriate policies is necessary. The next section is devoted to comparing the evolution of the countries in clubs 1 and 2 with the aim of identifying which polices may offer better results in order, first, to control the evolution of the FPHIV rates and, second, to be in a position of winning the battle against HIV/AIDS in the near future.

3.2. What forces drive the creation of the clubs?

The results of the previous section prove that the evolution of the FPHIV rates in Sub-Saharan Africa exhibits different patterns of behavior and that it is possible to split the countries into two separate groups. Now we need to explain why these differences occur, which could help us to draw some insights to know which policies are more relevant in the fight against this pandemic. The identification of the key policies is not an easy task, especially if we recognize the existence of multiple factors that may explain these differences. We can find some of them in the literature. For instance, some authors have recently analyzed the role of education in the recent decline of the HIV prevalence rates.

In this regard, we can cite the papers of Alsan and Cutler (2013), Behrman (2015) and De Neve et al (2015), who study the cases of Uganda, Malawi and Botswana, respectively. Following De Neve et al (2015), we can appreciate that increasing the number of years of secondary schooling had a large protective effect against HIV risk in Botswana, particularly for women. Similar results are obtained for the previously mentioned authors.

Therefore, we can understand education as a social vaccine to reduce the spread of HIV, an idea supported by authors such as Vandemoortele and Delamonica (2000) and Amaugo et al (2014).

We should also consider the evolution of the economy as a very important factor to battle against HIV/AIDS. Some authors, such as Mbirimtengerenji (2007), consider that poverty, and its consequences, is a crucial point of HIV transmission. It comes as no surprise that
HIV/AIDS is often referred to as a disease of poverty. However, as Mufune (2014) points out, the relationship between poverty and HIV transmission is not clear, because countries with similar levels of poverty do not exhibit similar levels of prevalence rate. Thus, some economic variables need to be included to verify whether this relationship exists and, if so, its direction.

From a different point of view, some authors have analyzed the influence of the use of contraceptive methods on HIV transmission. We can cite the recent papers of Magadi and Magadi (2017) and Mabaso et al (2018) where the Kenyan and the South-African cases are analyzed, respectively. These authors find some relationship between the use of the condom as a contraceptive method and HIV transmission. However, the direction of this relationship is not clear and an appropriate use seems to be more crucial to diminish the risk of HIV transmission than the mere use of this method. In any event, we consider it interesting to study whether this effect is valid for other countries in order to find a general result.

Finally, we consider the degree of urbanization of the country. Since the paper of Dyson (2003), some authors have studied whether HIV/AIDS presence is more an urban than a rural problem. We should also cite the papers of Asiedu (2012), Hajizadeh et al (2014) and Taaffe et al (2016) in this regard. According to them, HIV/AIDS seems to be more related to urban population, although the rural/urban differences have diminished in the recent years.

Having selected the different factors, we should now choose the most appropriate variables. In spite of the problems of data availability, we have been able to collect a relatively high number of explanatory variables, although we have had to remove some countries from the study due to missing data, finally using 36 of the 45 countries that were initially employed for the convergence analysis. The list of explanatory variables and
the removed countries are reported in Appendix A. Table 3 presents the mean of the most relevant variables for each club. As we can see, the youth unemployment rate and female condom use take very different values for each clubs, whilst the differences for the other variables are lower. We can also appreciate that per capita GDP, the Human Development Index and female condom use take larger values for club 1 than for club 2. This result could be considered somewhat counter-intuitive because we would expect the countries with the highest FPHIV rates (club 1) to show smaller values of per capita GDP and the Human Development Index and a lower percentage of females that use condoms in their sexual relationships than the countries with the smallest FPHIV rates.

However, this is a mere descriptive analysis and it would be more appropriate to use more robust methods to determine which variables allow us to explain why a particular country is assigned to club 1 or 2. To that end, we have estimated a probit model. Given that club 2 is the largest, the dependent variable takes the value 0 if the country has been included in club 2 and 1 when the country belongs to club 1. The results we have obtained are shown in Table 3. These results have been obtained by using a general-to-particular encompassing strategy. We have first estimated a general model by ordinary least squares with all the variables included in Table A1 and, then, removed the non-significant variables one-by-one. Then, we have estimated the probit model with the selected variables. To avoid the problems generated by the possible presence of non-observed heterogeneity, we have employed robust estimation methods[1]. As can be seen, we can discriminate the characteristics of the two clubs by employing just 4 variables. The youth unemployment rate reflects the evolution of the economy in the sense that it is expected that countries with a higher HDI value and a low youth employment rate should exhibit a lower FPHIV rates than the rest.

Similarly, countries with a high percentage of female population aged 15-24 who used a
condom during their last intercourse in the last 12 months are mostly included in club 2. This result is somewhat counterintuitive, as we have earlier mentioned, and should be interpreted with some caution or it could lead us to draw erroneous conclusions. First, we should recall the results reflected in Table 3, where countries included in club 1 exhibit the highest percentages of female condom use. However, we should not conclude that this is the cause of the high female prevalence rates in these countries. Rather, these large percentages in the use of condom are denoting the impact of health policies which have extended the use of condom and, as a consequence, these countries have controlled the incidence rates, the first step to stop the extension of the HIV epidemic. Furthermore, the results of Magadi and Magadi (2017) and Mabaso et al (2018) had previously warned of the importance of a consistent use of the condom, more than its mere use. So, more efforts seem to be necessary in this regard.

The third variable is the percentage of urban population. As we can see, the countries included in club 2 seem to exhibit highest values of this variable. Thus, it seems that the advantages of living in relatively large cities, mainly economics of scale, are more important than its disadvantages in order to control the HIV/AIDS epidemic.

Finally, the last variable included in the model is female persistence to the last year of primary, which reflects the percentage of females enrolled in the first year of primary school who eventually reach the last year of primary education. So, if the female persistence value is high, large female prevalence rates are less likely. Moreover, if we calculate the marginal effects, we can observe that, if the countries included in club 1 could increase their female persistence to the levels of the countries in club 2, the probability of being included in club 1 would be reduced by 12%. These data prove the importance of education in the fight against the HIV/AIDS pandemic. This result is absolutely related to the abovementioned literature and offers additional evidence on the
importance of education in the fight against the HIV epidemic. However, our results are
more general that the previous studies because our evidence is not valid for a single
country, but rather for the set of countries with large female prevalence rates.
In order to appreciate the relationship between the explanatory variables included in the
model and the probability of a particular country being assigned to club 1, we have
graphically represented this probability for several values of female persistence to the
last year of primary (FPP) and youth male unemployment rates (YMUR), whilst the rest of
the variables take the average values of the countries included in club 1. Figure 3.a.
reflects the evolution of the probability when FPP takes values in the (30, 90) interval. As
we can observe, the probability is greater than 0.9 whenever FPP is greater than 55%,
whilst it is 0.8 if FPP takes the mean value of the total sample (63). Similarly, the
probability of being included in club 1 is not lower than 50% until FPP takes values greater
than 77. If we take into account that only 6 countries exhibit these values in our sample,
we can understand how difficult it is to move from club 1 to club 2 for a particular country
only using educational policies. Similar results are obtained if we analyze Figure 3.b. We
can observe in this case that values of the YMUR greater than 30% imply probabilities
greater than 90% of being included in club 1. If the YMUR take the total sample median
value (15.4%), this probability reduces to 62% and it is lower than 50% when the YMUR
takes the total sample mean (10%). Finally, if we combine the evolution of both variables,
the results are more encouraging. For instance, if the policies adopted by a country
included in club 1 lead it to augment the FPP and YMUR to the total sample median values,
then the probability of being included in club 1 is just 42%. So, the combination of
socioeconomics variables, together with maintaining the current health policies, may help
to definitively control the HIV/AIDS epidemic in the near future.
4. Discussion

This paper analyses the evolution of the HIV/AIDS epidemic in Sub-Saharan Africa from a time series perspective. We have focused on two different measures of this problem: the HIV prevalence rate and the HIV incidence rate. Given the data availability, we have disaggregated the HIV prevalence rate by gender. The use of the recent advances in convergence analysis have allowed us to study whether these two measures converge and exhibit a unique behavior across the sample size, which covers 1990-2016, or whether, by contrast, they exhibit different patterns of behavior. If the latter case is found, then we should conclude that the epidemic is not controlled and that some countries still exhibit a different pattern of behavior to the rest, in spite of the great effort made by the Sub-Saharan countries with extraordinary support from the international community.

Our results lead us to conclude that the male HIV prevalence and the total HIV incidence rates show a unique pattern of behavior. This implies that those countries with the largest rates at the beginning of the sample have reduced the distance with respect to those with the smallest rates, which could be interpreted as the success of the policies adopted. Moreover, we have verified that this result is relatively recent, in the sense that a different conclusion is drawn when the 1990-2010 sample is considered, at least for the total HIV incidence rate. Consequently, it seems that all the policies adopted, which were defined by the MDG agenda, have been quite effective in the fight against the HIV/AIDS epidemic and both these rates seem to be under control.

However, we can reject the presence of a unique pattern of behavior for the female HIV prevalence rate. Rather, we observe that the female rate of the countries with the highest prevalence rate (Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Uganda, Zimbabwe and Zambia) plus Equatorial Guinea and Sierra Leone, with
a somewhat large growth in the recent years, behaves differently with respect to the rest of the Sub-Saharan countries. Thus, this convergence analysis helps us to both identify the existence of a focus where the HIV/AIDS is not controlled yet and in which countries. Having found the origin of the differences, we then tried to determine which factors may drive them. To that end, we have estimated a probit model with the dependent variable taking the value 0 if the country belongs to club 2 (the largest club) and 1 if the country belongs to club 1 (the club with the countries that exhibit largest female HIV prevalence rates). We have used several explanatory variables that capture the different socioeconomics aspects of these countries, mainly related to education, economics and sexual habits, all of them commonly identified as key factors to understand the HIV/AIDS transmission. The variables finally included in the model are the percentage of urban population, the youth unemployment rate, the percentage of the female population aged 15-24 who used a condom in their last intercourse in the last 12 months and the percentage of female children enrolled in the first year of primary school who eventually reach the last year of primary education. The results obtained imply that the probability of passing from club 1 to club 2 increases with an improvement of the economic situation, the more consistent use of the contraceptive methods and, especially, the increment of the female education level. We have analyzed the evolution of the probability of being included in club 1 when the socioeconomic variables change. The combination of an increase in female persistence to the last year of primary and a reduction of the male youth unemployment rate to their respective sample mean would be quite effective and would reduce the probability of being assigned to club 1 to below 50%. This result reinforces the idea that general education improvements, especially those addressed to the female population, are crucial to eradicate the HIV/AIDS pandemic, although they should be accompanied by taking appropriate decisions on both economic and health
policies.

5. Conclusions

The recent evolution of AIDS/HIV prevalence and incidence rates invites us to be somewhat optimistic about the control of this pandemic. However, we have still found serious differences in the evolution of the female prevalence rates. Our results can help us to identify the most relevant variable to do it, being crucial the female education levels. However, we should note that the adoption of our suggested policies should be accompanied by the continuation of the support of the international community. We must recognize that the progress made in the fight against HIV/AIDS has been partially achieved due to a very large financial investment from the international community, as Oberth and Whiteside (2016) note. If this support is not maintained, it does not seem possible for these economics to provide sufficient resources to the HIV/AIDS fight and, consequently, all the achievements might suffer a serious setback.

Declarations

Authors’ contributions

Both authors have participated in all the Sections of the paper in a similar proportion. The authors have read and agreed to submit this manuscript.

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Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.
Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Due to technical limitations, tables are only available as a download in the supplemental files section.

Figures
Figure 1. σ-convergence

This figure represents the evolution of the standard deviation of the HIV female prevalence (FPHIV), male prevalence (MPHIV) and total incidence (TIHIV) rates.
Figure 2. Average value of the estimated clubs

This figure presents the average values of PFHIV rates of the countries included in clubs 1 and 2.

Figure 2

Average value of the estimated clubs
Figure 3a. Evolution of the probability of a country being included in club 1 as a function of the female persistence to the last year of primary.

Figure 3b. Evolution of the probability of a country being included in club 1 as a function of the male youth unemployment rate.

Figure 3

Figure 3a. Evolution of the probability of a country being included in club 1 as a function of the female persistence to the last year of primary. Figure 3b. Evolution of the probability of a country being included in club 1 as a function of the male youth unemployment rate.
Supplementary Files

This is a list of supplementary files associated with the primary manuscript. Click to download.

- Appendix A.pdf
- Tables.pdf
- Equations.jpg