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An In-Depth Analysis of Demographic Shifts and their Effects on HIV/AIDS Prevalence in Eastern African Countries

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ABSTRACT

Eastern African countries rank in the top ten most highly infected nations globally. To shed light on this, therefore this study investigated the impact of population dynamics on Human Immunodeficiency Virus (HIV) prevalence using a two-stage residual inclusion (2SRI) regression model to address potential endogeneity. The Hausman Test confirmed endogeneity among the variables, justifying the 2SRI model's application. Key findings indicate that population growth rate, fertility rate, and the population aged 15-64 significantly and positively affect Human Immunodeficiency Virus (HIV) prevalence. The instrumental variable, Children ages 0 to 14 young individual infected by HIV, 15 to 24 newly affected by Human Immunodeficiency Virus (HIV), and Children 0 to 14 living with Human Immunodeficiency Virus (HIV), was validated for strength, demonstrating robustness against weak instrument issues. Results revealed that a 1% increase in population growth rate leads to a 53% increase in Human Immunodeficiency Virus (HIV) prevalence. Additionally, the Dumitrescu & Hurlin Granger non-causality test established that population growth rate Granger causes Human Immunodeficiency Virus (HIV) prevalence. These findings underscore the critical role of demographic factors in shaping Human Immunodeficiency Virus (HIV) prevalence and highlight the necessity for targeted public health interventions to manage and reduce Human Immunodeficiency Virus (HIV) prevalence effectively.

Keywords: Control Function Approach, Demographic Shift, Eastern African Countries, HIV Prevalence, Two-Stage Residual Inclusion (2SRI)

I. INTRODUCTION

HIV and AIDS continue to be a significance major global health concern despite tremendous efforts made in both international and local efforts to combat the pandemic. At a UN Special General Assembly in 2001, it was voted to recognize HIV/AIDS as a global public health emergency, increase international action against the pandemic, and mobilize resources (Govender et al., 2021). An international effort was launched by the Millennium Development Goal 6 of the Millennium Declaration of 2000 to address the HIV/AIDS epidemic. Two decades and US$ 109.8 billion in donor support later, it is time for the international community to reassess regional success.

The frequency of AIDS-related deaths has dropped because of antiretroviral medication (ART); nonetheless, not everyone has access to treatment, and there is still uncertainty around the availability of effective vaccines and curative treatments. Programs for awareness and prevention have been suggested to be a more practical strategy (Zhao et al., 2018)(Zhao et al., 2018). Sadly, these promises were not kept because of the high prevalence of HIV and the limited accessibility of antiretroviral drugs among key communities. The multifactorial spread of HIV is significantly influenced by social factors. HIV testing had to adhere to ethical standards protecting patient confidentiality; this, coupled with stigma and discrimination, may have concealed the illness in many communities and may continue to do so. Developing countries were ill-equipped to handle the additional burden that HIV/AIDS imposed on their already fragile healthcare systems, particularly those in Africa (Bogart et al., 2021).

There were other factors at play when the outbreak turned into a pandemic. Perhaps because of unresolved systemic concerns, preventive interventions like the use of condoms, stopping mother-to-child transmission, voluntary male medical circumcision, and community awareness campaigns have not been as effective as expected (Elias & Tchuenche, 2012). Since more People Living with HIV (PLHIV) were receiving antiretroviral medication, a decline in incidence and death was expected. It was anticipated that preexposure prophylaxis, and viral suppression which gave rise to the theory that "undetectable equals untransmutable" and prenatal regimens would further inhibit viral transmission. HIV infections differ geographically and even among nations. The attempts to contain the HIV pandemic are significantly impacted by these disparities in HIV incidence. (PEPFAR, 2023)

Between 2017 and 2050, it is predicted that the East African region will rank among the ten with the greatest population growth. This will affect regional mortality, fertility, and life expectancy (Kitole et al., 2023: Tile et al., 2023). The EAC is the region with the highest number of HIV/AIDS victims, according to the UN, accounting for 45% of all HIV infections and 53% of all HIV-positive individuals worldwide, despite the region's rapid population transition (Govender et al., 2021). Of these victims, 35 million are adults and 1.7 million are children under the age of fifteen.

The study objective was to examine how population dynamics affect HIV/AIDS prevalence in eastern African nations is the goal of this research.

II. LITERATURE REVIEW

2.1 Empirical Reviews

The daily residency status, HIV status, and HIV care status of every one were determined by (Larmarange et al., 2018) using data from clinic visits, ART prescriptions, viral load and CD4 count, migration, and deaths. The study focused on the influence of population dynamics on the population's HIV care cascade. The study was carried out in KwaZulu-Natal, a rural region of South Africa. Position was determined using scores ranging from 0 (undiagnosed) to 4 (at the top of the HIV treatment continuum). (Suppressed by viruses). Every adult resident living with HIV who entered or left the community had their cascade score compared to the average score of their cluster at the time of entry or departure. Then, determine the annualized overall contribution, broken down by component of change, of each entry and exit to the average cascade score. The research discovered that population dynamics limited the average cascade score's growth over time in all clusters.

Furthermore, based on national HIV estimate data, (Khalifa et al., 2019) study on the Demographic Change and HIV pandemic Projections to 2050 for Adolescents and Young People Aged 15-24, 148 projects that the HIV pandemic would peak in 2050. By sex and five-year age group, the numbers of HIV-positive individuals and new HIV infections were predicted. Projections were made based on three main hypotheses: future patterns in HIV incidence, antiretroviral therapy coverage, and antiretroviral coverage for preventing mother-to-child transmission. The results cover nine different geographical areas. According to the study, between 2010 and 2050, there will be 10% more adolescents and young people, but there will be 61% fewer individuals with HIV. It is anticipated that between 2010 and 2050, new HIV infections among adolescents and young people will drop by 84% in Eastern and Southern Africa, which has the worst HIV epidemic in the entire globe. In West and Central Africa, which is where the second-largest HIV pandemic is located, fewer new cases are anticipated to occur by 35%.

According to (Nsuami & Witbooi, 2018) research, pre-exposure prophylaxis and ARV therapy are included in a model of HIV/AIDS population dynamics. The management of HIV infection has lately been accomplished with the use of oral pre-exposure prophylaxis (PrEP) and antiretroviral therapy (ART). Utilizing an antiretroviral drug is what pre-exposure prevention entails to shield those who are HIV-negative from contracting the disease. A new HIV/AIDS transmission model, incorporating ART and PrEP, is proposed in the research. Through simulations, we show that our model can be used to evaluate the effects of ART and PrEP uptake in each population. Future HIV prevalence estimates can also be calculated using the model. The research establishes the global stability of the disease-free equilibrium as well as the global stability of the endemic equilibrium in the model's most general instance, which permits PrEP users to default. We also provide thought-provoking simulations based on newly released South African data.

Bloom & Luca, (2021) researched the dynamics and evidence of the HIV epidemic's effects on population and household structure. She used earlier examples of this impact to predict future changes using demographic theory and reviewed more recent evidence to look for signs of these changes. According to the research, there are only a few age groups where slight increases in the male-to-female ratio are starting to become noticeable (about 15% among 25–34-year-olds). In some age pyramids, similar-sized increases in the percentage of people aged 15 to 29 compared to people aged 30 to 54 are seen. These "youth bulges" are anticipated to disappear, while an ageing effect gradually sets in because the epidemic influences fertility. Over time, the size of all age groups will decrease, but middle-aged adults will experience this change comparatively less. In the most affected nations, the percentages of widows and orphans have grown. For widows, fewer remarriage odds were seen.

Mkwashapi et al., (2023)conducted a study on how the HIV epidemic has affected fertility in sub-Saharan Africa. The information for sub-Saharan Africa was gathered from Demographic and Health Surveys, published studies, and individual correspondence. The effect of the HIV/AIDS pandemic on the number of births in Uganda was shown using a mathematical model. utilizing a research methodology that involves data review and analysis from the numerous individual studies that have looked at the relationships among HIV/AIDS and fertility. Research revealed that fertility was lower among HIV-infected women than HIV-uninfected women, with the exception of those between the ages of 15 and 19, when the selective pressure of sexual debut on pregnancy and HIV infection led to greater fertility rates among the HIV-infected. Because of this fertility disparity, there was a 0.37% (95% confidence interval 0.30%, 0.44%) decline in total fertility that could be attributed to the community for every 1% increase in HIV prevalence.

2.2 Theoretical Foundation

2.2.1 Epidemiological Theory

A comprehension of the relationship between infectious disease epidemiology and demography, it is important to consider the kind and calibre of the evidence at our disposal as well as the steps we take to go from anecdote to general guidelines and from hypothesis to theory (Paz & Dujardin, 2005). We can make educated guesses about how changes in host population structure may have impacted the epidemiology of certain illnesses based on a thorough understanding of the natural history and transmissibility of certain infections as shown by observational studies (Silk et al., 2019). Examples of coincident changes are provided by historical and archaeological records of population size and organization, as well as patterns of disease and mortality. These include the introduction of new pathogens during the formation of civilizations and the decline in disease linked to better living conditions and hygiene (Manego et al., 2017)

Examples are used to illustrate general concepts in the study of the relationship between infections and demographics, as well as the opposite. However, since infections like HIV, malaria, TB, influenza, and bubonic plague dominate the relationship between diseases and demography, these cases are seldom typical (Manego et al., 2017). Therefore, by looking at patterns and factors of health and illness within communities, epidemiological theory seeks to understand how diseases spread and why some groups are more vulnerable than others.

2.2.2 Theoretical Model

You can adapt the traditional SIR model to incorporate birth and death processes when thinking about a scenario in which the population is not constant. As a result, the SIRS model is created, which has terms for the birth rate (μ) and death rate (δ). The SIRS model equations are as follows.

This equation shows the rate of change of the number of vulnerable individuals (v) over time (t). It is a function of the transmission rate (β), the number of people who have been disposed of (v), and the number of people who have spread the disease to others (d), divided by the total population (N). In this case, the rate at which people are born into the exposed class is proportionate to the size of the population at that time.

$$\frac{\partial V}{\partial t} = \mu N - \beta\frac{V}{n} - aV \quad \text{...} \quad (1)$$

The rate of change of the number of diseased persons (HIV) with time (t) is represented by this equation. Individuals who transfer from the exposed class to the diseased class are represented by the first part of the equation, while those who recover from the illness are represented by the second part of the equation. The recovery rate is expressed as y.

$$\frac{\partial HIV}{\partial t} = \beta\frac{HIV}{n} - yHIV - aHIV \quad \text{...} \quad (2)$$

III. METHODOLOGY

The study employed a non-experimental research approach by Examine the recorded data sets from the World Data Bank for each nation between 1990 and 2021. The United Nations Population Division, worldwide population forecasts, census reports, statistical materials from the National Statistics Office, demographic statistics, and population data were some of the sources from which these global numbers were compiled.

This method is especially helpful in situations where conducting experiments would be immoral or impossible, like when examining the dynamics of HIV commonness in the overall population. The non-experimental research design of this study contributes to a realistic portrayal of how population dynamics affect HIV prevalence. Utilizing World Bank data was a cost-effective, reliable, and appropriate choice for the study, especially when the dataset was gathered by reputable organizations (Johnston, 2014; Tile et al., 2024). The Eastern African countries

Tanzania, Uganda, Kenya, Burundi, and Rwanda were chosen for the unity of analysis, and the availability of a large and representative sample of countries also enhanced the learning's peripheral legitimacy.

This implies that the study's findings might apply to comparable circumstances in other Sub-Saharan African nations. nevertheless, a few disadvantages of experimental study methods include the inability to modify relevant variables and the lack of control over irrelevant aspects, are lessened by the non-experimental research design.

3.1 Model Estimation

The study uses a two-stage residual inclusion model to address the endogeneity between HIV prevalence and random error, this is because population dynamics have an important effect on HIV prevalence, on the other hand, HIV prevalence has important effects on the population dynamics (Kitole et al., 2022). Therefore, there are feedback effects between population dynamics and HIV prevalence. Consider the model estimation below

$$HIVP_t = \beta_0 + \beta_1 PD_t + \beta_1 HIVP_{t-1} + \omega_t \quad (3)$$

But population dynamic can be affected by the other factors together with the HIV prevalence and the equation now becomes.

$$PD_t = \beta_0 + \beta_1 HIVP_t + \beta_2 FR_t + \beta_3 DR_t + \beta_4 LER_t + \upsilon_t \quad (4)$$

Therefore, by substituting equation 33 into equation 32, the equation becomes.

$$HIVP_t = \beta_0 + \beta_0 + \beta_1 HIVP_t + \beta_1 HIVP_{t-1} + \beta_2 FR_t + \beta_3 DR_t + \beta_4 LER_t + (\upsilon_t + \omega_t) \quad (5)$$

Now Let

$K_0 = (\beta_0 + \beta_0)$

$H_1 = (\beta_1 HIVP_t + \beta_1 HIVP_{t-1})$

$PD_t = (\beta_2 FR_t + \beta_3 DR_t + \beta_4 LER_t)$

$\hat{u} = (\upsilon_t + \omega_t)$

Now the equation becomes.

$$HIVP_t = K_0 + H_1 + PD_t + \hat{u} \quad (6)$$

Nonetheless, the instrumental variable (IV) and the two-stage residual inclusion (2SRI) have been used to ease these difficulties. According to (Kitole et al., 2022), 2SRI is the most effective method for managing endogeneity in both linear and non-linear models. Two steps are involved in 2SRI. Firstly, residuals from the estimated functions are calculated to a reduced form, and the second-stage regression then includes these residuals as extra explanatory variables.

The control function technique, which helps to manage both endogeneity and heterogeneity, is generally an extension of the two-stage residuals with null hypothesis testing of the exogeneity. It is more commonly referred to as the new stage reduction equation (Kitole et al., 2022) The HIV prevalence, for which Equations (3) and (4) were found to be precisely characterized, was the tool employed to suppress this endogeneity that emerged throughout the estimation process. Nevertheless, considering HIV prevalence and population trends.

The identification of possible endogeneity problems that might have an impact on the estimate of Equations (3) and (4) motivated the use of an instrumental variable model in this investigation. Endogeneity arises when there is a correlation between the variables of interest and the error term in a statistical model (Gammadigbe, 2021). If this endogeneity is not addressed, it may induce bias and inconsistent parameter estimations, which could compromise the validity of the study's conclusions.

The study utilized a robust econometric technique, the two-stage residual inclusion and control function approach regression method, to address the issues posed by endogeneity. This approach was selected because of its exceptional capacity to estimate Equation (3) and (4) simultaneously, thereby resolving the endogeneity and heterogeneity issue (Kitole et al., 2023: Tile et al., 2023)

The key component of this strategy is its ability to instrument for the potentially endogenous variable (HIV prevalence) by using an instrumental variable, in this case, children under 14 newly infected with HIV, young adults 15 to 24 newly infected with HIV, and children 0 to 14 living with HIV. A variable that has a correlation with the endogenous variable of interest but is unaffected directly by the error term is called an instrumental variable. The study aimed to decipher the intricate association between HIV prevalence and prevalence by using this instrumental variable (Kitole et al., 2023: Tile et al., 2024)

HIV prevalence, which is the incidence of HIV/AIDS, was regarded as a latent dependent variable in Equation (7). It is impacted by a collection of explanatory variables X_1 that are thought to have an impact on the prevalence of HIV/AIDS in addition to the latent population dynamics (PD). This equation's disturbance term, (ω), is meant to have a normal distribution and takes into account any unexplained fluctuation. The dependent variable in equation (4) is population dynamics. It is thought to depend on latent HIV/AIDS prevalence in addition to other external factors represented by the symbols$\beta_2 FR_t$, $\beta_3 DR_t$, $\beta_4 LER_t$.. Population dynamics are influenced by the latent HIV/AIDS variable and these exogenous influences together.

To sum up, Equations (3) and (4) were simultaneously estimated in this work using the instrumental variable model, namely the two-stage residual inclusion regression approach. By incorporating an instrumental variable to separate the relationship between HIV prevalence and population dynamics in the context of East African countries, our strategy addressed the endogeneity dilemma.

Table 1
Variable Measurement

Variables	Measurements	Expected sign
Dependent variables		
HIV prevalence	Total number of people living with HIV	
Independent variables		
Fertility rate	Number of births per thousand population per year	+
Net migration Death rate	Number of deaths per thousand population per year	-
Life expectancy rate	The mean number of years a cohort of people might expect to live	+
Population growth Number of children living with HIV	Total number of children living with HIV	+
Number of adults living with HIV	Total number of adults living with HIV	+
Number of males living with HIV	Total number of males living with HIV	+
Number of females living with HIV	Total number of females living with HIV	+

IV. FINDINGS & DISCUSSIONS

4.1 Response Rates

Stipulated results in Table 2 show that on average East African fertility rate is 5 per cent per year and the minimum fertility recorded in all selected East African countries from 1980 to 2020, moreover, the lowest fertility rate recorded was 0.785 while the maximum was 7.405 per cent per. Also, the results that on average the mortality rate in East African countries was 105.8987 people per thousand between 1980 to 2020 and the minimum amount of the mortality rate recorded was 0.973 people per thousand moreover the maximum record was 341.2 people per thousand this was the highest mortality rate recorded so far.

Table 2 Descriptive Statistics

Variable	Observation	Mean	Minimum	Maximum
Fertility rate	160	5.469575	0.785	7.405
Mortality rate	160	105.8987	0.973	341.2
Net migration	160	-16713.3	-137427	1244966
Life expectancy	160	52.74191	32	69.329
Prevalence of HIV Total	160	5.058125	4	10.1
Children Infected with HIV	160	92836.88	50056	250000
Adults infected with HIV	160	46573.75	25000	180000
Prevalence rate Female	160	3.320625	2	10.4
Prevalence rate Male	160	1.24625	0.5	3.2
Antiretroviral therapy coverage	160	36.34375	20	100

Additionally, net migration on average in all selected East African countries recorded 16713 people per year where there is more outmigration to other countries than in-migration and the minimum amount of net migration record between the mentioned year is 137427 outmigrants peoples per year, and the maximum amount of the net migration shows that there is 1244966 people migrated to East Africa from outside the selected counties. Moreover, Table 2 shows that the life expectancy in East African countries on average is 52 years while the minimum life expectancy rate is 32 years, and the maximum is 69 years. Additionally, HIV/AIDS prevalence is the total number of people living with HIV in a given population on average shows that the total number of people living with HIV/AIDS is 508997% per year, while the minimum is 4% per year, and the maximum is 10% in a year.

Number of children infected with HIV in each population on average shows that the total number of children infected with HIV/AIDS is 92836.88 children, while the minimum is 50056 children, and the maximum number of children infected with HIV is 250000. Additionally, the number of adults infected with HIV on average results shows that the total number of adults infected with HIV/AIDS is 46573.75 adults, while the minimum is 25000 adults, and the maximum number of adults infected with HIV is 180000. Moreover, the rate of HIV infection to males in a given population on average shows that the rate of males infected with HIV/AIDS in East African countries is 1.2 per cent per year, while the minimum rate of males infected with HIV/AIDS in East African countries is 0.5 per cent per year, and the maximum rate of male infected with HIV/AIDS in East African countries is 3percent per year. Additionally, the rate of HIV infection to females in a given population on average shows that the rate of females infected with HIV/AIDS in East African countries is 3 per cent per year, while the minimum rate of females infected with HIV/AIDS in East African countries is 2 per cent per year, and the maximum rate of female infected with HIV/AIDS in East African countries is 10 per cent per year and the antiviral therapy coverage to peoples living with HIV on average it shows that 36 people per year attend the service while the minimum attendant of people living with HIV is 20 peoples per year and the maximum number of people attending the antiviral therapy was 100 peoples per year.

The findings show the population growth rate in East African countries from the period of 1990 to 2021. The population is still growing in East Africa where the trends in its countries show a horizontal trend with a declining sign where the population is growing at a declining rate as shown that the highest record population growth rate was recorded by Rwanda in 1999s where it recorded the population growth rate of 7 per cent. But also, Rwanda has the highest record population growth rate but it also has the lowest population growth rate where in 1993 it recorded a population growth rate of negative 4 per cent and later its population continued to grow at a higher speed than the other countries.

population growth rate is still in the positive region where shows that the population is still growing at a positive rate, therefore apart from efforts of the global to reduce the population growth rate by introducing several programs in developing countries such as family planning programs but still East Africa records a positive population growth rate, and this will continue for several years to come. This may be attributed to several factors such as an increase in life expectancy in most of the East African countries, Migration from the neighbouring countries, and a decline in the death rate of children which increases the number of live persons per year in the countries Tile et al., (2023)

Since the 1990s, results show that most of the countries started at a low rate during the 1990s and the later number of cases in HIV positive increased until the maximum point in the 2000s which was a mark of turning point to most of the East African countries. Now about all countries in East Africa show a declining trend of HIV prevalence means the total number of people living with HIV has been declining in recent years compared to the previous years of 1990. But the number is increasing at a decreasing rate which means there are still a few people living with HIV it does not mean that the number is declining negatively. This may be attributed to several programs that are introduced to fight against HIV/AIDS in most developing countries such as the provision of free condoms to all areas with a high risk of transmitting HIV such as in markets, bars, schools, and universities. (Yoshikawa et al., 2020)

4.2 Estimation Results

A two-stage residual inclusion regression model was used in this study to examine how population dynamics affect the prevalence of HIV/AIDS in each of the countries under investigation. Concerns about possible endogeneity between the independent variables (factors influencing population dynamics) and the dependent variable (HIV prevalence) are the reason for using this modelling approach. The study used children ages 0 to 14 who were newly infected with HIV and young people ages 15 to 24 who were newly infected as an instrumental variable to address this issue.

Nonetheless, the Hausman Test was used in the study to confirm the existence of endogeneity. The results of this diagnostic evaluation, which are shown in Table 3, showed that at a significance level of 1%, the null hypothesis was categorically rejected. This rejection indicates strong evidence of endogeneity between the variables being studied. As a result, it was decided that the use of a two-stage residual inclusion model would be suitable for determining how these variables affected the dependent variable. This modelling strategy was thought to be beneficial since it provides more accurate estimations of the interrelationships between the variables by successfully addressing the endogeneity issue.

Table 3

Durbin Score and Wu-Hausman Test

Test	Test score	P-values
Durbin (score) chi2 (1)	36.8897	(0.0000)
Wu-Hausman F (1,151)	45.6173	(0.0000)

Creating a suitable tool to explain the structural equation is one of the main obstacles to endogeneity control with the IV approach. As a result, the strongest and most legitimate instruments can be identified by evaluating them. According to academics (Kitole et al., 2022), excellent instruments are exogenous in the model specification and have a high degree of correlation to the endogenous variable without having any causal direct influence on outcome measures. Determining whether an instrument possesses these three characteristics is made easier by choosing to check for validity.

The instruments used in this instance were Children 0 to 14 living with HIV, Young People ages 15 to 24, and Children 0 to 14 newly infected. Its validity and strength needed to be confirmed. A weak instrument test was carried out to determine the instrument's strength in this inquiry; the findings are shown in Table 4. Even at a 5% significance level, the eigenvalue statistic outperformed all other statistics in Table 4, according to the results of the weak instrument test. This result suggests that the selected instrument is robust and has the strength required to be used in the investigation. Therefore, it is clear that the problem of a weak instrument is not present in this investigation. There is no direct impact of the instrument used in our model on the outcome variable. Instead, it only has an indirect effect that is mediated by the treatment variable. This confirms that our instrumental variable approach is valid for assessing our independent factors' causal effects on the dependent variable.

Table 4

Instrument Strength by Eigenvalue Statistic

Minimum eigenvalue statistic = 91.8609							
Critical Values			Number of endogenous regressors:1				
Ho: Instruments are weak			Number of excluded instruments: 1				
					5%	10% 20%	30%
2SLS relative bias					13.91	9.08 6.46	5.39
					10%	15% 20%	25%
2SLS	Size of nominal	5%	Wald	test	22.30	12.83 9.54	7.80
LIML	Size of nominal	5%	Wald	test	6.46	4.36 3.69	3.32

The 2SRI has been utilized to control the endogeneity issue in the models, improving the results and making them more suitable in column 1. Because heterogeneity has been suppressed, the interaction term insignificance explains why heterogeneity is not an issue in this model. While residuals themselves are significant in column 1 of 2SRI and inconsequential in column 2 of the control function approach, the coefficient of multiplicative interaction effects of residual and HIV/AIDS prevalence is insignificant in column 2. As a result, 2SRI will be used for both the estimation and interpretation of the results in this case.

Therefore, the findings in Table 5 show that the population growth rate is significantly and positively affecting the HIV prevalence of the region, such that a one per cent increase in population growth rate in the region per year, increases the total number of people living with HIV by 53 per cent, other factors remain constant. Population growth rate comes from several factors such as net migration, death rate, and fertility rate once the population grows at a certain percentage where initially the population had some number of people living with HIV hence it increases the number of people living with HIV at a current period. This result is not in line with that of Khalifa et al., (2019) who researched projections of the adolescent and young adult population's demographic changes and the HIV epidemic through the year 2050 for those aged 15 to 24 showed that while the proportion of adolescents and Between 2010 and 2050, there will be a 10% increase in young adults overall, whereas the percentage of HIV-positive young people will decrease by 61%. The world's largest HIV epidemic is currently located in Eastern and Southern Africa; projections indicate that between 2010 and 2050, the number of new HIV infections among adolescents and young people in this region will decrease by 84%.

The fertility rate is significant and positively affects the total number of people living with HIV in the region, that is as the number of births women increase per year increases the HIV prevalence by 22 per cent in the region. This may be attributed to the number of new babies born with HIV infections that is mother to child infections also fertility increases the population in a certain area and once the population increases means urbanization which accelerates the rate of new infection in the region hence the total number of people living with HIV increases. This result is in line with that of Khalifa et al., (2019) who conducted a study on Demographic change and HIV epidemic projections for adolescents and young adults aged 15 to 24 using national HIV estimates files. The study projects that between 2010 and 2050, the number of adolescents and young people will increase by 10%, while the number of HIV-positive individuals will decrease by 61%. The largest HIV epidemic in the world is found in Eastern and Southern Africa, where it is predicted that between 2010 and 2050, the number of new HIV infections among adolescents and young adults will drop by 84%.

Population ages 15 to 64 is positive and significantly affects the HIV prevalence in the region, that is as the number of people aged 15 to 64 increases it also increases the number of people living with HIV/AIDS, other factors remain constant. This may be attributed to the fact that the population aged 15 to 64 are in danger of practising HIV/AIDS risk behaviours such as sexual intercourse, drinking alcohol behaviour and other prostitution behaviours. This result is consistent with that of (Swai et al., 2017), who investigated the prevalence of HIV and risk factors for the virus among individuals 50 years of age and older in the Rombo district of Northern Tanzania. The study found that the virus was more common in women (2.1%) than in men (1.3%), with a prevalence of 1.7% (n=10). Only 40% (n=216) of respondents knew anything about HIV prevention, compared to 60% (n=350) who knew about HIV transmission. Additionally, the study supports that of (Mahy et al., 2014) who found that adults 50 years of age and older have HIV after researching Increasing trends in HIV prevalence among people aged 50 and older: evidence from estimations and survey data. Since around 1995, all age groups under 5 have seen an increase in the worldwide HIV prevalence among older people.

Table 5

Effects of Population Dynamics on HIV/AIDS Prevalence

Dependent variable HIV/AIDS prevalence	Estimation Technique 2SRI	Estimation Technique Control function approach
Population growth rate	0.535***	0.536***
	(0.0514)	(0.0532)
Fertility rate	0.221***	0.221***
	(0.0141)	(0.0141)
Population_ages15-64	0.425***	0.425***
	(0.0283)	(0.0283)
Life expectancy	-0.000383	-0.000383
	(.55E-05)	(2.55E-05)
Net migration	9.75E-08	9.70E-08
	(9.23E-08)	(9.25E-08)
Residual	0.136***	0.136***
	(0.0119)	(0.0123)
HIV prevalence * Residual		-5.82E-05
		(0.00057)
Constant	-6.848***	-6.857***
	(0.442)	(0.447)
Observations	**159**	**159**
R-squared	**0.846**	**0.846**

Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1

4.3 Causality Test

Panel data causation tests are used to investigate the causal connections among the variables in a panel dataset. Hence, examining causality in panel data can offer a significant understanding of the dynamics and correlations across variables in this organized dataset. The purpose of this study was to evaluate if population changes are a cause or effect of HIV prevalence by applying a causality test to find the causal relationships between population growth and HIV/AIDS prevalence (Lopez & Weber, 2017).

Dumitrescu & Hurlin Granger's non-causality test introduced a single lag by default. The test's result in this instance refutes the null hypothesis that Population growth rate does not Granger-cause Prevalence of HIV and accepts the null hypothesis that Population growth rate does Granger cause Prevalence of HIV for at least one-panel var (country ID)(Lopez & Weber, 2017). The values acquired for W (W-bar), Z (Z bar), and (Z-bar tilde) are reported in the output. The P-values for the last two statistics are given using the conventional normal distribution as a basis.

Table 6

Dumitrescu & Hurlin Granger Non-Causality Test

Lag order: 1		
W-bar	28.7197	
Z-bar	43.8287	(p-value = 0.0000)
Z-bar tilde	38.264	(p-value = 0.0000)

H_0: Population growth rate does not Granger-cause Prevalence of HIV.

H_1: Population growth rate does Granger cause Prevalence of HIV for at least one-panel var (country ID).

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

The examination of the relationship between population dynamics and HIV prevalence has ultimately revealed a robust relationship between population growth, fertility rates, and the age distribution of the HIV-positive population, which is defined as those who are 15 to 64 years old. The important policy implications of these findings should be noted by governments and organizations fighting the HIV/AIDS epidemic. The findings showed a positive correlation between the rise in population and the prevalence of HIV. When there is a sharp rise in the population and a strain on healthcare resources, it may be challenging to provide comprehensive HIV prevention and treatment services.

Moreover, an important determinant of HIV prevalence is the age distribution of the population, especially that portion in the 15–64 age group. The high prevalence in this age group may imply a significant risk of transmission. These findings emphasize the need for an all-encompassing approach to HIV prevention and control. In addition to healthcare and treatment, good policies should address broader socioeconomic and demographic concerns. By approaching these issues comprehensively, governments and organizations can work to reduce the prevalence of HIV and ultimately improve public health outcomes.

5.2 Policy implications

Governments must therefore pass legislation promoting family planning, access to contraception, and sexual education to effectively control population increase and reduce the burden on healthcare systems. Furthermore, as indicated by the positive relationship between HIV prevalence and reproduction rates, thorough sexual and reproductive health education is crucial. Legislators should provide the public with the knowledge and resources needed to make informed decisions about family planning, including HIV prevention and safe sex practices. In this regard, it is essential to have access to affordable, reliable contraception as well as healthcare services.

Public health policies and programs should be developed with this age group in mind, offering easy access to diagnosis and treatment in addition to information and awareness-raising. Aside from drug abuse, gender inequality, and other factors that contribute to HIV transmission in this community, interventions should also focus on other socioeconomic determinants of health.

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