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THE CONTRIBUTION OF EDUCATION TO POPULATION GROWTH IN RWANDA

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ABSTRACT

Purpose: This study explores education's contribution to Rwanda's population growth and its determinants, such as fertility, mortality, and migration.
Design/ Methodology/ Approach: The study uses secondary data from 2005 to 2020 sourced from databases of the World Bank, the United Nations, and the National Institute of Statistics of Rwanda. Specifically, quantitative research methodologies are used, including descriptive analysis, correlations, visualisations, multiple and multivariate linear regression, correlation, and comparative study, alongside econometric analysis such as multicollinearity, normality, and heteroscedasticity tests to ensure the quality, validity, and reliability of the results.
Research Limitation: While the study utilises advanced statistical methods, the findings may not be fully generalisable across all contexts, particularly if the sample does not represent the broader population.
Findings: Results indicate a statistically significant negative relationship between expenditure on education and population growth rate with (correlation is -0.896, regression coefficient is -0.298, R^2 is 0.8846, p-value is 0.000). A unit increase in education expenditure reduces the population growth rate by 0.298. The R^2 of 0.8846 suggests that 88.46% of the model is well explained. Additionally, spending on education shows a negative association with the total fertility rate (coefficient is -1.101, p-value is 0.000) and the Crude death rate (coefficient is -58.446, p-value is 0.000), indicating that higher education expenditure reduces fertility and mortality. However, there is no significant relationship between net migration (coefficient is 1.009, p-value is 0.109).
Practical Implications: This study contributes to understanding the relationship between education and population growth rate in Rwanda, offering insights for policy interventions to control population growth.
Social Implications: We recommend target policy interventions, such as increasing investment in education and addressing regional and gender disparities by focusing on areas with such cases. This controls fertility and mortality rates while also slowing long-term population growth.
Originality/ Value: This study addresses the knowledge gap by examining how education impacts population growth rates. It provides empirical evidence and an econometric model to help policymakers use education to manage and predict future population dynamics.

Keywords*: Contribution. education. population growth. regression model. Rwanda*

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INTRODUCTION

Global population growth has surpassed more than expected in recent decades. This rise has resulted from lower mortality and higher fertility (Pimentel et al., 1997). According to World Bank projections, the population reached 8 billion in 2022, up from an estimated 2.5 billion in 1950, with 1 billion added since 2010 and 2 billion since 1998. The population is expected to grow by approximately 2 billion during the next 30 years, from 8 billion to 9.7 billion by 2050. This fast expansion has become a serious global concern due to the unequal distribution of resources and population (Joseph et al., 2015).

Serious problems such as poverty, economic dependency, resource depletion, environmental degradation, and political and social instability arise due to population growth. Growth rates must be decreased to mitigate the adverse effects of rapid population growth. Nations can use demographic investment programs to accomplish this decrease. Several researchers say education is a key factor in reducing the population increase rate. Some scientists, such as Albouy & Lequien (2009); Cutler & Lleras-Muney (2006); Mccrary et al. (2006) evaluated the directional association between education and population growth using population growth determinants. They found that fertility and mortality fall as one's educational levels increase. Education, particularly for women, helps shape their reproductive behaviours in deciding when, how and whether to have children. Women increase awareness about using contraceptive methods and seek skilled health practitioners to get advice on their reproductive health, thereby reducing the risk of mortality and unwanted fertility.

For this reason, education has been strongly emphasised in Rwanda as one of the control measures. Various policies were established to increase access to education, improve quality, and address gender disparities in schooling (Nizeyimana et al., 2021). These efforts were made to develop more educated individuals who would impact population growth in various ways, including reduced fertility and mortality. To assess the impact of education on population increase, see education and the determinants of population growth trends. According to statistics from 1996, 56.9% of Rwandans aged six and above finished elementary school, 3.9% completed secondary school, and 0.2% graduated from university. However, since 2011, the population has increased to around 2 million in primary, 486 thousand in secondary, and 87 thousand in post-secondary. These changes in schooling are associated with lower fertility and death rates. Looking at fertility after 1996, we can observe that the total fertility rate was 6.1 in 1996 but had dropped to 4.3 by 2011. Similarly, in 2011, the mortality rate fell to 7.3 deaths per 1000 people, down from about 28 fatalities per 1000 people in 1996.

Even though we discuss the benefits of education in moderating population growth rates, there is still a shortage of understanding regarding this relationship since other scholars have not

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thoroughly examined this knowledge in the Rwandan context. Due to a shortage of this knowledge, policymakers cannot control the population growth rate effectively. Therefore, this research aims to explore education's contribution to population growth by providing statistical evidence. We will analyse the effect of education on determinants of population growth, such as fertility, mortality, and net migration in Rwanda. Additionally, we examine current education patterns by gender, region, and area of residence and formulate a predictive model to assist policymakers in forecasting future population growth.

Rwanda is facing a significant challenge of uncontrolled population growth, which has become a critical concern for the nation. Since the mid-1990s, following the Genocide against the Tutsi, Rwanda's population has increased dramatically, doubling from approximately 5.6 million in 2005 to 13.2 million in 2022 (NISR, 2022). Projections indicate that, without effective intervention, the population could surge to 23 million by 2050. This rapid growth poses numerous challenges, including the overuse of natural resources, rising poverty levels, and increased government spending. The strain on the environment and slowing economic progress are significant concerns. From these issues, scholars have suggested that the primary key to controlling this rapid growth. (Lutz & KC, 2011). However, the extent to which education contributes is still unrecognisable since no empirical research explains their relationship. This knowledge gap limits policymakers' ability to predict the population's growth using education as a tool. This study aims to explore the contribution of education to the population growth rate in a case study of Rwanda. It will present evidence of the impact of education and, lastly, construct an econometric model explaining their relationship, which policymakers could use to predict population growth by controlling other factors.

Exploring the contribution of education to the population growth rate provides crucial insights into how educational attainment influences population growth determinants. By analysing the impact of education on population growth and its determinants, we can help policymakers design targeted interventions that promote educational access and quality, thereby reducing fertility and achieving manageable population growth. This knowledge is vital for Rwanda, where fertility rates remain high. Additionally, this research extends to policymaking, enabling policymakers to develop more informed and effective strategies. For example, integrating family planning, education on sexual and reproductive health in schools, providing incentives for education for girls, and ensuring that education policies are inclusive and equitable can directly address the problem of rapid population growth. Moreover, the research fills a critical knowledge gap about Rwanda's education and population growth rate relationships. Other researchers' studies established the relationship between education and population growth in different countries, for instance (Lutz & KC, 2011). In Rwanda, this relationship is absent. The study, therefore, provides insights that reflect the country's socioeconomic context. This local understanding of relationships is crucial. Therefore, the findings

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of this research can contribute to global discourse on population growth and development. Countries worldwide that experience challenges similar to those in Rwanda can offer valuable lessons and best practices. This knowledge exchange can foster international collaboration and support in addressing the common goal of sustainable population management through education.

The research is geographically centred in Rwanda, and we are particularly interested in exploring education's contribution to the population. It will explore the relationship between education and population growth, focusing on how educational attainment affects key determinants such as fertility, mortality, and migration. The research will employ quantitative methods using a time series dataset from 2005 to 2020 sourced from the World Bank and the UN and a cross-sectional survey conducted from 2019 to 2020 by the National Institute of Statistics of Rwanda (NISR).

THEORIES UNDERPINNING THE STUDY

Rwanda's population growth rates differ. According to NISR (2022), Rwanda's population will vary in size, structure, and composition during the next 30 years compared to now. The population is estimated to grow from 13.2 million in 2022 to 23.6 million by 2052. This growth follows a geometric progression formula: $P_1 = P_0(1 + r)^t$, where P1 represents the future population, P0 represents the current population, r is the growth rate, and t is the period. Which means the population's geometric growth rate. If nothing is done, the population will exceed the predicted number, causing a range of problems, as stated by (Pimentel et al., 1997), such as economic instabilities and a strain on biological resources. However, various drivers of population increase have been explored, with fertility being the most important factor. Fertility is the average number of children a woman would have if she experienced current age-specific fertility (Götmark & Andersson, 2020). If the fertility rate continues to rise, the population will outpace expectations. The figure below depicts Rwanda's population growth patterns from 1960.

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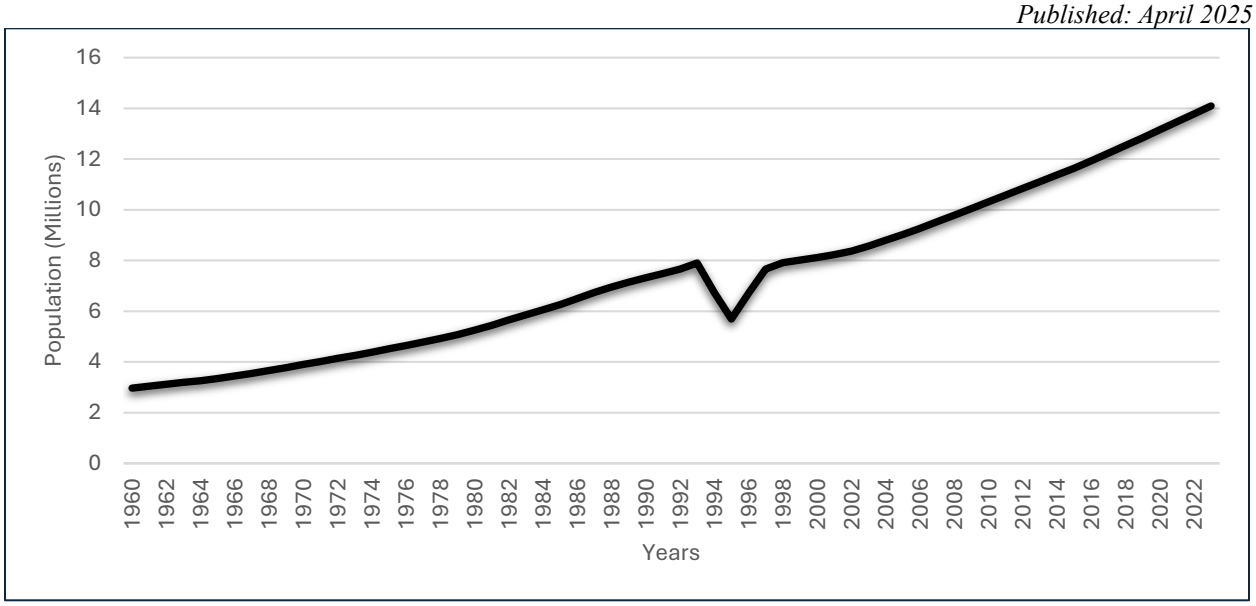

Figure 1: Population growth of Rwanda from 1960

As discussed in the introduction, promoting education is the most effective strategy for controlling population growth. Education influences population dynamics through several interconnected pathways. Firstly, it plays a crucial role in the Demographic Transition Theory, where increased education levels, especially among women, lead to lower fertility rates by promoting contraceptive use, delaying marriage, and reducing family size. Additionally, Human Capital Theory highlights that education enhances economic productivity and health outcomes, leading to higher incomes and better access to healthcare, which collectively slow down population growth. Moreover, Easterlin's Relative Income Hypothesis suggests that education raises aspirations for a higher standard of living, resulting in smaller family sizes. Empirical evidence supports these theories, showing that each additional year of female education significantly reduces fertility rates, lowers child mortality due to better health practices, and increases economic opportunities, encouraging smaller families. Furthermore, education fosters cultural and behavioural changes, promoting modern family planning methods and gender equality, thus reducing population growth rates.

Understanding the education structure of Rwanda

Education transmits knowledge, skills, values, habits, and beliefs from sender to receiver. It is categorised as formal and informal education. Formal education refers to a structured education system from pre-primary or primary school to university. The following are characteristics: formal education is structured and systematic education (follows a well-defined curriculum and schedule), it is institution-based; certificates, diplomas and degrees are provided after completion; learners

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gain skills by being delivered by qualified instructors, teachers, or lecturers, and regulated and managed by a recognised body or authority. Informal education, on the other hand, encompasses learnings that occur outside formal education, and it is not organised, not structured or institutionalised and can happen in various settings without degrees or certifications delivered.

Formal education levels

According to Republic of Rwanda Ministry of Education (2018), the levels of education are pre-primary education, primary, secondary (lower and upper), vocational training, and tertiary education. Primary education is mainly attended by children aged 3 to 6 years, and it aims to prepare children and help them grow their minds by doing manual activities and interacting with other children. Primary education is followed by pre-primary education. At this stage, a student learns more about reading and writing. The primary purpose is to ensure that all students have acquired enough physical and intellectual skills to advance them in lower secondary education. This level lasts for six years after doing national examinations. Secondary education lasts six years, but it is organised into lower and upper secondary. Lower secondary education starts after finishing primary school and takes 3 years to complete. Upper secondary begins in senior four and ends in senior six with getting an advanced certificate. Another level is vocational training. For this type, people are trained with various skills that help them create their jobs or upgrade their employment skills, for example, people being taught masonry, sewing machines, software training, and/or entrepreneurial skills. The last category of education is tertiary education. For this category, students learn in the university and end up getting higher degrees such as (Bachelor, master's, PhD, and or professional), and this is the final level of education in Rwanda.

Education effects on determinants of population growth (fertility and mortality)

Generally, the number of children that a household decides to have is an expression of its perception of tangible and intangible costs and benefits of bearing children (Angeles et al., 2005)**.** It is believed that an educated person would want fewer children since educated people consider the future costs of having many children. It is not only this factor but also educated people shape their fertility behaviour by reproducing few and manageable numbers of children; this indicates that education correlates negatively to the fertility rate (Cygan-Rehm & Maeder, 2012). As women's educational attainment rises, women take measures to control births (Asmamaw et al., 2023). This led to a negative correlation between reduced fertility and longer school years for women and girls since the length of time the women spent in schools delayed marriage, developed knowledge of contraceptives, and had fewer children (McCray et al., 2006). Educational attainment supports population growth by lowering fertility and mortality and improving health outcomes.

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The issue of increased fertility has risen in emerging nations due to less progress in education, particularly for women. In developing countries, there is still a gender gap in education, and there are underdeveloped women attending schools; hence, this brings illiteracy, a high dropout rate, abortion cases, and early, early marriage, leading to high fertility caused by high dropout (Berg & Nelson, 2016)This led to population growth, which is mainly found in Africa. Education has played a crucial role in reducing the population growth rate in Rwanda. The gender gap in school attainment is being closed, and a considerable proportion of educated women has increased in this decade. As the Institute of Statistics said, the population growth rate has declined from high to low.

Empirical review

Lutz and Kc (2011) investigated the link between education and population growth and discovered that the world population depends on the degree of education humans have achieved. Education affects population growth by influencing fertility, death, and migration. Higher levels of education, particularly among women of reproductive age, result in fewer children. A greater proportion of women with higher levels of education utilise contraceptive techniques for fertility than those without education, lowering fertility rates. Another study by Athanase (2024) revealed a link between education and fertility rates, and he discovered a statistically significant association between education, mortality, and fertility rates.

Greater education levels are related to increased life expectancy and reduced fertility rates, which has resulted in greater populations. Kaffenberger et al. (2018) also investigated education and mortality determinants and discovered that females who have finished at least 6 years of schooling had a lower risk of newborn and child mortality. He discovered that a 21% drop in child mortality resulted in a 68% increase in women's attendance at basic education. If women have basic education, they become literate in caring for their children, seeking their children's health in an emergency, and obtaining prenatal and antenatal care from doctors. Albouy and Lequien (2009) showed a negative association between education and all mortality categories, which complements this conclusion. This suggests that the greater the education degree, the lower the mortality rate because their links are strong. Migration is also a factor influencing population increase. Some studies examine the impact of education on other factors but fail to consider migration because of its minor contribution to population increase. However, migration may result in latent population momentum, allowing population expansion to continue while fertility declines. Education cannot directly impact migration, which causes increased population growth. However, it may raise salaries, attract individuals from other countries to their target country, and result in population expansion. As Vakhitova and Coupe (2013) proposed, education raises salaries for various reasons. Education boosts productivity, allowing companies to pay greater wages. Some individuals will come to dwell in that location, increasing the population dispersion and population growth.

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RESEARCH METHODOLOGY

According to Mishra (2011) Research methodology is a systematic and scientific approach to collecting, analysing, and interpreting quantitative or qualitative data to answer research questions or test hypotheses. On the other hand, research is a methodological inquiry into a particular issue to obtain information or knowledge. This section explains the research methodology used in the research.

This research employs a quantitative approach utilising secondary data analysis. Data will be gathered from the World Bank, the United Nations (UN), and Rwanda Demographic and Health Surveys (RDHS) from the NISR database. The dependent variable, population growth rate (PGR), will be analysed into independent variables, including educational expenditure (ED), unemployment rate (UNEMPRATE), urbanisation rate (URBRATE), and healthcare expenditure (HEXP), again education expenditure will be analysed with fertility, mortality, and migration (measured by net migration). Statistical software such as STATA or R will be utilised for data cleaning, regression analysis, and modelling to assess the impact of education on population dynamics. The study will employ regression models such as multiple and multivariate linear regression analysis. We will use a multiple regression model to explore how much education (measured by expenditure on education) contributes to population growth. Multivariate regression is used to examine the impact of education expenditure on three outcome variables: fertility, mortality, and migration (measured by net migration).

The model specification

A multiple linear regression used population growth rate as a dependent variable, education expenditure as an independent variable, and finally, Employment rate, urbanisation rate and Health expenditure as control variables. Multivariate linear regression used three outcome variables, fertility, mortality, and migration, along with education expenditure, as independent variables. Below is the model specification form:

Education and population growth

$$PGR = f\ (ED, UNEMPRATE, URBRATE, HEXP) \quad (1)$$

Econometrically,

$$PGR = \beta_0 + \beta_1 ED + \beta_2 UNEMPRATE + \beta_3 URBRATE + \beta_4 HEXP + \varepsilon \quad (2)$$

Where: POP: population growth rate, EDUC: expenditure on education, UNEMPRATE: unemployment rate, URBRATE: Urbanization rate, HEXP: Health expenditure, ε: stochastic disturbance or error term. β_0: intercept or the population growth when independent or control

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variables are not contributed. $\beta_{i,\ i=1,2,3,4}$ are the coefficients explaining the independent or control variables' relationship to dependent variables.

Education, fertility, mortality, and net migration

Functional form

$$\begin{pmatrix} \text{TFR} \\ \text{CDR} \\ \text{NMR} \end{pmatrix} = \text{f}\begin{pmatrix} \text{ED} \\ \text{ED} \\ \text{ED} \end{pmatrix} \quad (3)$$

Econometrically,

$$\begin{pmatrix} \text{TFR} \\ \text{CDR} \\ \text{NM} \end{pmatrix} = \begin{pmatrix} \beta_{0\text{F}} \\ \beta_{0\text{D}} \\ \beta_{0\text{M}} \end{pmatrix} + \begin{pmatrix} \beta_{1\text{F}} \\ \beta_{1\text{D}} \\ \beta_{1\text{M}} \end{pmatrix} \text{ED} + \begin{pmatrix} \varepsilon_{\text{F}} \\ \varepsilon_{\text{D}} \\ \varepsilon_{\text{M}} \end{pmatrix} \quad (4)$$

$$\begin{aligned} TFR &= \beta_{0F} + \beta_{1F}ED + \varepsilon_F \\ CDR &= \beta_{0D} + \beta_{1D}ED + \varepsilon_D \\ NM &= \beta_{0M} + \beta_{0M}ED + \varepsilon_M \end{aligned} \quad (5)$$

Where, ED: Education measured by expenditure on education, TFR: Total fertility rate, CDR: Crude death rate, NM: Net migration, $\beta_{0_{\text{F,D,M}}}$: intercept or the value of total fertility rate, Crude death rate, and net migration when the independent variable is zero (when there is no relationship between education and these determinants), $\beta_{1_{\text{F,D,M}}}$: coefficients of fertility rate, Crude death rate, and net migration (representing the relationship between education and population growth determinants) $\varepsilon_{\text{F,D,M}}$: stochastic disturbance or error term of these 3 determinan

RESULTS AND DISCUSSION

This chapter presents data analysis and interpretation of the study's findings and gives an in-depth analysis of the collected data. The findings are organised systematically, highlighting patterns and trends relevant to our research questions. After the data are presented, we have a thorough discussion, during which we analyse the implications of the findings by comparing them with current research.

The narrowing gender gap in educational attainment aligns with studies like UNESCO (2019), which highlight the success of gender-sensitive policies in improving education access in sub-

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Saharan Africa. However, some researchers, such as Smith et al. (2021), argue that rural and marginalised communities remain underrepresented in higher education despite progress. This indicates that while Rwanda has made strides in gender parity, challenges in equitable access persist for certain groups, particularly those in rural areas.

The disparities in education between rural and urban areas reflect global trends, as the World Bank (2020) reported, emphasising that urban areas have better access to quality education. However, Jones (2022) suggests cultural norms may influence gender disparities more than geographic factors. This perspective highlights the need to examine the interplay between cultural beliefs and regional disparities to understand their combined impact on education in Rwanda. The finding that males surpass females at every education level mirrors the findings of Brown et al. (2020), who document persistent gender imbalances in many developing countries. Conversely, specific regions, such as Ethiopia (Tesfaye, 2018), report faster improvements in female enrollment rates due to aggressive outreach programs. This contrast suggests that Rwanda may benefit from adopting similar targeted interventions to accelerate progress toward gender equality in education.

The positive correlation between education and contraceptive use aligns with Bongaarts (2015), who highlights that education enhances awareness and access to family planning methods. On the contrary, studies like Caldwell et al. (2017) argue that cultural and religious beliefs sometimes outweigh educational influence in contraceptive decisions. This indicates that while education is crucial, addressing cultural barriers may be equally important in improving contraceptive uptake in Rwanda. The observation that education reduces population growth is consistent with studies by Schultz (2002), which show that female education significantly lowers fertility rates. However, other studies, such as Pritchett (2013), caution that economic opportunities may mediate the relationship, suggesting that the role of unemployment should be explored further in your analysis. This underscores the importance of considering economic context when examining the impact of education on population dynamics.

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Trends in educational attainment

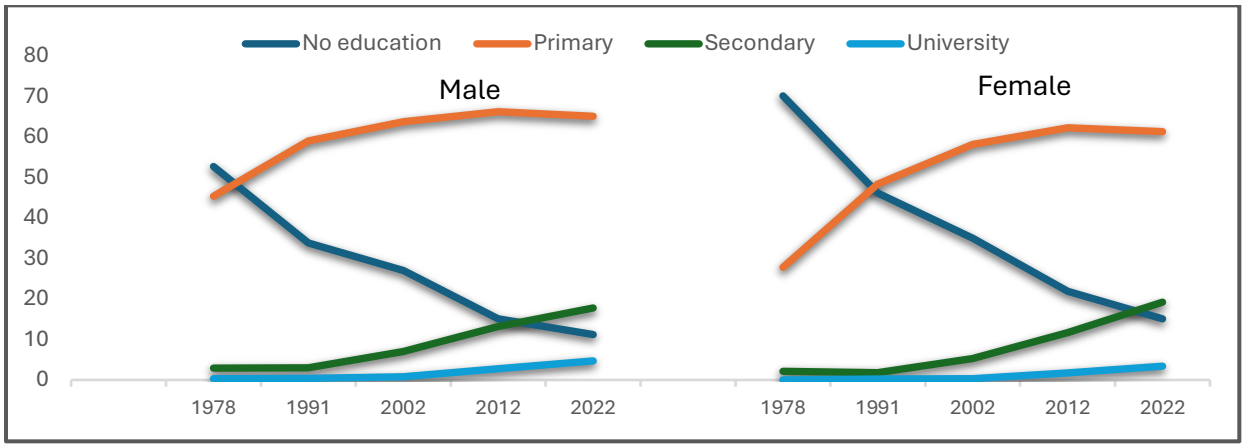

Figure 2: percentage level of education attainment by gender from 1978.

Over the decades, educational attainment in Rwanda has undergone significant changes, reflecting broader societal shifts and policy interventions to increase access to education. In 1978, a stark contrast in educational attainment existed between males and females. Among males, 52.7% had no formal education, while 70.1% of females were in the same category. By 1991, the percentage of males with no education had decreased to 33.8%, and for females, it had dropped to 46.1%, marking the beginning of efforts to improve educational access, especially for girls.

The trend of increasing educational attainment continued into the new millennium. By 2002, only 27% of males and 35% of females had no education, significantly increasing primary education completion. For males, the proportion with primary education rose from 45.3% in 1978 to 63.7% in 2002, while for females, it increased from 27.8% to 58.1%. Although the gender gap persisted, it began to narrow as educational reforms and gender-sensitive policies were implemented.

By 2012, the improvements in educational attainment were even more pronounced, with only 15.1% of males and 21.9% of females having no education. The proportion of those completing primary education continued to rise, and secondary education significantly increased. Among males, the percentage with secondary education rose to 13.2%, and among females, it reached 11.7%. This period reflects the impacts of sustained investment in secondary education and the increasing importance of higher levels of schooling for all genders.

The most recent data from 2022 underscores substantial progress. The proportion of males with no education has declined to 11.2%, and for females, it has dropped to 15.1%. Primary education remains dominant, with 65.1% of males and 61.3% of females completing it. Secondary education

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continues its upward trajectory, reaching 17.8% for males and 19.2% for females, indicating near parity. Although still relatively low, university education shows steady growth, with 4.7% of males and 3.4% of females attaining this level. These trends are crucial for understanding the role of education in shaping Rwanda's demographic and socio-economic landscape, as higher education levels, particularly among women, contribute to lower fertility rates and sustainable population growth.

Education by gender and region of residence

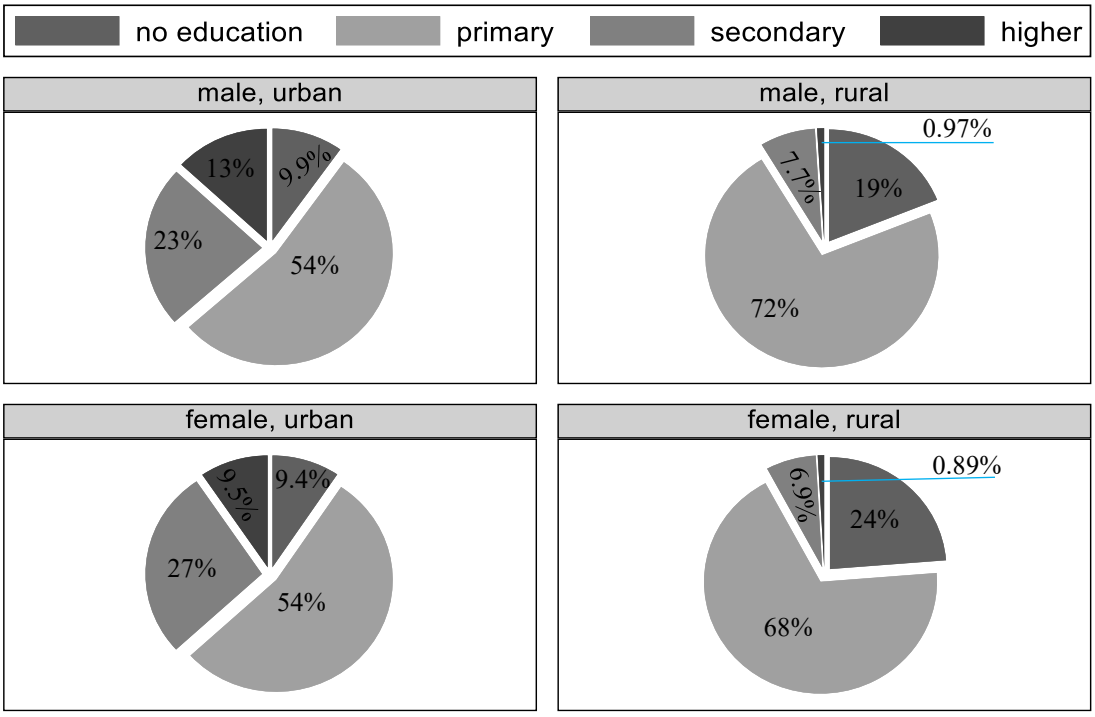

Figure 3: Education by gender.

Figure 3 illustrates the educational attainment of household heads segmented by gender (male and female) and type of residence (urban and rural). In urban areas, male and female household heads comprise a considerable portion of the population with primary education (54%). Urban males have a slightly higher percentage with higher education (13%) than urban females (9.5%). Secondary education levels are higher among urban females (27%) than urban males (23%).

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However, around 9.9% of urban males and 9.4% of urban females have no formal education, indicating a small segment without basic educational attainment.

In rural areas, most household heads, male (72%) and female (68%), possess only primary education, highlighting the prevalence of basic educational attainment in these settings. Secondary education is attained by 19% of rural males and 24% of rural females, suggesting that rural females might have slightly better access to secondary education. Higher education is rare among rural household heads, with only 0.97% of males and 0.89% of females achieving this level. Additionally, 7.7% of rural males and 6.9% of rural females have no formal education. These disparities underscore significant challenges in accessing advanced educational opportunities in rural areas and highlight the need for targeted educational policies to bridge these gaps.

Distribution of education by gender

Table 1: Education by gender

EDUCATION LEVEL	GENDER		
	Male	Female	Total
No Education	3,877	1,707	5,584
Primary	15,472	5,454	20,926
Secondary	2,361	991	3,352
Higher	711	247	958
Total	22,421	8,399	30,820

Pearson chi2(3) = 55.9984 P-value= 0.000

The Table 1 presents the distribution of education levels by gender in Rwanda, highlighting a significant gender disparity across different education levels. Specifically, it shows that males consistently surpass females at every level of education. The disparity is particularly pronounced at the primary education level, with 15,472 males compared to 5,454 females. This trend continues into secondary and higher education, with males significantly surpassing females.

Furthermore, the data reveals that most of the population has only attained primary education, with 20,926 individuals in this category. In contrast, the number of individuals with secondary and higher education is much lower, totalling 3,352 and 958, respectively. The statistical significance of this gender disparity is confirmed by a p-value of 0.000. This p-value, being less than the threshold (5%) indicates a strong association between gender and education level, suggesting that the observed gender disparities in education exist.

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Distribution of Education by Region

Table 2: Education by region

EDUCATION LEVEL	REGION					
	Kigali	South	West	North	East	Total
No education	208	1,300	1,679	790	1,607	5,584
primary	1,740	5,188	5,076	3,418	5,504	20,926
secondary	846	556	657	519	774	3,352
higher	365	150	155	124	164	958
Total	3,159	7,194	7,567	4,851	8,049	30,820

Pearson chi2(12) = 2100 P-value = 0.000

The table reveals notable regional disparities in educational attainment across Rwanda, with significant variations among the five regions: Kigali, South, West, North, and East. Kigali stands out with the lowest number of individuals without education, at 208, while the South and East regions report higher numbers, 1,300 and 1,607, respectively. Primary education is most prevalent in the South and East, with 5,188 and 5,504 individuals, highlighting a broader reach in these areas compared to Kigali, where 1,740 individuals have primary education. Secondary education levels are modest, with the highest numbers in the West and the lowest in the North. Higher education attainment remains limited overall, with Kigali having the highest number (365) and the North the lowest (124), underscoring significant access challenges, particularly in rural regions.

The Pearson chi-square test confirms the statistical significance of these regional differences, with a chi-square value of 2100 and a p-value of 0.000. This result indicates that the variations in educational attainment across regions are not random but reflect a meaningful disparity.

Contraceptive Methods Use by Educational Levels.

Table 3: contraceptive method used by educational level.

Contraceptive Method	Education level				
	No education	primary	secondary	higher	Total
Not Using	2,945	8,143	1,302	314	12,704
Pill	190	1,383	215	74	1,862
IUD	49	233	134	155	571
Injections	652	2,956	412	68	4,088
Male Condom	92	814	139	47	1,092
Female Sterilization	92	539	120	60	811
Male Sterilization	6	56	0	0	62
Periodic Abstinence	162	628	64	41	895

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Withdrawal	159	668	77	11	915
Other Traditional	7	25	8	2	42
Implants/Norplant	1,206	5,155	780	122	7,263
Lactational Amenorrhea	0	36	15	3	54
Female Condom	0	10	0	0	10
Emergency Contraception	0	7	12	9	28
Standard Days Method	24	273	74	52	423
Total	5,584	20,926	3,352	958	30,820

Pearson chi2(42) = 2.2e+03 P-value = 0.000

The Table 3 illustrates the relationship between contraceptive method usage and educational level in Rwanda, showing a significant variation in contraceptive use across different educational levels. Among women with no education, a substantial number (2,945) are not using any contraceptive method. In contrast, the number of women not using any contraceptive method decreases as educational levels increase, with 8,143 women with primary education, 1,302 with secondary education, and 314 with higher education not using any method. This indicates that higher education levels correlate with increased use of contraceptive methods. People with no education are less likely to use various contraceptive methods due to a lack of awareness. Therefore, enhancing educational opportunities is vital for promoting contraceptive use and effectively controlling population growth in Rwanda.

Education effect on population growth

Table 4: Multiple linear regression results

Source	SS	df	MS	Number of Obs =	16
				F (4, 11) =	21.09
Model	0.198413	4	.049603348	Prob > F =	0.000
Residual	0.025871	11	.002351937	R-squared =	0.8846
				Adj R-squared =	0.8427
Total	0.224285	15	.014952313	Root MSE =	0.0485

PGR	Coefficient	Std. errs.	t	P>t	[95% conf.	interval]
ED	-0.29833	0.0445735	-6.69	0.000	-.3964389	-0.2002277
UNEMPRATE	-0.02124	0.0462303	-0.46	0.655	-.1229899	0.0805145
URBRATE	-0.20474	0.100719	-2.03	0.067	-.4264224	0.0169395
HEXP	0.018747	0.0258059	0.73	0.483	-.0380515	0.0755454
_cons	11.84195	2.078581	5.70	0.000	7.267021	16.41687

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Model:

$$PGR = 11.84 - 0.298\,ED - 0.021\,UNEMPRATE - 0.204\,URBRATE + 0.018\,HEXP + \varepsilon \quad (6)$$

Table 4 offers valuable insights into the relationship between education, health expenditure, and population growth. Education (ED) significantly predicts the population growth rate (PGR) among these variables. The education coefficient is -0.29833, indicating a negative association between education and population growth rate. Specifically, the population growth rate decreases by about 0.29833 units for each unit increase in the education index. This relationship is statistically significant, with a t-value of -6.69 and a p-value of 0.000. The 95% confidence interval for this coefficient, ranging from -0.3964 to -0.2002, reinforces the reliability of this finding. This suggests that higher education levels contribute to reduced population growth, likely due to better-educated individuals having fewer children and greater access to family planning resources.

Effect of education on fertility, mortality, and migration

Table 5: Multivariate linear regression analysis

Equation	**Obs**	**Parms**	**RMSE**	**R-sq**	**F**	**P>F**
TFR	16	2	.1982326	0.7655	45.70546	0.0000
CDR	16	2	7.936311	0.8515	80.27569	0.0000
NM	16	2	.7184315	0.1727	2.921816	0.1095
	Coefficient	Std. err.	t	P>t	[95% conf.	interval]
TFR						
ED	-1.10155	.1629371	-6.76	0.000	-1.451015	0.7520841
_cons	25.67211	3.138673	8.18	0.000	18.94033	32.4039
CDR						
ED	-58.4461	6.523241	-8.96	0.000	-72.43705	-44.45513
_cons	1186.525	125.6579	9.44	0.000	917.0159	1456.034
NM						
ED	1.009384	.5905139	1.71	0.109	-.2571421	2.275911
_cons	-28.6688	11.37513	-2.52	0.024	-53.066	-4.271544

Model:

$$\begin{matrix} TFR \\ CDR \\ NM \end{matrix} = \begin{pmatrix} 25.672 \\ -1186.525 \\ -28.668 \end{pmatrix} + \begin{pmatrix} -1.101 \\ -58.446 \\ 1.009 \end{pmatrix} ED + \begin{pmatrix} \varepsilon_F \\ \varepsilon_D \\ \varepsilon_M \end{pmatrix} \quad (7)$$

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$$\begin{aligned} TFR &= 25.672 - 1.101ED + \varepsilon_F \\ CDR &= 1186.525 - 58.446ED + \varepsilon_D \\ NM &= -28.668 + 1.009ED + \varepsilon_M \end{aligned} \quad (8)$$

The model for Total Fertility Rate (TFR) demonstrates strong explanatory power, with an R-squared value of 0.7655, indicating that about 76.55% of the variance in TFR is explained by education. The F-statistic of 45.71, with a p-value of 0.0000, confirms the model's statistical significance. The coefficient for education is -1.10155, with a standard error of 0.1629, yielding a t-value of -6.76 and a p-value of 0.000, suggesting that higher education levels are associated with lower fertility rates. Specifically, a unit increase in education expenditure is linked to a 1.1 unit decrease in TFR. The 95% confidence interval for this coefficient, ranging from -1.451 to -0.7521, underscores the robustness of this negative relationship. The constant term of 25.67 implies that the fertility rate would be considerably higher without education.

Regarding Crude Death Rate (CDR), the model exhibits even stronger explanatory power, with an R-squared value of 0.8515, indicating that education explains 85.15% of the variance in CDR. The F-statistic is 80.28, with a p-value of 0.0000, confirming the model's statistical significance. The education coefficient is -58.4461, with a standard error of 6.5232, resulting in a t-value of -8.96 and a p-value of 0.000. This suggests a significant reduction in crude death rates associated with higher education levels. A unit increase in education expenditure leads to a decrease of 58.44 units in CDR. The 95% confidence interval, ranging from -72.44 to -44.46, further supports the strong negative impact of education on mortality rates. The constant term, 1186.525, indicates that the crude death rate would be notably higher without educational influences.

Regarding Net Migration (NM), the model shows a lower explanatory power, with an R-squared value of 0.1727, meaning that only 17.27% of the variance in NM is explained by education. The F-statistic of 2.92 and a p-value of 0.1095 suggest the model is not statistically significant at standard levels. The coefficient for education is 1.0094, with a standard error of 0.5905, resulting in a t-value of 1.71 and a p-value of 0.109. Although the positive coefficient indicates a possible positive relationship between education and net migration, the result is not statistically significant. The 95% confidence interval, ranging from -0.2571 to 2.2759, reflects considerable uncertainty in the estimate. The constant term, -28.67, implies a negative baseline level of net migration, but this result is also insignificant.

Summary of all findings

Multivariate regression results: The multiple regression shown in Table 4 indicates that predictors collectively, as stated in the model, explain 88% of the variation in population growth rate (PGR). An F-statistic of 21.09 and a p-value of 0.000 confirm that the model is statistically significant. The coefficient of education expenditure is -0.298, and the p-value is 0.000, indicating a strong

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negative relationship between education and population growth. For a unit increase in education, expenditure decreases the population growth rate by 0.298.

Multivariate regression results: A multivariate regression analysis explored the relationship between expenditure on education and three outcome variables such as TFR (Total Fertility Rate), CDR (Crude Death Rate), and NM (Net Migration). After regression, the R-square of these variables are 0.7655, 0.8515, and 0.1727, respectively. These R-squares indicate that expenditure on education explains much variation in TFR and CDR but not in NM.

Education and fertility: Education and fertility have a significant negative relationship (p-value =0.000, coefficient=-1.101). This implies that a unit of education spending lowers the total fertility rate by 1.1 babies. This is consistent with existing knowledge that higher levels of education, specifically for women, lower their fertility by increasing their knowledge of contraceptives and shaping their reproductive behaviours.

Education and mortality: Education and fertility have a significant negative relationship (p-value =0.000, coefficient=-58.446). This implies that a unit of education spending lowers the crude death rate by 58 people. This is also linked with existing knowledge that higher levels of education lead to improved health outcomes, economic conditions, and access to healthcare services, decreasing the risk of mortality.

Education and migration: Findings indicated no significant relationship between expenditure on education and net migration. Results showed a coefficient of 1.009 and a p-value of 0.109, greater than the threshold of 5%. The R-squared of 0.1727 (17.27%) suggests that other factors play a greater part in influencing net migration.

Table 6: Comparisons research findings

Aspects	**Our research findings**	**Others research findings**	**Comparisons**
Education and population growth rates	We found a statistically significant negative correlation, with a p-value of 0.000 and a coefficient of parameter of -0.299	Global population trends depend on progress in education. Higher levels of education are associated with a reduction in the fertility rate, mortality, and migration patterns (Lutz & Kc, 2011)	Our findings align with those of Lutz & Kc (2011), highlighting education's contribution to reducing population growth rates.

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Education and fertility rates	The multivariate linear regression results indicated that there is a strong negative relationship between education and fertility rate since the p-value is 0.000, with a coefficient term of -1.101	(Mahanta, 2016) analysed the relationship between education and fertility and has found a negative relationship since the number of children becomes less as education, specifically for women, increases	Both findings are consistently 100 per cent since results indicated a negative relationship.
Education and mortality rate	Multivariate linear regression results show a negative relationship between education and mortality. The p-value is 0.00, and the coefficient term is -58.446 per 1000 deaths. The extent to which education contributes is 85.15%	(Athanase, 2024) analysed their relationship and have found that higher levels of education are associated with a reduction of mortality rate, which means both have a negative relationship	Our findings align with those (Athanase, 2024), highlighting the role of education in mortality reduction; both results are the same.
Education and migration (measured by net migration)	From our results, we found that there is a positive relationship between education and migration. However, this relationship is not statistically significant since the p-value is 0.109, which is higher than the threshold.	Dustmann and Glitz (2011) investigated the relationship between education and migration and found that both have positive relationships. Since people would like to migrate externally to search for better education, the value of external education is higher than that of the original country. This	Both studies highlighted a significant positive relationship between education and migration.

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		promotes external migration.	
Education by gender	There is a statistically significant difference in education by gender; the p-value is 0.000. Males take a larger proportion in school attainment than females	Huggins and Randell (2007) analysed education in Rwanda and found that girls still lag in educational achievement and access, which means there is still a gender difference in education.	Both studies highlighted gender disparities in education achievements.
Education and type of contraceptive method type	From cross-tabulation results, there is an association between the type of contraceptive use and education attainment; the p-value is 0.000.	Angeles et al. (2005), in their analysis, have found that those with higher educational levels have higher conception probabilities than those who did not; contraceptive use is associated with educational attainment.	Both studies highlighted the significant association between education attainment and education.

CONCLUSION AND RECOMMENDATION

Conclusion

The study explored the contribution of education to the population growth of Rwanda. The findings underscore that increased expenditure on education is closely associated with a lower population growth rate (correlation=-0.896, coefficient=-0.298, p-value=0.000) and its determinants, such as fertility rates (coefficient=-1.101, p-value=0.000) and mortality rate (coefficient=-58.446, p-value=0.000). Expenditure on education not only improves access to schooling but also enhances education quality, equipping individuals with better knowledge and skills. This empowerment leads to improved economic opportunities and a higher quality of life. Educated individuals make more informed decisions regarding family size and invest more in the health and education of their children, creating a virtuous cycle of benefits for future generations. The contribution of education expenditure to population growth in Rwanda is substantial. It acts as a catalyst for sustainable

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development and social transformation. Policymakers should persist in prioritising education funding, recognising its pivotal role in shaping the country's demographic and economic future.

Areas for Further Research

In the future, other researchers should explore different areas to build on this study's findings. They should use primary data sources and, again, conduct time series studies to examine the long-term effect of education on population growth and other beneficial socioeconomic outcomes. It is important to investigate gender-specific educational strategies to address the disparities in education and their implications for population growth. Furthermore, investigating the relationship between education and other economic factors, such as health services and GDP, and their impact on population growth will give a comprehensive understanding.

Recommendations

Based on the findings, education plays a crucial role in influencing population growth in Rwanda. Therefore, the following recommendations are proposed to the Rwandan government to harness education's potential for sustainable demographic management effectively.

Firstly, enhancing educational accessibility should be a priority. The government must significantly increase investment in education, particularly in rural areas with limited access. This includes building more schools and providing adequate classrooms. By improving educational infrastructure, more students will have the opportunity to attend school, which will help control fertility rates. The study indicates that 86.49% variation in fertility rates is explained by education expenditure, highlighting the critical role of education in population control. Thus, by investing in education, the government can effectively manage population growth.

In addition to enhancing accessibility, it is essential to decentralise educational resources. Currently, Kigali city has a higher concentration of secondary and higher education institutions than the provinces. The government should ensure a more equitable distribution of educational facilities across all regions to address this disparity. By investing in developing educational infrastructure in underserved areas, the government can facilitate easier access to quality education for all Rwandans. This regional distribution of educational resources will help reduce disparities in educational attainment and its associated demographic impacts, such as fertility and mortality rates.

Moreover, promoting female education is crucial for demographic management. The government should implement policies that support female education, such as rewarding high-achieving female students and offering scholarships. These measures will help increase female literacy rates and reduce fertility and mortality rates among women in their reproductive years. Despite existing

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policies favouring females, there is still a significant gender gap in educational attainment. Therefore, continued efforts to promote gender equality in education are necessary.

Lastly, it is important to encourage further research on the relationship between education and demographic factors. A mixed research method should be employed to examine the long-term effect of education on population growth and other socioeconomic outcomes. Policy-oriented research should provide valuable insights into optimising educational policies to enhance their impact on population growth and overall socio-economic development.

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APPENDICES

World Bank and UN datasets were used.

YEAR	PGR	ED	UNEMPRATE	URBRATE	HEXP	TFR	CDR	NM	Log (NMR)
2005	2.66	18.54	11.93	16.9	7.73	5.18	105.4	-23051	-10.05
2006	2.69	18.69	11.65	16.9	7.61	5.07	94.0	-20195	-9.91
2007	2.68	18.92	11.64	16.9	7.86	4.96	84.5	-17724	-9.78
2008	2.64	18.97	11.57	16.9	7.57	4.85	76.3	-16880	-9.73
2009	2.61	19.18	11.68	16.9	7.81	4.73	69.6	-15121	-9.62
2010	2.57	19.35	11.68	16.9	8.09	4.61	63.8	-8394	-9.04
2011	2.46	19.43	11.80	16.9	7.94	4.49	58.5	-5358	-8.59
2012	2.38	19.52	11.70	16.9	8.11	4.37	54.9	-14824	-9.60
2013	2.38	19.61	11.80	16.9	6.78	4.25	52.0	-15833	-9.67
2014	2.39	19.54	11.87	17.0	6.99	4.22	49.6	-15027	-9.62
2015	2.44	19.44	11.85	17.0	6.65	4.19	47.7	-14477	-9.58
2016	2.48	19.38	11.80	17.1	6.96	4.16	46.1	-2605	-7.87
2017	2.44	19.40	11.88	17.1	6.39	4.13	44.7	-5169	-8.55
2018	2.39	19.40	10.76	17.2	6.70	4.10	43.4	-10794	-9.29
2019	2.40	19.43	11.24	17.3	6.33	4.03	42.0	-11823	-9.38
2020	2.37	19.38	11.83	17.4	7.32	3.95	40.5	-1579	-7.36

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Dataset used (RDHS 2019-2020)

REGION	AREA_OF_RESIDENCE	EDUCATION_LEVEL	GENDER	CONTRACEPTIVE_USE
Kigali	Rural	Primary	Female	Not Using
Kigali	Rural	Primary	Female	Not Using
Kigali	Rural	Secondary	Male	IUD
Kigali	Rural	Secondary	Male	IUD
Kigali	Rural	Secondary	Male	Injections
Kigali	Rural	Secondary	Male	Injections
Kigali	Rural	Secondary	Male	Injections
Kigali	Rural	Secondary	Male	Implants/Norplant
Kigali	Rural	Secondary	Male	Implants/Norplant
Kigali	Rural	Secondary	Male	Implants/Norplant
Kigali	Rural	Secondary	Male	Pill
Kigali	Rural	Secondary	Male	Pill
Kigali	Rural	Primary	Male	Implants/Norplant
Kigali	Rural	Primary	Male	Implants/Norplant
Kigali	Rural	Primary	Male	Implants/Norplant
⋮	⋮	⋮	⋮	⋮

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