

RESEARCH ARTICLE

Estimation of rural and urban under-five mortality rates in Kenya: The role of migration

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Abstract

Analysis of the under-five mortality rate allows policy makers to identify disparities in health outcomes across populations defined by characteristics such as place of residence, income levels, or educational attainment. It also provides guidance for designing health interventions and policies, and for monitoring progress toward program targets. When estimating the under-five mortality rate for a given region using an indirect method based on survey reports, all reported child deaths are typically attributed to the mother's region of residence at the time of the survey. This assumption can substantially affect regional under-five mortality rates in areas that receive migrants from regions with markedly different mortality regimes. The aim of this study was therefore to establish trends in the under-five mortality rate for rural and urban regions in Kenya while accounting for migration between these regions. This study used secondary data from six demographic and health surveys conducted in Kenya from 1989 to 2014. The Q-FIVE program was used to indirectly derive the set of the under-five mortality rates. These rates were then adjusted for the effects of migration using a sub-area mortality estimation approach. The results reveal that population movement between regions with different mortality rates can alter regional under-five mortality rates. By adjusting the under-five mortality rates derived for each region, we obtained clear and consistent trends across the two regions. Further research should consider the effects of migration across the socioeconomic spectrum.

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1. Introduction

Under-five mortality rate is a powerful indicator of overall health system performance, including healthcare systems, nutrition, environmental conditions, and socioeconomic factors. Reducing child mortality is a key objective for improving population development worldwide. The significance of children's survival is evident in the global community's commitment to reducing child mortality. The first world landmark on child survival was the 1990 World Summit for Children, which called for countries to reduce infant and child mortality to a third by 2000 (United Nations, 1990). This commitment was renewed in 2000 under goal 4 of the millennium development goals (MDG 4), which required countries to reduce under-five mortality by two-thirds between 1990 and 2015 (UN, 2015). The MDGs were succeeded by sustainable development goals (SDGs). Goal

3.2 of the SDGs calls for countries to reduce under-five mortality to 25 or fewer deaths per 1,000 live births by 2030 (UN IGME, 2018).

There has been remarkable progress in child survival, especially since the 1990s. Globally, the under-five mortality dropped from 96 deaths/1,000 live births in 1990 to 46 deaths/1,000 live births in 2015. During this period, under-five mortality in sub-Saharan Africa declined from 186 to 93 deaths/1,000 live births (United Nations, Department of Economic and Social Affairs, Population Division, 2019). This achievement is associated with social progress, including reductions in illiteracy and poverty levels and improvements in the availability and utilization of health services, such as immunization, vaccination, and safe delivery (United Nations, 2015). Despite this achievement, child survival is marked by huge disparities among populations defined by various characteristics. One such characteristic is the geographical place of residence, such as rural and urban regions (UN IGME, 2018). Rural and urban disparities in child survival in sub-Saharan African countries are documented, with the latter showing a better outcome (Bocquier *et al.*, 2011; Brockerhoff, 1994; Van Malderen *et al.*, 2019; Yaya *et al.*, 2019). This mortality gap between urban and rural regions is associated with differences in access and utilization of health care services (Govindasamy *et al.*, 1993). Research on disparities in rural and urban child health indicators in the sub-Saharan Africa region has been reinvigorated by rapid urbanization, largely driven by migration from rural regions (Bocquier *et al.*, 2011). For instance, the percentage of the urban population in Kenya rose from 55.3% in 1990 to 76.7% in 2024 (United Nations, Department of Economic and Social Affairs, Population Division, 2025). Therefore, the effect of migration in Kenya should be considered when calculating under-five mortality rates for rural and urban regions.

Migration is important in under-five mortality analysis because it can influence child survival in different ways. First, migration can affect child survival in migrant households depending on their adaptability capacity to their new socioeconomic and health environments (Kathare *et al.*, 2024). Second, under-five mortality rates for subpopulations within a country computed under the assumption of non-migration were likely to be erroneous. This is because some of the reported deceased children of migrant women would have died in a different location from their current residence (Kathare *et al.*, 2024). Schmertmann & Sawyer (1996) also reported that women's migration can affect regional estimates of child mortality rate. The severity of this effect depends on the disparities in mortality, age patterns of migrants population, and the number of migrants. According to

Bocquier *et al.* (2011), overlooking the role of migration in child mortality estimation would yield biased estimates in countries undergoing rapid urbanization and would lead to significant rural–urban disparities in child mortality. Moultrie *et al.* (2013) suggested that migration factors should be considered when interpreting child mortality estimates if migration is significant. Otieno Onyango *et al.* (2011) also pointed out that failing to account for migration in Kenya would obscure the true differences in child mortality between rural and urban areas. In this study, we estimate trends in under-five mortality for rural and urban regions in Kenya, accounting for the effect of migration. The results are instrumental in targeting and monitoring health interventions in the country.

2. Data and methods

2.1. Data sources

Data for this study were obtained from six demographic and health surveys (DHS) conducted in Kenya between 1989 and 2014. DHS data were chosen for several reasons: First, the DHS provides high-quality demographic data. For instance, using similar surveys from Ghana, Swanson *et al.* (2019) showed that sample-based estimates were reliable. Odwe (2015) also showed that there were no significant errors from the 1989, 1993, 1998, 2003, 2008/2009, and 2014 Kenya DHS data that would affect the demographic estimates derived from them. Second, DHS data are collected periodically at short intervals (usually every 5 years), which is advantageous for trend analysis compared to census data. The data used in this study were collected from birth and individual recode files. Variables of interest included in these files for the study were the current place of residence, duration of stay in the current residence, age of women, and birth histories. These data, together with the data collection procedure and relevant documentation, such as ethical reviews, are accessed at <https://dhsprogram.com/data/>. For legitimate academic research, the data files are available upon request.

2.2. Under-five mortality rate estimation

The Brass indirect method was used to compute the under-five mortality rates. This method was chosen because it is a powerful procedure that provides a good estimate of the under-five mortality rate using summary birth history data. For “summary birth history,” women provided the number of live births they have ever had and the number of those who are currently alive. They also state their ages or the period since their first birth, which is used as a proxy measure of exposure to their children (Arthur & Stoto, 1983; Fotso *et al.*, 2007; Harsha Bangura *et al.*, 2016; Rajaratnam *et al.*, 2010). In DHS, women provide their full birth histories, which include all the children

they have ever had, the date of birth for every child, and the date of death for deceased children. In this case, summarized birth history data for the application of the Brass indirect method could be generated from the DHS full birth histories. Birth history data from DHS and National Fertility Surveys could also be used to estimate under-five mortality rate or to construct models that, in turn, use summary birth history data to estimate under-five mortality rates indirectly (Ayele *et al.*, 2016; Verhulst, 2016; Yadava & Tiwari, 2003). The focus on the under-five mortality rate in this study ensured that we had a reasonable sample size, both alive and dead, from the survey data. The Under-five mortality rate estimate associated with women aged 25–29 years is considered more reliable compared to those associated with younger women (Neupert *et al.*, 2019). Moreover, these older women are more likely to have spent part of their reproductive period in a different location before moving to their current residence compared to the younger women. This indicated that some of their deceased children could have died in a different location where the mother resided before moving to the current location. For instance, in an analysis of migration bias in under-five mortality rate estimates, Schmertmann & Sawyer (1996) reported higher odds ratios for under-five mortality rate among recent in-migrants, with the effect being more pronounced among older women. This suggests that older but recent migrants would have more of their children dying elsewhere than the younger migrants.

The Trussell's variant of the Brass indirect method is shown in Equation (1):

$$q(x) = k(i) D(i) \quad (1)$$

where $q(x)$ is the probability of dying before age, $k(i)$ is a scalar multiplier, and $D(i)$ is the proportion of the children dead among those born to women of age group i . $D(i)$ can be calculated using Equation (2):

$$D(i) = \frac{CD(i)}{CEB(i)} \quad (2)$$

where $CD(i)$ represents the number of children dead among the children ever born (CEB) to women of age group i .

The scale factor $k(i)$ in Equation (1) can be obtained using Equation (3):

$$k(i) = a(i) + b(i) \frac{P(1)}{P(2)} + c(i) \frac{P(2)}{P(3)} \quad (3)$$

where $P(1)$, $P(2)$, and $P(3)$ are the average number of CEB by women of age group 15–19, 20–24, and 25–29, respectively, and where a , b , and c are constants (United Nations, 1989).

For indirect mortality rate estimation, each of the seven age groups of women is associated with a given under-five mortality rate estimate and the corresponding time reference. Typically, the estimated under-five mortality rate for the age group 25–29 is more reliable because of less random error than in other age groups, which usually have smaller sample sizes (Neupert *et al.*, 2019). Reliable under-five mortality rate estimates can also be derived by averaging mortality rate estimates within the neighboring age group of 30–34 years (Central Bureau of Statistics, 2002). With survey data, even estimates corresponding to this age group may be inconsistent because of the small number of deceased children. To reduce random variance associated with small survey samples, we used the average mortality rate for the 25–29, 30–34, and 35–39 age groups as the under-five mortality rate. To estimate the under-five mortality rate, we used the United Nations Program for Child Mortality Estimation, the Q-FIVE, (United Nations, 2013) based on Trussell's regression equations. Trussell's equations model was selected because it is a third-generation of Brass variant model with greater flexibility when using empirical data and is less affected by random errors common in small-sample data. Q-FIVE is part of the MORTPAK software (Version 4.3, Department of Economic and Social Affairs, United Nations), which was developed for demographic measurement, primarily in developing countries, with a special focus on mortality rate analysis (United Nations, 2013).

2.3. Adjustment procedure for the effect of migration

To reduce the effect of migration on under-five mortality rates, we adopted a sub-area adjustment procedure. This method was used to obtain the infant mortality rate in a small area where observations are few, for the application of the indirect method (Neupert *et al.*, 2019). Similarly, survey data from migrant women are insufficient for the indirect method. Therefore, the under-five mortality rate for children who are born to non-migrant women was linked to that of children who are born to all the interviewed women in a given region. Now, the sub-area adjustment procedure is based on the premise that, under a similar pattern of age-fertility and mortality rate, there is a scale factor, λ , that differentiates the risk of mortality experienced in the “parent” area k , from those of any sub-area, r , as shown in Equation (4):

$$q_r(x) = \lambda_r q_k(x) \quad (4)$$

with $q(x)$ representing the probability that a newborn dies before attaining the age of x years. From the census data, λ was estimated using D , the proportion of the children dead among those born to women of age group 20–34. The age group 20–34 was selected because the recent under-

five mortality rate among women of the age group 15–19 is highly inconsistent and thus often ignored. The under-five mortality rate for women in the age groups 20–24 or 25–29 is considered the most reliable estimate. Although most women experience their reproductive period between the ages of 20 and 29, the number of observations from a small area may be insufficient. In this case, the age group was broadened to 20–34 when computing the λ to minimize random variance (Neupert *et al.*, 2019). The λ_r is calculated using Equation (5):

$$\lambda_r = \frac{D_{r,20-34}}{D_{k,20-34}} \quad (5)$$

Synonymously, there is a multiplier, ϕ , that links the under-five mortality rate for all interviewed women in a given region and the mortality rate for non-migrant women in that region. In this case, Equation (5) can be written as Equation (6):

$$\lambda_r = \frac{D_{r,20-39}}{D_{k,20-39}^*} \quad (6)$$

where $D_{r,20-39}$ and $D_{r,20-39}^*$ are the mean proportions of deceased children among those ever born to non-migrant women and those ever born to all the interviewed women within the 20–39 age group, respectively. The broad age group of 20–39 was used to ensure sufficient sample size from the survey data to calculate ϕ_r with minimal variance. $\phi_r < 1$ indicates that in-migration raised the proportion of children who died in the region of concern. In contrast, $\phi_r > 1$ suggests that in-migration lowered the proportion of children who died in the region of interest. In this study, the mortality rate obtained from birth histories of all interviewed women in a given region is considered the gross mortality rate. We classified residence into two mutually exclusive and exhaustive categories: rural or urban. Non-migrant women are therefore defined as those who have not changed their residential region since their first birth.

2.4. Performance of the adjustment procedure

The performance of the adjustment procedure was assessed sequentially as follows. First, we tested whether there was a significant difference in under-five mortality rates between the entire sample population and the under-five mortality rates among non-migrants. We then tested whether the adjusted mortality rates differed from those of non-migrants. Both tests were performed using paired-sample *t* tests. The results of the two tests were compared to determine whether the adjustment procedure reduced the effect of migration on the under-five mortality rate.

3. Results

Table 1 shows the adjustment scale factors for rural and urban regions for the six surveys computed using Equation (6). Except in 1993, migration resulted in an overestimation of the under-five mortality rate in urban regions ($\phi_r < 1$). Migration also led to overestimation of the under-five mortality rate in rural regions, except in 1993 and 2003.

Ideally, non-migrants should yield the most representative mortality estimates. We investigated whether gross mortality rates differed for non-migrants to warrant adjustments. For indirect mortality rate estimation, each of the three age groups of women is associated with seven under-five mortality rate estimates. The under-five mortality rate associated with the age group 15–19 years was discarded because of its high inconsistency (Neupert *et al.*, 2019). Thus, from the six surveys, we had 36 paired observations for comparison. The results presented in Table 2 show that in urban region, the gross under-five mortality rate was significantly different from that of non-migrants ($p < 0.05$). Further, the results show that for both rural and urban regions, the *p*-values are > 0.05 , indicating that the mortality rates adjusted for migration effects are similar to those of non-migrants. This suggests that the adjustment procedure provided valid results.

Figure 1 shows trends in gross under-five mortality rates for rural and urban regions, while Figure 2 shows the under-five mortality rates that are adjusted for the

Table 1. Adjustment scale factor by region and survey year for the Kenya demographic and health surveys

Year	1989	1993	1998	2003	2008/2009	2014
Urban	0.979	1.043	0.853	0.879	0.855	0.944
Rural	0.998	1.000	0.990	1.001	0.983	0.993

Table 2. Results of bootstrap paired sample *t*-tests for under-five mortality of the entire population versus that of non-migrants, and that adjusting for the effect of migration versus that of non-migrants

Region	Mean difference	Standard error	<i>p</i> -value
Mortality rates for the entire sample population versus the mortality rate for non-migrants in the respective regions			
Urban	7.600	1.787	0.002
Rural	0.597	0.356	0.106
Mortality rate adjusted for the effects of migration versus the mortality rate for non-migrants in the respective regions			
Urban	0.981	1.329	0.505
Rural	0.067	0.362	0.858

Note: The number of paired observations in each *t*-test is 36.

migration effect. Accordingly, the gross under-five mortality increased by 15.6% in rural regions and 17.5% in urban regions between the early 1980s and the late 1990s. During this period, the adjusted mortality rate increased by 15.9% and 5.5% for the rural and urban regions, respectively. By the early 2000s, the country started experiencing a steady decline in the under-five mortality rate. For gross mortality, the urban advantage appeared to have disappeared by early 2000s. However, after accounting for the effect of migration, the urban region maintained its child-survival advantage throughout the study period.

4. Discussion

Our study shows that the under-five mortality rate in Kenya increased between the early 1980s and the late 1990s in both rural and urban regions. During this period, rural areas experienced a higher under-five mortality rate than in urban areas. This aligns with earlier studies in Kenya that showed an increase in child mortality in the 1980s and 1990s (Hill *et al.*, 2001). Numerous composite comparative studies in sub-Saharan countries show better child survival outcomes in urban regions than in rural regions before 2000 (Bocquier *et al.*, 2011; Brouckerhoff, 1994). Several of the factors cited for the increased child mortality in the mid-1990s in Kenya included an increase in human immunodeficiency virus prevalence, worsening socioeconomic conditions, and a decline in the quality of healthcare services (Hill *et al.*, 2001). After the mid-1990s, Kenya began to experience steady improvements in child survival due to improved quality of life.

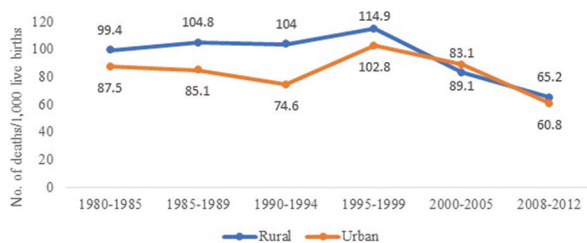


Figure 1. Trends of rural and urban under-five mortality rates based on gross estimates

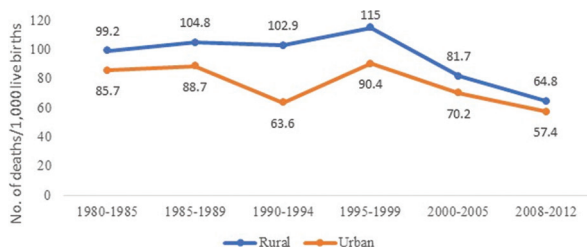


Figure 2. Trends of rural and urban under-five mortality rates based on adjusted estimates

The results also show that the under-five mortality rate for rural and urban regions in Kenya declining and converging in early 2000s. Previous studies in sub-Saharan Africa show a significant decline in child mortality between the 1990s and the 2010s (Ayele *et al.*, 2016; Delaunay, 2001; Garenne & Gakusi, 2006). Our study findings are consistent with these results and those showing a reversal of the rising under-five mortality in Kenya by the late 1990s and subsequent erosion of urban advantage in child survival (Kimani-Murage *et al.*, 2014). The decline in child mortality in the country is associated with improved health systems, including maternal healthcare services, such as deliveries in a health facility, deliveries by a skilled health service provider, and the uptake of postnatal care services for mothers and newborns. There has also been substantial improvement in healthcare-seeking behavior for child illnesses, such as pneumonia, diarrhea, and malaria (Kimani-Murage *et al.*, 2014; KNBS & ICF, 2015; Opiyo & Sawhney, 2014; Wafula *et al.*, 2012).

In this study, under-five mortality rates were overestimated in both rural and urban regions ($\phi_r < 1$) in most survey years of the Kenya DHS from 1989 to 2014, except in 1993 and 2003. This finding suggests a return movement of women from urban to rural regions. Several studies in sub-Saharan countries support this scenario. For example, Bocquier *et al.* (2011) observed a lower mortality rate among children born to rural-to-urban migrants before migration than among those born to rural non-migrants. When they migrate to urban areas, their survival chances improve to a level similar to that of urban non-migrants. On the other hand, children born to urban-to-rural migrants had a higher mortality rate in urban areas than those born to urban non-migrant migrants. Andersson & Drefahl (2017) also reported a greater mortality rate among children born to the returning migrants from southern Sweden, which is predominantly rural, to northern Sweden, which is predominantly urban. Other studies have also pointed out that urban-to-rural migrant households mainly consist of those that have not achieved their economic dreams. They mainly include the urban poor, who are living mostly in slums with inadequate social services (Fotso *et al.*, 2007; Van De Poel *et al.*, 2007). Several challenges that drive people to return from urban to rural areas in Kenya include low wages and high cost of living in urban areas (Okumu & Moenga, 2021). This study revealed the composite effect of migration from rural to urban regions on the under-five mortality rate estimates in Kenya. Urban regions had a larger mean difference in mortality rates between non-migrants and the entire sampled population compared to rural regions. This was because urban regions received a migrant population

from rural areas, who had a significantly higher mortality compared to rural non-migrants. This meant that some of the deceased children of these rural migrants who were assumed to have died in urban regions actually died in rural regions. The results are consistent with those of Schmertmann & Sawyer (1996), who reported that the effects of migration on child mortality estimates can be high in small geographic areas with frequent population exchanges. Such effects are more pronounced in low-mortality regions than in high-mortality regions.

After we adjusted the mortality rate estimates to reduce the effect of including children who died outside the current region of their mothers' residence, the rural–urban under-five mortality rate gaps remained evident throughout the study period, with the urban region maintaining the advantage of child survival over the rural region. The rural–urban child survival gap has been associated with socioeconomic disparities between the two regions, which typically favor urban regions (United Nations IGME, 2018). These findings differ from earlier studies in Kenya that reported a reversal of urban child survival advantage over the rural region in the early 2000s (Kimani-Murage *et al.*, 2014; KNBS & ICF, 2015).

One limitation of this study was that the DHS did not collect vital migration data, such as the date when the migrants arrived in their current place of residence. It was, therefore, not possible to capture series of movements for migrants. In this case, we used only basic information on time spent in the current location and previous location to establish the migration status of women. The adjustment factors were computed based on the mortality experiences of non-migrants women against all interviewed women. Thus, the mortality experiences of migrant women in their current place of residence were missed out. In addition, the indirect method assumes that children always reside in the same geographic location as their mothers. However, older children may reside in totally different locations. The young children of recent rural-to-urban migrants would have been left with their relatives in rural areas as their mothers seek job opportunities in urban areas. It would distort the mortality estimates for either region if the number of children left with relatives and mothers who depart for a different region is significant. Other limitations include non-proportional allocation of samples to rural and urban regions. This could mask the true disparities in under-five mortality rates between these regions.

5. Conclusion

This study showed that imported mortality from rural regions statistically overestimated the under-five mortality rate in urban regions. When the under-five mortality rates

were adjusted for the effect of migration using the small-area approach, the convergence in rural–urban under-five mortality rates disappeared. The urban region maintained higher child survival than the rural region for the study period. The study shows that although Kenya has made progress in child survival, the rural–urban child survival gap remained evident even by the late 2010s. The findings of this study provide grounds to conclude that computing the under-five mortality rate for regions prone to migration with different mortality regimes, without adjusting for migration, distorts mortality rates for the regions. Further research should consider the effect of migration on the socioeconomic spectrum.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: All authors

Formal analysis: Alfred M. Kathare

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Methodology: Alfred T.O. Agwanda

Writing–original draft: Alfred M. Kathare

Writing–review & editing: Kimani Murungaru, Alfred T.O. Agwanda

Ethics approval and consent to participate

The tools and procedures of the DHS are reviewed and approved by the ICF Institutional Review Board (IRB). Data analysis was performed under the original research ethical approvals of the ICR Macro and with participants' consents obtained during the data collection. Before each interview or biomarker test is conducted, a consent statement is read to the respondent in a language she can understand. The informed consent statement contains information on the purpose and the procedures of the survey. Participants are also informed of potential risks and benefits, and of their choice to participate or terminate the interview at any time. Respondents are further informed that their identity and information will be kept strictly confidential. For children and adolescents, consent is obtained from a parent or guardian. These documents are available at <https://dhsprogram.com/>

Methodology/Request-for-documentation-of-ethical-review.cfm.

Consent for publication

Consent for publication of this manuscript is under DHS consent and ethical approval that are available at <https://dhsprogram.com/Methodology/Request-for-documentation-of-ethical-review.cfm>.

Availability of data

The data used in this study are from the birth and individual recode for the six Demographic and Health Surveys conducted in Kenya between 1989 and 2014. This data is available from the Demographic and Health Survey repository at: https://dhsprogram.com/data/dataset_admin/index.cfm. Access to the dataset requires registration and is granted only for legitimate research purposes. A guide on applying for dataset access is available at: <https://dhsprogram.com/data/Access-Instructions.cfm>.

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