# Is There an Urban Advantage in Child Survival in Sub-Saharan Africa? Evidence from 18 Countries in the 1990s

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**Abstract** Evidence of higher child mortality of rural-to-urban migrants compared with urban nonmigrants is growing. However, less attention has been paid to comparing the situation of the same families before and after they migrate with the situation of urban-to-rural migrants. We use DHS data from 18 African countries to compare child mortality rates of six groups based on their mothers' migration status: rural nonmigrants; urban nonmigrants; rural-to-urban migrants before and after they migrate; and urban-to-rural migrants before and after they migrate. The results show that rural-to-urban migrants had, on average, lower child mortality before they migrated than rural nonmigrants, and that their mortality levels dropped further after they arrived in urban areas. We found no systematic evidence of higher child mortality for rural-to-urban migrants compared with urban nonmigrants. Urban-to-rural migrants had higher mortality in the urban areas, and their move to rural areas appeared advantageous because they experienced lower or similar child mortality after living in rural areas. After we control for known demographic and socioeconomic correlates of under-5 mortality, the urban advantage is greatly reduced and sometimes reversed. The results suggest that it may not be necessarily the place of residence that matters for child survival but, rather, access to services and economic opportunities.

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## Introduction    33

Nearly all studies that have examined rural-urban differences of demographic and health    34
outcomes in sub-Saharan Africa show that urban residents fare better than rural residents.    35
Most of these analyses are based on cross-sectional data, such as the Demographic and    36
Health Surveys (DHS), which provide nationally representative samples for rural and    37
urban areas based on respondents' current residence. Eligible residents of selected    38
households in urban and rural areas are interviewed, and their experiences are attributed    39
to the current place of residence. For instance, children whose mothers are interviewed in    40
a given location at the time of interview are assumed to have been living in that location    41
during the exposure period. Estimates for under-5 mortality rates that are published in    42
DHS reports make the implicit assumption that all children under risk as well as their    43
mothers lived in the mothers' current place of residence during the 10-year period that    44
such rates cover. However, it is likely that some families could have migrated to the    45
current place of residence recently and also that some of the children may have lived apart    46
from their mothers during the reference period. With the high level of migration from    47
rural to urban areas that is taking place in most African cities, overlooking the effect of    48
migration can bias the urban and rural mortality estimates and the associated advantage or    49
disadvantage of living in a particular residential area.    50

This article contributes to the renewed interest in the effect of rural-to-urban    51
migration on various demographic and health outcomes by measuring the direction and    52
extent of the migration bias in rural-urban differences in infant and child mortality in    53
sub-Saharan Africa. We use DHS data collected from 18 African countries between    54
1995 and 2001 to examine the extent and direction of bias in rural-urban differences in    55
infant and child mortality rates after controlling for the mother's residence. We also    56
compute and compare child mortality rates by migration status of the mother. A key    57
departure from previous studies that have restricted the analysis only to children born    58
after migration is that we also generate mortality rates for children born before the    59
mother's migration. This allows us to compare the migrants' child mortality experience    60
before they migrated and afterward with the child mortality experience of the    61
nonmigrant populations in both the sending and receiving areas. Urban-rural differences    62
in mortality are also compared using multivariate analysis to control for known    63
demographic and socioeconomic correlates of child mortality.    64

## Background    65

The urban advantage in health indicators in Africa dates back to the nineteenth    66
century with the establishment of urban enclaves that were set up to provide social    67
services for the immigrant colonial settlers (Gould 1998). Disproportionate provision    68
of water, sanitation, health care, and other social services in urban areas created huge    69
disparities in health outcomes between urban and rural residents. In his review of    70
trends in rural-urban differences in child mortality in Africa, Gould (1998) argued    71

that rural mortality has remained higher than urban mortality for more than a century 72
after the arrival of the immigrant colonial settlers. This urban health advantage, 73
coupled with the fact that most Africans live in rural areas, has led to a focus on rural 74
areas in development planning and poverty reduction. However, with rapid 75
urbanization in sub-Saharan Africa, a new picture is emerging. Between 1980 and 76
2000, the region's urban population grew by about 4.7% per year, compared with 77
3.5% for the developing countries as a whole (United Nations Population Division 78
2006). Rapid urbanization in Africa is caused by a high natural increase in urban 79
areas and the influx of mostly young adults migrating rural areas to cities in search 80
of better livelihood opportunities. While the region has been experiencing rapid 81
urban population growth, per capita gross domestic product (GDP) fell by an annual 82
average of 0.8% between 1980 and 2000 (World Bank 2004). As a consequence of 83
the sluggish economic performance and increasing levels of urbanization, large 84
proportions of the urban population in many African countries are living in abject 85
poverty and in overcrowded housing structures that do not have basic amenities, 86
such as safe drinking water, sanitation, and garbage disposal services (APHRC 2002; 87
Montgomery 2009; United Nations Human Settlements Programme [UN-Habitat] 88
2003). The rapid growth of the urban poor population in Africa has renewed interest 89
in rural-urban and intra-urban differences in health and development indicators 90
(Harpham 2009; Montgomery 2009; UN-Habitat 2003). 91

Although improvement in rural health was the main cause of the narrowing of the gap 92
between rural and urban mortality during most of the past half century, the declining urban 93
advantage in African cities in recent times has been attributed to the stalling, and 94
sometimes worsening, urban health indicators (Gould 1998; UN-Habitat 2003). 95
Experience from the history of developed countries suggests that the direction and 96
extent of rural-urban differences in child mortality depends on the level and rate of 97
urbanization as well as the urban areas' economic capacity to generate employment 98
opportunities and provide basic amenities. If the projected increase in African 99
urbanization to more than 48% in 2030 (UN Population Division 2006) is realized 100
without substantial improvement in economic performance and urban governance, it 101
looks inevitable that the urban health disadvantage that characterized the major Western 102
cities at the turn of the nineteenth century will be more pervasive in Africa (Gould 1998; 103
Harpham 2009; Williamson and Galley 1995; Winter 1979; Woods and Hinde 1987). 104

In recent years, monitoring rural-urban demographic and health differences has 105
been made possible by the availability of data, such as those collected under the 106
DHS program. Although the DHS program does not collect migration histories that 107
would enable analysts to take complete account of residence during a reference 108
period, it collects information on duration of stay in the current place of residence 109
and, for migrants, on the point of origin. This enables some reconstruction of 110
migration status during the reference period for most respondents. Using DHS and 111
other types of data, some studies have demonstrated the value of taking into account 112
migration when assessing rural-urban differences of demographic and health 113
indicators in developing countries. Although a few of these studies found no 114
significant difference in health outcomes between migrants and nonmigrants (see, 115
e.g., Coast 2006), the vast majority have found that migrants generally exhibit 116
markedly different health and demographic outcomes compared with populations in 117
their places of origin and destination, even if the direction of the association varies 118

across countries and by the health issue under consideration (Brockerhoff and Yang 1994; Chattopadhyay et al. 2006; Kiros and White 2004; Konseiga et al. 2009; McKinney 1993; Ssengonzi et al. 2002; Stephenson et al. 2003).

With respect to child survival, almost all published studies on the effect of migration on child health in developing countries have been based on cross-sectional data and typically show that rural-to-urban migrants have higher survival probabilities than rural natives, but lower probabilities than urban natives. For instance, Brockerhoff (1990) showed (using 1986 Senegalese data) that children of rural-to-urban migrants experienced much higher risks of under-5 mortality than children of urban nonmigrants. To verify whether the findings of a 1990 Senegal study applied regionally and in other developing regions, Brockerhoff (1995) analyzed 15 DHS surveys carried out between 1986 and 1990 in sub-Saharan Africa, North Africa, Asia, and Latin America. His analysis confirmed the findings of the Senegal study by showing that children of rural-to-urban migrants had poorer survival chances than other urban children, and went further to show that the disadvantage faced by the migrants was more pronounced in big cities than in smaller urban centers. The study also showed that the excess mortality of migrant children in big cities was concentrated in low-quality housing areas, where recent migrants typically live. These findings are compatible with many studies that show that the urban poor sometimes have much higher mortality rates than rural populations (National Research Council 2003; Van de Poel et al. 2007).

The Brockerhoff studies have a number of limitations. First, for migrants, the studies examined the survival status of children born after the mother's migration, but they left out those born before migration. Second, the studies did not look at urban-to-rural migrants. Finally, the 1995 study pooled data from 15 countries to increase the number of cases for computing child mortality for each migration group. Given the differences in patterns and levels of migration across the regions covered by the study, the results may not give an accurate reflection of how migration affects child survival in various countries of sub-Saharan Africa. This caution is important because studies in other regions have not found results that were consistent with Brockerhoff's findings. For example, in a study that used cross-sectional data from India, Stephenson et al. (2003) did not find a statistically significant difference in the mortality risks of children of rural-to-urban migrants compared with urban natives after socioeconomic and health utilization factors were controlled for.

## Possible Sources of Migration Bias

Analysts of retrospective demographic surveys, such as the World Fertility Surveys and the DHS program, often compute rural or urban demographic indicators by using the residence of the respondents at the time of the survey. These estimates are derived under the implicit assumption that the respondents experienced the events (such as death or birth) in the same area of residence where they were interviewed. However, when migration is significant, the extent of rural-urban differences in these demographic indicators is likely to be biased because some of the events could have taken place in previous places of residence. For instance, one can expect the urban-rural difference in child mortality to be underestimated if rural areas exhibit higher

levels of mortality and a sizable proportion of the child deaths take place in rural areas prior to the mother's migration to urban areas. Rural-urban differences would, therefore, be biased, depending on the proportion of migrants among respondents as well as the proportion of the events they experienced outside their current place of residence.

Another important consideration is that DHS surveys collect information on the place of residence of the mother only. This ignores the possibility that mothers and children may be separated for various reasons. For instance, some urban-based mothers may send their children to rural areas because of the low cost of child rearing and education in rural areas compared with urban areas. Children may also be fostered out, and so their environment could differ from that of their mothers (McDaniel and Zulu 1996). To calculate the urban and rural mortality rates properly, one would need data that indicate the residential histories of the children for which the rates are being computed throughout the reference period. Unfortunately, such data are not available in many cross-sectional surveys, including the DHS. Information on change and duration of residence has been collected in the contraceptive calendar histories for the few countries that have administered this module. However, these data are collected only for women who used contraception in the past five years.

For the analysis of childhood mortality, this potential bias of separate residence between mothers and their under-5 children should be small because the majority of under-5 children live with their mothers. For the 18 African countries in this study, between 3.5% and 8.8% of under-5 children lived away from their mothers at the time of the survey (median value, 4.7%). Gabon is rather unusual, with about 14% of under-5 children living away from their mothers. Thus, while acknowledging the possibility of bias introduced by different residences between mothers and their children, we are unable to control for this in the present article because we do not have the data on children's residential histories.

## Methodology

The choice of which sub-Saharan African countries to include in this study is constrained by the availability of DHS data that have information on previous place of residence (i.e., urban or rural) and the duration of stay of the mother in the current place of residence. After examining DHS data sets, we are able to use data from 18 countries that conducted DHS surveys between 1995 and 2001 (middle year, 1998). The 18 countries represent different conditions of urbanization as shown in Table 1. Ethiopia, Malawi, Niger, Rwanda, and Uganda, with less than 20% of their population classified as urban, are the least urbanized but with fast annual urban growth rates of more than 4%; Benin, Central African Republic (CAR), Chad, Kenya, Mali, Mozambique, Tanzania, and Togo have moderate urbanization of between 20% and 40% and an annual urban growth rate of about 4%; and Cameroon, Ghana, Nigeria, and Senegal have between 41% and 50% of their population classed as urban, with an annual urban growth rate of about 3.6%. About 83% of Gabon's population live in urban areas, and the urban population growth is about 2.5%.

The importance of migration cannot be discarded as a minor bias when examining urban-rural differences in infant and child mortality. Table 1 (also

**Table 1** Percentage of mothers in 18 African countries by migration status for those who have lived in both areas (unweighted sample)

| Country | Nonmigrant Urban (1) | Migrant Rural-Urban (2) | Nonmigrant Rural (3) | Migrant Urban-Rural (4) | Total | % Urban, Previously Lived in Rural Area (2) / ((1) + (2)) | % Rural, Previously Lived in Urban Area (4) / ((3) + (4)) | % Urban (UN estimate) |
|---|---|---|---|---|---|---|---|---|
| Benin 2001 | 21.5 | 7.2 | 37.7 | 33.7 | 100 | 25.1 | 47.2 | 41.8% |
| Cameroon 1998 | 20.2 | 11.6 | 33.5 | 34.7 | 100 | 36.5 | 50.9 | 45.6 |
| CAR 1994/1995 | 32.0 | 10.1 | 34.6 | 23.4 | 100 | 23.9 | 40.4 | 38.0 |
| Chad 1996/1997 | 18.0 | 10.6 | 56.5 | 14.9 | 100 | 37.1 | 20.9 | 22.4 |
| Ethiopia 2000 | 7.4 | 11.2 | 74.5 | 6.9 | 100 | 60.4 | 8.5 | 15.2 |
| Gabon 2000 | 50.5 | 15.0 | 8.6 | 25.9 | 100 | 22.9 | 75.1 | 82.8 |
| Ghana 1998 | 23.1 | 6.0 | 26.7 | 44.1 | 100 | 20.7 | 62.3 | 34.6 |
| Kenya 1998 | 10.8 | 13.5 | 61.2 | 14.5 | 100 | 55.6 | 19.1 | 19.1 |
| Malawi 2000 | 9.8 | 11.5 | 60.0 | 18.6 | 100 | 54.0 | 23.7 | 15.2 |
| Mali 2001 | 18.1 | 11.8 | 53.1 | 17.0 | 100 | 39.5 | 24.3 | 30.3 |
| Mozambique 1999 | 18.6 | 13.9 | 58.4 | 9.2 | 100 | 42.9 | 13.5 | 28.6 |
| Niger 1998 | 14.2 | 9.8 | 68.6 | 7.4 | 100 | 41.0 | 9.7 | 18.1 |
| Nigeria 1999 | 26.7 | 5.0 | 42.6 | 25.8 | 100 | 15.7 | 37.7 | 43.2 |
| Rwanda 2000 | 8.3 | 11.8 | 76.4 | 3.5 | 100 | 58.6 | 4.3 | 5.7 |
| Senegal 1997 | 29.6 | 14.3 | 40.3 | 15.8 | 100 | 32.6 | 28.1 | 40.4 |
| Tanzania 1999 | 14.5 | 14.5 | 57.5 | 13.5 | 100 | 49.9 | 19.0 | 25.7 |
| Togo 1998 | 20.1 | 11.8 | 33.5 | 34.6 | 100 | 37.0 | 50.8 | 29.9 |
| Uganda 2000/2001 | 13.8 | 8.5 | 60.2 | 17.6 | 100 | 38.1 | 22.6 | 12.3 |
| 18 Countries | | | | | | | | |
| Weighted 1998 | 18.1 | 9.6 | 53.3 | 19.1 | 100 | 34.7 | 26.4 | 29.2 |

*Notes:* Unweighted estimates from DHS, except UN estimate at the time of the survey for "% Urban" (UN Population Division 2006). Weighted 1998: average at median year of survey (1998), weighted by countries' population.

computed from DHS data) shows that one-third of mothers who lived in urban areas at the time of the survey had lived in rural areas before. The proportion varies from less than 25% (Benin, CAR, Gabon, Ghana, and Nigeria) to more than 50% (Ethiopia, Kenya, Malawi, Rwanda, and Tanzania). Conversely, more than one-quarter of mothers

who are classified as rural residents in the DHS country report lived in urban areas previously. The proportion varies from less than 10% (Ethiopia, Niger, and Rwanda) to more than 40% (Benin, Cameroon, CAR, Ghana, and Togo. The proportion for Gabon is 75%). Because the majority of under-5 children live with their mothers, the preceding figures can be used to assess the error of wrongly assigning births and deaths of children to urban or rural areas. From UN estimates of urbanization (last column of Table 1), we note that countries that are less than 20% urban have both high proportions of mothers currently in urban areas who had lived in rural areas and low proportions of mothers currently in rural areas who had lived in urban areas. The opposite holds for countries with urbanization levels of 35% or higher. In other words, the likelihood of biased urban mortality estimates is higher in countries that are at an early stage of the urban transition, whereas bias in rural mortality estimates is more likely in countries that are well advanced in the urban transition.

Under-5 mortality rates as published by DHS vary from 105 per 1,000 live births in Kenya to 303 in Niger across the 18 countries (see Table 2). The weighted average rate is 160 per 1,000 in these countries, with an urban rate of 118 and a rural rate of 173. In this article we calculate infant and child mortality rates for the 10-year period before the survey, and hence, the analyses in this article pertain roughly to the conditions prevailing in the early 1990s. Information on the duration of stay in the current place of residence (urban or rural) and on the previous place of residence of the mother is available through two questions asked in the women's questionnaire: "How long have you been living continuously in (name of locality, town or city of current residence)?" and "Just before you moved here, did you live in a city, in a town, or in the countryside?" We use this information to estimate infant and child mortality rates that are adjusted for migration status. The age at death is computed in months, and censoring time is also computed in months. The month and year of birth for children are available for 85% of children. The lowest percentages with complete details on date of birth are found in Benin (52%), Togo (67%), Mozambique (71%), and Senegal (75%), and the percentage varies between 84% and 98% in the other 14 countries. In the DHS, the age at death is supposed to be recorded in months before the age of 1, and in years thereafter. In some countries, age at death is recorded in months before the age of 2. Age heaping (rounding of reported ages to completed years) is very common at 12 and 24 months.

With these limitations on age precision in mind, we compute Kaplan-Meier estimates of the under-5 life table for the 10-year period preceding the survey. Children born before this period but who were alive during this period are left-censored and are considered at risk until the age of 5. Our estimation differs from the actuarial method (i.e., the method used in DHS country reports) in that the actuarial method uses aggregates of the number of deaths and persons at risk during the 10-year period to compute rates of death. Additionally, the DHS uses unequal time intervals (less than 1 month, 2 to 3 months, 4 to 5 months, 6 to 11 months, 12 to 23 months, 24 to 35 months, 36 to 47 months, and 48 months to 59 months) to compute death rates, although age at death is given in months before the age 1. Our Kaplan-Meier (KM) estimates, on the other hand, use equal one-month intervals, making use of the age at death or at censoring as it is

**Table 2** Comparison of childhood mortality rates for 18 African countries for the period 0–9 years before the survey, computed using the actuarial (DHS) and Kaplan-Meier (KM) estimation techniques (adjusted and not adjusted for migration of the mother)

| Country and Survey Year | Area | Infant Mortality Rate | | | Child Mortality Rate | | | Under-5 Mortality Rate | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | DHS Report | KM Estimate | | DHS Report | KM Estimate | | DHS Report | KM Estimate | |
| | | | Not Adjusted | Migration Adjusted | | Not Adjusted | Migration Adjusted | | Not Adjusted | Migration Adjusted |
| Benin | Urban | 72.9 | 77.5 | 79.6 | 65.5 | 60.9 | 60.1 | 133.6 | 133.7 | 134.9 |
| 2001 | Rural | 104.5 | 113.8 | 114.3 | 79.3 | 70.7 | 71.4 | 175.5 | 176.4 | 177.5 |
| | Total | 94.8 | 102.8 | 102.8 | 75.0 | 67.6 | 67.6 | 162.7 | 163.4 | 163.4 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Cameroon | Urban | 61.0 | 73.4 | 72.0 | 53.0 | 43.1 | 47.6 | 110.7 | 113.4 | 116.4 |
| 1998 | Rural | 86.9 | 95.3 | 97.8 | 80.2 | 75.6 | 75.7 | 160.1 | 163.8 | 166.1 |
| | Total | 79.8 | 89.4 | 89.4 | 72.3 | 66.3 | 66.3 | 146.3 | 149.7 | 149.7 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| CAR | Urban | 79.9 | 86.1 | 87.8 | 65.5 | 48.7 | 49.6 | 133.6 | 130.6 | 133.0 |
| 1994/1995 | Rural | 116.3 | 119.9 | 119.8 | 70.3 | 68.9 | 69.0 | 178.4 | 180.5 | 180.6 |
| | Total | 101.8 | 106.4 | 106.4 | 63.2 | 60.7 | 60.7 | 158.6 | 160.7 | 160.7 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Chad | Urban | 99.3 | 116.8 | 113.2 | 52.9 | 83.4 | 80.8 | 128.6 | 190.5 | 184.9 |
| 1996/1997 | Rural | 116.3 | 132.4 | 133.5 | 70.3 | 86.4 | 87.2 | 178.4 | 207.3 | 209.1 |
| | Total | 101.8 | 129.0 | 129.0 | 63.2 | 85.7 | 85.7 | 158.6 | 203.6 | 203.6 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Ethiopia | Urban | 96.5 | 105.3 | 108.9 | 57.6 | 49.3 | 46.8 | 148.6 | 149.4 | 150.7 |
| 2000 | Rural | 114.7 | 124.9 | 124.4 | 87.8 | 80.3 | 80.4 | 192.5 | 195.2 | 194.8 |
| | Total | 112.9 | 122.9 | 122.9 | 84.5 | 76.9 | 76.9 | 187.8 | 190.3 | 190.3 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |

t2.1 t2.2 t2.3 t2.4 t2.5 t2.6 t2.7 t2.8 t2.9 t2.10 t2.11

Rural-Urban Deffrences in Child Mortality

| Country | Measure | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gabon 2000 | Urban | 60.7 | 64.7 | 64.2 | 29.5 | 25.7 | 27.1 | 88.4 | 88.8 | 90.0 |
| | Rural | 62.2 | 68.3 | 70.5 | 40.2 | 33.9 | 30.5 | 99.9 | 99.9 | 97.5 |
| | Total | 61.2 | 65.7 | 65.7 | 52.4 | 27.8 | 27.8 | 110.4 | 91.7 | 91.7 |
| | Signif. u-r | n.a. | * | | n.a. | | | n.a. | * | * |
| Ghana 1998 | Urban | 42.6 | 47.5 | 54.3 | 35.7 | 32.2 | 34.8 | 76.8 | 78.2 | 87.9 |
| | Rural | 67.5 | 76.4 | 76.0 | 58.4 | 50.4 | 50.6 | 122.0 | 123.0 | 122.7 |
| | Total | 61.2 | 69.1 | 69.1 | 52.4 | 45.6 | 45.6 | 110.4 | 111.5 | 111.5 |
| | Signif. u-r | n.a. | * | * | n.a. | * | | n.a. | * | * |
| Kenya 1998 | Urban | 55.4 | 62.1 | 66.9 | 34.8 | 28.2 | 21.7 | 88.3 | 88.5 | 87.2 |
| | Rural | 73.8 | 79.9 | 79.0 | 37.6 | 32.2 | 33.4 | 108.6 | 109.5 | 109.8 |
| | Total | 70.7 | 76.9 | 76.9 | 37.1 | 31.5 | 31.5 | 105.2 | 106.0 | 106.0 |
| | Signif. u-r | n.a. | * | * | n.a. | * | | n.a. | * | * |
| Malawi 2000 | Urban | 82.5 | 90.8 | 89.6 | 71.3 | 63.1 | 66.4 | 147.9 | 148.1 | 150.1 |
| | Rural | 116.7 | 132.0 | 132.4 | 106.0 | 87.6 | 87.3 | 210.4 | 208.0 | 208.2 |
| | Total | 112.5 | 126.9 | 126.9 | 101.7 | 84.5 | 84.5 | 202.7 | 200.7 | 200.7 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Mali 2001 | Urban | 105.9 | 123.5 | 125.2 | 88.1 | 70.2 | 69.7 | 184.6 | 185.0 | 186.1 |
| | Rural | 131.9 | 160.1 | 159.7 | 139.8 | 114.0 | 114.2 | 253.2 | 255.9 | 255.6 |
| | Total | 126.2 | 152.0 | 152.0 | 128.3 | 104.1 | 104.1 | 238.2 | 240.3 | 240.3 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Mozam-bique 1997 | Urban | 100.8 | 106.8 | 101.4 | 55.2 | 52.7 | 58.1 | 150.4 | 153.8 | 153.6 |
| | Rural | 159.7 | 175.7 | 177.2 | 91.9 | 77.7 | 76.2 | 236.9 | 239.7 | 239.9 |
| | Total | 147.4 | 161.2 | 161.2 | 83.7 | 72.0 | 72.0 | 218.7 | 221.7 | 221.7 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Niger 1998 | Urban | 79.9 | 89.4 | 86.1 | 106.8 | 97.4 | 96.0 | 178.1 | 178.1 | 173.8 |
| | Rural | 146.7 | 160.8 | 161.2 | 211.7 | 198.8 | 199.0 | 327.4 | 327.6 | 328.1 |
| | Total | 135.8 | 149.1 | 149.1 | 193.0 | 180.6 | 180.6 | 302.6 | 302.8 | 302.8 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |

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**Table 2** (continued)

| Country and Survey Year | Area | Infant Mortality Rate | | | Child Mortality Rate | | | Under-5 Mortality Rate | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | DHS Report | KM Estimate | | DHS Report | KM Estimate | | DHS Report | KM Estimate | |
| | | | Not Adjusted | Migration Adjusted | | Not Adjusted | Migration Adjusted | | Not Adjusted | Migration Adjusted |
| Nigeria | Urban | 59.3 | 71.0 | 71.2 | 51.6 | 42.3 | 44.8 | 107.8 | 110.2 | 112.8 |
| 1999 | Rural | 74.9 | 90.8 | 91.3 | 73.4 | 57.7 | 57.1 | 142.8 | 143.2 | 143.2 |
| | Total | 70.7 | 85.4 | 85.4 | 67.4 | 53.4 | 53.4 | 133.3 | 134.3 | 134.3 |
| | Signif. u-r | n.a. | * | * | n.a. | * | | n.a. | * | * |
| Rwanda | Urban | 77.9 | 86.7 | 82.9 | 68.7 | 64.0 | 64.6 | 141.3 | 145.2 | 148.2 |
| 2000 | Rural | 123.5 | 134.6 | 134.2 | 105.7 | 102.1 | 101.4 | 216.2 | 223.0 | 221.9 |
| | Total | 117.4 | 128.3 | 128.3 | 101.2 | 97.4 | 97.4 | 206.7 | 213.2 | 213.2 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Senegal | Urban | 50.2 | 56.2 | 59.4 | 41.4 | 36.7 | 38.2 | 89.5 | 90.8 | 95.3 |
| 1997 | Rural | 79.1 | 95.8 | 94.6 | 93.7 | 80.7 | 80.4 | 165.4 | 168.7 | 167.4 |
| | Total | 69.4 | 82.5 | 82.5 | 75.2 | 65.0 | 65.0 | 139.4 | 142.1 | 142.1 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Tanzania | Urban | 87.3 | 96.2 | 97.7 | 59.6 | 51.8 | 34.8 | 141.6 | 143.0 | 129.7 |
| 1999 | Rural | 113.0 | 124.2 | 123.3 | 59.7 | 47.9 | 52.1 | 165.9 | 166.1 | 168.8 |
| | Total | 107.8 | 118.5 | 118.5 | 59.7 | 48.7 | 48.7 | 161.1 | 161.5 | 161.5 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| Togo | Urban | 65.3 | 70.1 | 77.1 | 38.4 | 39.3 | 46.4 | 101.3 | 106.6 | 120.6 |
| 1998 | Rural | 85.0 | 92.7 | 91.1 | 79.1 | 73.8 | 72.3 | 157.4 | 159.6 | 156.6 |
| | Total | 80.3 | 87.3 | 87.3 | 69.0 | 65.2 | 65.2 | 143.8 | 146.8 | 146.8 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Uganda | Urban | 54.5 | 58.8 | 69.5 | 48.7 | 43.6 | 44.3 | 100.5 | 99.8 | 110.8 |
| 2000/2001 | Rural | 93.7 | 101.8 | 101.0 | 77.3 | 67.9 | 68.1 | 163.8 | 162.7 | 162.2 |
| | Total | 89.4 | 97.0 | 97.0 | 74.0 | 65.1 | 65.1 | 156.8 | 155.8 | 155.8 |
| | Signif. u-r | n.a. | * | * | n.a. | * | * | n.a. | * | * |
| 18 Countries | Urban | 68.5 | 78.3 | 79.5 | 53.4 | 45.8 | 45.8 | 117.7 | 120.3 | 121.7 |
| Weighted | Rural | 99.9 | 112.1 | 112.1 | 81.2 | 70.6 | 71.0 | 172.5 | 174.3 | 174.5 |
| 1998 | Total | 92.3 | 104.3 | 104.3 | 74.8 | 64.8 | 64.8 | 159.7 | 161.9 | 161.9 |

*Notes*: n.a. indicates that data are not available. Weighted 1998: average at median year of survey (1998), weighted by countries' population.

*Difference between urban and rural estimates is significant at the 5% level.

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recorded from the field. These differences notwithstanding, the DHS and KM   258
computation of the infant and under-5 mortality uses the same formula,   259

$$F(x) = 1 - S(x) = 1 - \left[ \prod_{0 \le ax} (1 - {}_{a+n}q_a) \right],$$

except that $n=1$ for KM computations, whereas $n$ is arbitrarily fixed at unequal   260
time intervals for DHS computations.   262

   The difference in computation between the actuarial (DHS) and the KM methods   263
in the presence of age heaping is explained in the Appendix. For this study, the   264
difference between the estimates should be negligible when the age interval $(a, a + 1)$   265
is small, but the assumption of evenly distributed deaths can produce imprecise   266
estimates when the age intervals are quite large (i.e., six-month or one-year   267
intervals). The gain in precision produced by KM estimates that use monthly   268
intervals is limited, however, by age heaping and by the use of age at death in years,   269
especially for child mortality. Overall, the DHS and the KM methods give about the   270
same estimation of under-5 mortality rates, as shown in Table 2 (see the DHS Report   271
and the KM Estimate Not Adjusted columns). The main reason for preferring the   272
KM method over the DHS method is that by including both right- and left-censored   273
cases, the KM estimates enable us to better compute the mortality rates by place of   274
residence, as explained in the remainder of this section.   275

   We attribute the deaths to the place of residence at the time of death, and not to   276
the place of residence at the time of the survey. Let us take the example of a mother   277
of three who moved from a rural to an urban area in 1995, five years before the   278
survey in 2000. For simplicity, suppose that all events occurred mid-year. Suppose   279
also that the first child was age 13 and lived in a rural area before the age of 5: that   280
is, the first child was left-censored at the age of 3 when entering the 10-year   281
observation period, and right-censored when reaching the fifth birthday. Both left-   282
and right-censoring are noninformative in this case because they correspond to   283
arbitrary date (opening of the 10-year observation period) and age (fifth birthday).   284
This child contributes to the rural population at risk only, and not to the urban area   285
where the mother is now living. In other words, all pre-migration exposures to the   286
risk of dying and actual death, if it occurs, are attributed to the area of residence prior   287
to the migration of the mother. The second child was born in a rural area and lived   288
there from birth up to 3.5 years. This child is right-censored at this age for the   289
computation of the rural mortality, contributing 3.5 years to the rural population at   290
risk. After the migration of the mother, the second child is left-censored in the urban   291
population: that is, the child enters the urban population at risk at age of 3.5 until the   292
fifth birthday. In other words, the second child contributes 3.5 years to the rural   293
mortality estimate and 1.5 years to the urban mortality estimate. If a death occurs, it   294
will be attributed to the area of residence prior to migration or to the current area of   295
residence of the mother, depending on whether she migrated after or before the death   296
of the child. The third child was born three years prior to the survey in the urban area   297
and is right-censored at age 3, contributing to the urban mortality estimate only. All   298
post-migration deaths are attributed to the current area of residence of the mother.   299

   Information on the change of residence is available only in calendar years and not   300
in months in the DHS data. Instead of arbitrarily centering the change of residence in   301
the middle of the year when the migration occurred, we apply a weight in the form   302

of a step function. Returning to the earlier example of the second child, if we know 303
only that the migration occurred during the year 1995, weights will be applied for 304
the urban area according to the monthly calendar (1/12 for January, 2/12 for 305
February, and so on, until 12/12 for December), and the opposite weight (11/12 for 306
January, 10/12 for February, and so on) for the rural area. In addition, because the 307
information is available for the last change of residence only, we make the 308
assumption that only one change of residence occurred in the past 10 years: that is, 309
the previous area of residence before migration stayed the same until the time of 310
migration. We define the KM estimates as "adjusted for migration" when they are 311
computed by using the preceding procedure; KM estimates that are "not adjusted" 312
attribute the whole period of exposure and deaths to the place where the mother was 313
living at the time of the interview. The different estimates are presented in Table 2 314
and are discussed in the next section. 315

Because the focus of this article is on urban-rural differences in child mortality, 316
we disregard urban-to-urban and rural-to-rural movements. Therefore, mortality rates 317
can be compared for six categories of migratory streams for the mothers: (1) rural 318
nonmigrants, (2) urban nonmigrants, (3) rural-to-urban migrants before migration, 319
(4) rural-to-urban migrants after migration, (5) urban-to-rural migrants before 320
migration, and (6) urban-to-rural migrants after migration. The computation of these 321
mortality rates is possible only because we are referring to the migration status of the 322
mother, and not of the child. For example, the under-5 mortality estimate of rural-to- 323
urban migrant mothers before their migration aggregates the children who were alive 324
(or died) in rural areas before migration out of the rural area. For the same rural-to- 325
urban migrant mothers, the under-5 mortality estimate after migration aggregates the 326
children who moved with their mothers to urban areas with children who were born 327
(or died) in urban area. Only the children who were alive at the time when their 328
mother moved are accounted for at the origin and at the destination. We are, 329
therefore, able to compare the under-5 mortality of the children who lived with their 330
mothers before their migration with the mortality of those who lived with their 331
mothers after they migrated (Table 3). To measure the significance of the difference 332
between urban and rural mortality rates, we use 95% confidence intervals as 333
estimated by the KM method. If the two confidence intervals overlap, the rates are 334
not significantly different from each other. 335

We also carry out multivariate semiparametric proportional hazard (Cox) 336
regression to test whether the differences in child mortality across various migration 337
categories remain significant after controlling for various demographic, socioeco- 338
nomic, and environmental factors known to influence child mortality. The model is 339
of the following form: 340

$$\lambda_{\mathbf{x}(t)}(t \mid \mathbf{x}(t)) = \lambda_0(t).\exp^{\mathbf{x}(t)\beta},$$

where $\mathbf{x}(t)$ is a vector of independent, possibly time-varying covariates, and $\beta$ is the 342
associated vector of coefficients: 343

$$\mathbf{x}(t)\beta = x_f\beta_f + m_{ru}\beta_{ru} + m_{ur}\beta_{ur} + r_{nm}\beta_{nm} + r_{ru}(t)\beta_{ru} + r_{ur}(t)\beta_{ur} + x_S\beta_S$$

In the preceding equation, $x_f\beta_f$ represents a set of fixed covariates that are defined at 345
birth and stay constant for the whole observation period: the sex of the child, birth 346

**Table 3** Childhood mortality rates by migration status of the mother for 18 African countries

| Country and Survey Year | Area | Infant Mortality Rate | | | Child Mortality Rate | | | Under-5 Mortality Rate | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | Nonmigrant | Urban to Rural | Rural to Urban | Nonmigrant | Urban to Rural | Rural to Urban | Nonmigrant | Urban to Rural | Rural to Urban |
| Benin | Urban | 79.0 | 91.3 | 70.7 | 62.2 | 55.3 | 46.4 | 136.2 | 141.6 | 113.8 |
| 2001 | Rural | 115.7 | 112.5 | 51.8 | 74.5 | 60.5 | 65.5 | 181.6 | 166.2 | 113.9 |
| | Total | 103.1 | 108.3 | 66.1 | 70.2 | 59.3 | 51.1 | 166.0 | 161.2 | 113.8 |
| | Signif. u-r | * | | | | | | * | | |
| Cameroon | Urban | 70.3 | 74.2 | 83.8 | 40.7 | 65.0 | 55.6 | 108.1 | 134.4 | 134.7 |
| 1998 | Rural | 102.9 | 68.1 | 81.7 | 80.1 | 59.1 | 24.6 | 174.7 | 123.2 | 104.3 |
| | Total | 94.0 | 70.4 | 83.5 | 68.9 | 61.3 | 50.8 | 156.5 | 127.4 | 130.1 |
| | Signif. u-r | * | | | | | | * | | |
| CAR | Urban | 83.9 | 124.7 | 94.5 | 49.9 | 53.1 | 42.8 | 129.6 | 171.2 | 133.3 |
| 1994/1995 | Rural | 119.6 | 119.7 | 131.5 | 68.9 | 76.7 | 30.4 | 180.2 | 187.2 | 157.9 |
| | Total | 104.9 | 121.4 | 103.3 | 61.0 | 69.2 | 39.8 | 159.4 | 182.2 | 139.0 |
| | Signif. u-r | * | | | | | | * | | |
| Chad | Urban | 110.8 | 97.2 | 129.4 | 78.2 | 46.3 | 103.5 | 180.3 | 139.0 | 219.6 |
| 1996/1997 | Rural | 132.3 | 146.0 | 166.2 | 86.6 | 96.8 | 86.8 | 207.5 | 228.7 | 238.6 |
| | Total | 128.2 | 133.0 | 136.8 | 85.0 | 83.6 | 100.7 | 202.3 | 205.5 | 223.7 |
| | Signif. u-r | * | | | | | * | * | | |
| Ethiopia | Urban | 101.2 | 143.3 | 102.7 | 38.0 | 99.2 | 39.4 | 135.4 | 228.3 | 138.1 |
| 2000 | Rural | 124.8 | 106.7 | 119.2 | 80.3 | 63.9 | 93.1 | 195.0 | 163.8 | 201.2 |
| | Total | 123.1 | 128.7 | 112.2 | 77.1 | 82.4 | 67.7 | 190.8 | 200.5 | 172.3 |
| | Signif. u-r | * | | | | | * | * | | |
| Gabon | Urban | 65.5 | 76.9 | 35.2 | 26.5 | 54.5 | 10.3 | 90.2 | 127.3 | 45.1 |
| 2000 | Rural | 66.1 | 66.6 | 114.5 | 29.3 | 29.4 | 44.2 | 93.4 | 94.0 | 153.6 |

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Rural-Urban Deffrences in Child Mortality

| Country | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | 65.6 | 71.0 | 57.0 | 27.0 | 39.7 | 18.7 | 90.8 | 107.9 | 74.6 |
| | Signif. u-r | * | | * | | | | | | * |
| Ghana 1998 | Urban | 44.2 | 85.4 | 67.4 | 27.8 | 48.8 | 55.7 | 70.7 | 130.0 | 119.4 |
| | Rural | 79.0 | 68.0 | 63.0 | 55.8 | 39.1 | 63.7 | 130.4 | 104.4 | 122.7 |
| | Total | 68.1 | 72.0 | 66.2 | 46.5 | 41.2 | 56.4 | 111.5 | 110.2 | 118.9 |
| | Signif. u-r | * | | | | | | * | | |
| Kenya 1998 | Urban | 62.9 | 101.0 | 52.1 | 19.1 | 19.9 | 30.9 | 80.8 | 118.9 | 81.3 |
| | Rural | 78.9 | 83.8 | 73.2 | 32.6 | 31.0 | 65.3 | 108.9 | 112.2 | 133.7 |
| | Total | 77.0 | 91.4 | 60.9 | 31.0 | 26.7 | 26.7 | 105.6 | 115.7 | 102.6 |
| | Signif. u-r | * | | | | | | * | | |
| Malawi 2000 | Urban | 82.3 | 132.8 | 55.4 | 65.8 | 88.0 | 46.1 | 142.7 | 209.1 | 98.9 |
| | Rural | 130.9 | 150.7 | 158.6 | 87.9 | 81.5 | 75.9 | 207.3 | 219.9 | 222.5 |
| | Total | 126.8 | 143.8 | 103.6 | 85.9 | 84.0 | 59.0 | 201.8 | 215.7 | 156.5 |
| | Signif. u-r | * | | * | | | | * | | * |
| Mali 2001 | Urban | 118.0 | 167.5 | 133.4 | 64.4 | 90.7 | 80.3 | 174.9 | 242.0 | 203.0 |
| | Rural | 161.9 | 140.0 | 148.8 | 114.8 | 112.6 | 96.2 | 258.1 | 236.8 | 230.7 |
| | Total | 153.5 | 146.4 | 138.9 | 105.1 | 107.3 | 85.8 | 242.5 | 238.0 | 212.8 |
| | Signif. u-r | * | | | | | | * | | |
| Mozambique 1997 | Urban | 95.5 | 122.8 | 111.7 | 47.8 | 166.7 | 56.6 | 138.7 | 269.1 | 162.0 |
| | Rural | 177.5 | 161.6 | 201.2 | 76.4 | 64.1 | 92.7 | 240.3 | 215.4 | 275.3 |
| | Total | 164.1 | 148.0 | 132.1 | 71.3 | 97.8 | 63.6 | 223.7 | 231.3 | 187.3 |
| | Signif. u-r | * | | * | | * | | * | | * |
| Niger 1998 | Urban | 77.5 | 108.9 | 109.9 | 89.3 | 123.0 | 112.2 | 159.8 | 218.5 | 209.8 |
| | Rural | 164.1 | 56.3 | 154.3 | 199.4 | 205.5 | 145.6 | 330.7 | 250.2 | 277.4 |
| | Total | 153.1 | 70.8 | 119.6 | 183.7 | 185.2 | 119.4 | 308.7 | 242.9 | 224.7 |
| | Signif. u-r | * | | | | | | * | | * |
| Nigeria 1999 | Urban | 71.7 | 76.3 | 59.4 | 41.3 | 64.6 | 55.7 | 110.1 | 136.0 | 111.8 |
| | Rural | 92.6 | 83.2 | 83.1 | 59.8 | 42.0 | 20.2 | 146.9 | 121.7 | 101.6 |

**Table 3** (continued)

| Country and Survey Year | Area | Infant Mortality Rate | | | Child Mortality Rate | | | Under-5 Mortality Rate | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Nonmigrant | Urban to Rural | Rural to Urban | Nonmigrant | Urban to Rural | Rural to Urban | Nonmigrant | Urban to Rural | Rural to Urban |
| | Total | 86.7 | 81.6 | 65.1 | 54.5 | 47.1 | 49.7 | 136.5 | 124.9 | 111.6 |
| | Signif. u-r | * | | * | | | | * | | |
| Rwanda | Urban | 82.2 | 128.8 | 78.9 | 62.4 | 140.5 | 62.1 | 139.5 | 251.2 | 136.1 |
| 2000 | Rural | 134.3 | 166.3 | 120.1 | 101.6 | 134.2 | 76.1 | 222.2 | 278.2 | 187.1 |
| | Total | 129.9 | 155.8 | 93.2 | 88.5 | 137.2 | 66.9 | 215.6 | 271.6 | 153.9 |
| | Signif. u-r | * | | * | | | | * | | |
| Senegal | Urban | 53.7 | 96.5 | 72.1 | 33.9 | 74.9 | 44.9 | 85.8 | 164.2 | 113.7 |
| 1997 | Rural | 97.2 | 83.5 | 38.9 | 82.8 | 63.9 | 62.2 | 172.0 | 142.1 | 98.7 |
| | Total | 83.4 | 86.7 | 65.7 | 66.3 | 66.7 | 47.7 | 144.2 | 147.6 | 110.3 |
| | Signif. u-r | * | | | | | | * | | |
| Tanzania | Urban | 102.2 | 175.8 | 81.5 | 43.3 | 16.9 | 21.7 | 141.1 | 189.7 | 101.4 |
| 1999 | Rural | 121.6 | 153.0 | 98.5 | 47.8 | 53.6 | 180.0 | 163.6 | 198.4 | 260.8 |
| | Total | 118.8 | 157.2 | 86.8 | 47.1 | 47.7 | 64.4 | 160.4 | 197.4 | 145.6 |
| | Signif. u-r | | | * | | | * | | | * |
| Togo | Urban | 75.6 | 98.0 | 54.6 | 37.3 | 112.1 | 21.7 | 110.0 | 199.1 | 75.1 |
| 1998 | Rural | 95.5 | 82.4 | 49.3 | 72.5 | 68.2 | 104.3 | 161.1 | 145.0 | 148.5 |
| | Total | 90.6 | 85.6 | 52.8 | 63.4 | 76.9 | 45.3 | 148.2 | 155.9 | 95.7 |
| | Signif. u-r | * | | | | * | * | * | | * |
| Uganda | Urban | 54.3 | 109.7 | 65.4 | 40.6 | 57.8 | 44.0 | 92.8 | 161.2 | 106.5 |
| 2000/2001 | Rural | 102.0 | 90.5 | 72.0 | 69.2 | 46.0 | 63.0 | 164.1 | 132.3 | 130.5 |
| | Total | 97.9 | 99.4 | 68.7 | 66.7 | 50.5 | 50.8 | 158.1 | 144.9 | 116.0 |
| | Signif. u-r | * | | | | | | * | | |

| 18 Countries | | Urban | 77.1 | 100.9 | 73.9 | 42.2 | 67.7 | 50.9 | 116.0 | 161.7 | 121.0 |
| Weighted | | Rural | 112.8 | 104.6 | 102.7 | 71.7 | 61.5 | 75.4 | 175.9 | 159.5 | 169.7 |
| 1998 | | Total | 105.2 | 106.8 | 85.4 | 65.2 | 64.4 | 57.6 | 163.3 | 164.0 | 139.1 |

*Notes*: n.a. indicates that data are not available. Weighted 1998: average at median year of survey (1998), weighted by countries' population.

*Difference between urban and rural estimates is significant at the 5% level.

cohort, preceding birth interval, and the mother's age at birth. The terms $m_{ru}\beta_{ru}$ and $m_{ur}\beta_{ur}$ symbolize the rural-to-urban and urban-to-rural migration status, respectively, and are also constant over the observation period. The following terms of the equation are dummy indicators of place of residence for each of the migration status: $r_{nm}\beta_{nm}$ for the rural nonmigrants, $r_{ru}(t)\beta_{ru}$ for the rural-to-urban migrants, and $r_{ur}(t)\beta_{ur}$ for the urban-to-rural migrants. These indicators are the only time-varying covariates (depending on time $t$) that are used in the model; they measure the rural-to-urban relative risk of dying for each migration status and are presented in Table 4. Note that the indicator for the nonmigrant does not vary with time. Finally, the term $x_S\beta_S$ pertains to the covariates as measured at the time of the survey: the mother's and father's education and occupation, water source, toilet facility, wealth quintiles, and region of residence.

The results in Table 4 are presented for each of the three migration statuses of the mother; and for three models, from the simplest to the most complete. Following the notation of the methodological section, the first model includes the migration status only:

$$\mathbf{x}(t)\beta = m_{ru}\beta_{ru} + m_{ur}\beta_{ur} + r_{nm}\beta_{nm} + r_{ru}(t)\beta_{ru} + r_{ur}(t)\beta_{ur}. \tag{1}$$

The second model includes the same variables plus the fixed covariates (defined at birth),

$$\mathbf{x}(t)\beta = x_f\beta_f + m_{ru}\beta_{ru} + m_{ur}\beta_{ur} + r_{nm}\beta_{nm} + r_{ru}(t)\beta_{ru} + r_{ur}(t)\beta_{ur}, \tag{2}$$

whereas the third model also includes the covariates that are defined at the time of the survey:

$$\mathbf{x}(t)\beta = x_f\beta_f + m_{ru}\beta_{ru} + m_{ur}\beta_{ur} + r_{nm}\beta_{nm} + r_{ru}(t)\beta_{ru} + r_{ur}(t)\beta_{ur} + x_S\beta_S. \tag{3}$$

For all models, only the coefficient of interest—$\beta_{nm}$, $\beta_{ru}$, and $\beta_{ur}$, showing the rural-to-urban relative risks—are presented in Table 4. (The full results are available on request from the authors.) A relative risk ratio higher than 1 shows that the rural under-5 mortality rate is higher than the urban rate.

## Results

The comparison of the mortality rates computed by the KM and DHS methods (Table 2) shows that infant mortality rates based on the former are consistently higher than those based on the latter method. The median percentage difference is +9% (minimum, +5%; maximum, +20%). The effect on child mortality rate is opposite, showing a negative difference (minimum, –19%; maximum, –4%), with a median value of −13%. However, the urban-rural differences in both infant and under-5 mortality are in the expected direction, showing significantly higher mortality in rural areas than in urban areas.

Overall, the two computation methods produce about the same under-5 mortality estimates in all countries. Because our method of estimation is no

**Table 4** Rural versus urban relative risk of dying before fifth birthday by migration status of the mother for 18 African countries

| Country | National Under-5 Mortality Rate (adjusted for migration) | Nonmigrants | | | Rural-to-Urban Migrants | | | Urban-to-Rural Migrants | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Benin | 163.4 | 1.365** | 1.134** | 1.065 | 0.999 | 1.125 | 1.145 | 1.211** | 1.203* | 1.198* |
| Came-roon | 149.7 | 1.702** | 1.255* | 1.146 | 0.783 | 0.753 | 0.772 | 0.91 | 0.918 | 0.912 |
| Central Africa | 160.7 | 1.417** | 1.176* | 1.033 | 1.233 | 1.233 | 1.167 | 1.089 | 1.17 | 1.157 |
| Chad | 203.6 | 1.177** | 1.091 | 0.945 | 1.13 | 1.102 | 1.069 | 1.703* | 1.746* | 1.766* |
| Ethiopia | 190.3 | 1.434** | 1.01 | 0.701* | 1.543* | 1.416 | 1.334 | 0.705 | 0.775 | 0.789 |
| Gabon | 91.7 | 1.045 | 1.013 | 0.884 | 3.674** | 3.767** | 3.555** | 0.728 | 0.729 | 0.687* |
| Ghana | 111.5 | 1.892** | 1.570** | 1.058 | 0.967 | 0.91 | 0.874 | 0.787 | 0.809 | 0.767 |
| Kenya | 106.0 | 1.478** | 1.107 | 1.153 | 1.671 | 1.585 | 1.37 | 0.921 | 0.847 | 0.811 |
| Malawi | 200.7 | 1.506** | 1.271* | 1.517* | 2.588** | 2.253** | 2.211** | 1.083 | 1.146 | 1.134 |
| Mali | 240.3 | 1.544** | 1.308** | 1.018 | 1.16 | 0.997 | 1.004 | 0.945 | 0.993 | 1.008 |
| Mozam-bique | 221.7 | 1.834** | 1.642** | 1.168 | 1.831 | 1.688 | 1.658 | 0.85 | 0.914 | 0.809 |
| Niger | 302.8 | 2.369** | 1.971** | 1.548** | 1.430* | 1.227 | 1.216 | 1.094 | 1.152 | 1.192 |
| Nigeria | 134.3 | 1.342** | 1.083 | 1.042 | 0.987 | 1.084 | 1.092 | 0.903 | 0.794 | 0.721 |
| Rwanda | 213.2 | 1.645** | 1.261* | 1.197 | 1.469* | 1.382 | 1.446 | 1.161 | 1.374 | 1.358 |
| Tanza-nia | 161.5 | 1.203 | 1.121 | 1.372 | 2.533* | 2.05 | 1.562 | 1.024 | 1.118 | 1.368 |
| Togo | 146.8 | 1.529** | 1.223* | 1.12 | 1.956* | 1.896* | 1.928* | 0.715* | 0.713** | 0.700** |
| Uganda | 155.8 | 1.886** | 1.454** | 1.359* | 1.178 | 1.158 | 1.121 | 0.801 | 0.796 | 0.812 |
| Senegal | 142.1 | 2.149** | 1.681** | 1.13 | 0.827 | 0.887 | 0.863 | 0.837 | 0.865 | 0.857 |

*Notes:* Model 1: Cox regression with migration status as the only covariate. Model 2: Cox regression with migration status and fixed covariates: sex of child, birth cohort, preceding birth interval, mother's age at birth. Model 3: Same as Model 2 plus covariates measured at the time of the survey: parental education and occupation, water source, toilet facility, wealth quintiles, and region of residence.

*p<.05; **p<.01

more immune than the DHS estimation to the potential problem of age heaping 386
at age 12 months and the displacement of infant deaths to the childhood period, 387
we discuss infant, child, and under-5 mortality rates in the next section, but we 388
confine our discussion to under-5 mortality in subsequent sections. 389

Urban and Rural Mortality Estimates Adjusted for Migration Status 390

Comparing the KM estimates that are adjusted and not adjusted for migration 391
(Table 2), we find that the effect of adjusting for migration is mild for both infant 392
and child mortality. Controlling for mother's place of residence has little effect on 393
estimates for rural areas but affects some of the urban estimates. For example, 394
adjusting for migration reduces urban infant mortality in Chad and increases slightly 395
the rural rate, so that the overall result is a significant urban-rural difference. In 396
Ethiopia, Kenya, and Tanzania, urban infant mortality increases after we adjust for 397
migration, resulting in a loss of significance of the urban-rural difference. Similar 398
effects after we adjust for migration are found in Ghana and Nigeria for child 399
mortality, leading to loss of significance in the urban-rural difference. 400

Turning to under-5 mortality, the overall impact of adjusting for migration 401
status on urban-rural differences in under-5 mortality is minimal. The urban- 402
rural differences in under-5 mortality remain significant after adjustment for 403
migration in all countries except Gabon. In Chad and Tanzania, the urban-rural 404
difference in under-5 mortality becomes significant after adjustment for 405
migration. We conclude that the computation method has an effect on the 406
estimation of infant, child, and under-5 mortality rates, but this does not change 407
the main conclusion drawn from the DHS reports: the rural-urban gap in raw 408
under-5 mortality estimates remains substantial and significant (see also Fig. 1). 409
Further examination of the data shows a significant negative correlation between 410
the urban-rural difference and the level of rural under-5 mortality ($r=-.90$, 411
$p$ value $< .001$), demonstrating that where under-5 mortality is very high, the 412
urban-rural difference is relatively small. 413



**Fig. 1** Urban and rural under-5 mortality rates after controlling for migration status of the mother. Black diamonds denote a significant difference; the black square represents the weighted average for 18 countries; and the dotted line represents equality between urban and rural mortality rates
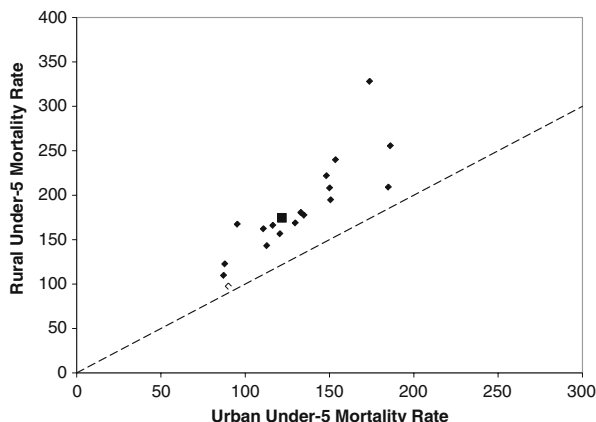
Mortality of Children Born to Rural-to-Urban Migrant Mothers          414

Table 3 presents infant, child, and under-5 mortality estimates by migration status of    415
the mother: nonmigrants (i.e., mothers who did not change residence across the    416
rural-urban boundary during the 10-year period), rural-to-urban migrants, and urban-    417
to-rural migrants. For the sake of brevity, we confine our discussion to the under-5    418
mortality rates only, starting with the mortality of children to mothers who moved    419
from rural to urban areas.    420
   In 11 of the 18 countries, the children of rural-to-urban migrant families    421
experience lower under-5 mortality before migration than do children of nonmigrant    422
rural mothers, confirming the hypothesis that out-migrants from rural areas tend to    423
be a select group, often with better outcomes than nonmigrants. For example, in    424
Benin, the pre-migration under-5 mortality rate for rural-to-urban migrants is 113.9    425
deaths per 1,000 live births compared with 181.6 for rural inhabitants who never    426
migrated. Generally, there is an advantage to migrating from rural to urban areas. In    427
the majority of countries, childhood mortality was lower *after* migration of the    428
mother to urban areas. However, this urban advantage is statistically significant at    429
5% level in only six countries (Gabon, Malawi, Mozambique, Niger, Tanzania, and    430
Togo). In 8 of the 18 countries, urban under-5 mortality of rural-to-urban migrants is    431
significantly higher than the mortality of urban natives; in four countries (Gabon,    432
Malawi, Tanzania, and Togo), migrants' children have significantly lower mortality;    433
and in six countries, there is no statistical difference in urban under-5 mortality rates    434
for migrants and natives.    435

Mortality of Children Born to Urban-to-Rural Migrant Mothers          436

In some countries, the children of urban-to-rural migrants experience high mortality    437
before their mothers' migration relative to other groups in urban areas (e.g., rural-to-    438
urban migrants or urban natives). Also, comparison of mortality risks of the same    439
children *before* and *after* the mother's migration shows that in 11 of the 18 countries,    440
urban-to-rural migrant families experience lower under-5 mortality *after* migration    441
(even though these results are not statistically significant at 5% level). Thus,    442
mothers' migration to rural areas appears to reduce the mortality risk for their    443
children. The small number of women who moved from urban to rural areas may    444
explain the lack of statistical significance, but the results still point to strong    445
peculiarity of the mortality risks of children of urban-to-rural migrants. Only in Chad    446
do we find that families of urban-to-rural migrants experience higher mortality *after*    447
migration, and this effect is statistically significant.    448
   We used weighted averages for all the 18 countries to compare the mortality of    449
the six subgroups by migration status. As Fig. 2 shows, children of rural    450
nonmigrants have, on average, higher mortality than the children of urban    451
nonmigrants (176 versus 116 deaths per 1,000 live births). The figure also shows    452
that the average under-5 mortality of urban nonmigrants is only slightly lower than    453
that of children of rural-to-urban migrants after the migration of their mothers (116    454
compared with 121 per 1,000). The pre-migration under-5 mortality rate for children    455
of urban-to-rural migrant mothers is also much higher than that for children of urban    456
nonmigrant mothers (162 versus 116 per 1,000). The post-migration under-5    457
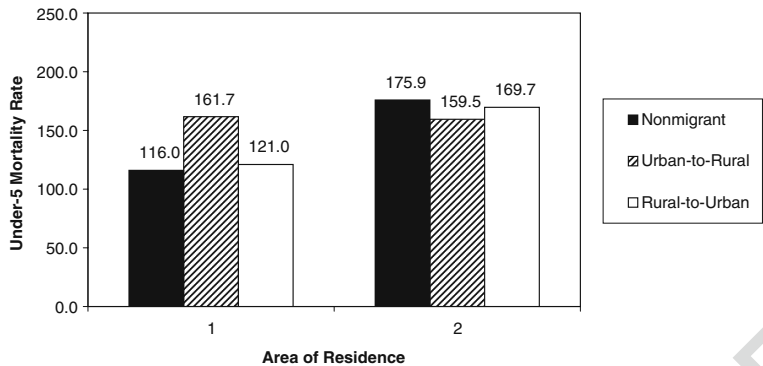
**Fig. 2** Under-5 mortality rates by area of residence and migration status of the mother (weighted average of 18 countries)

mortality of their children remains almost the same (160 per 1,000) as before    458
migration but is slightly better than under-5 mortality of rural children (164 per    459
1,000). If we consider the pooled data of the 18 countries together as representative    460
of the continent, it would appear that in sub-Saharan Africa, rural-to-urban migration    461
is beneficial to the survival of children; urban-to-rural migration is not detrimental to    462
their survival and, in some instances (as the preceding individual country results    463
show), might be beneficial.    464

Net Differences in Urban and Rural Under-5 Mortality    465

The differences between the six groups of migrants described earlier could be a reflection    466
of the social characteristics of the children or their mothers. To control for possible    467
confounders, we use semiparametric proportional hazard (Cox) models to examine the    468
urban-rural differences by migration status for each of the 18 countries (see Table 4).    469
Focusing on the models for nonmigrants and comparing the urban-rural differences in    470
under-5 mortality, we find that in Chad, Ethiopia, Kenya, and Nigeria, the differences    471
between urban and rural areas becomes insignificant when the migration status and    472
fixed covariates are introduced (Model 2). When additional variables measured at the    473
time of survey are added (Model 3), the urban-rural differences disappear in most    474
countries. Rural mortality remains significantly higher than urban mortality in Niger    475
(1% significance level), Uganda (5%), and Malawi (5%). Rather surprisingly, the urban    476
advantage in Ethiopia turns into a disadvantage (5% significance level) after we control    477
for covariates measured at the time of the survey (Model 3).    478

To turn to the results of the rural-to-urban migrants, we observe that the difference    479
in under-5 mortality of children *before* their mothers migrate from rural areas and    480
*after* migration to urban areas is statistically significant (at 5% level or 1%) in seven    481
countries (Model 1); after we adjust for covariates (Models 2 and 3), this difference    482
remains statistically significant (at the 5% level) in three countries only: Gabon,    483
Malawi, and Togo. In all three countries, the under-5 mortality in urban areas is    484
lower than when the families lived in rural areas.    485

Finally, for urban-to-rural migrants, we confine our discussion to four countries    486
(Benin, Chad, Gabon, and Togo) where there are some differences in mortality levels    487

for children *before* and *after* their mothers migrate. Higher mortality after arriving in     488
rural areas relative to the period when the mothers lived in urban areas remains     489
statistically significant (at 5% level) in Benin and Chad after we adjust for migration     490
status, fixed-level covariates, and covariates measured at the time of the survey     491
(Model 3). In Gabon and Togo, under-5 mortality is lower after migration to rural     492
areas, and this is statistically significant at the 5% level in Gabon and at the 1% level     493
in Togo. In the remaining countries, the urban-rural difference in under-5 mortality is     494
not statistically significant.     495

To summarize, the regression analysis show that after we control for migration     496
status and other factors, the urban-rural difference observed with raw estimates is     497
reduced or disappears in 14 of the 18 countries. The implication of this is that the     498
urban environment is beneficial to the survival of children mainly through     499
intermediate variables, such as the length of birth interval, parental education,     500
access to water and sanitation, and household wealth status. Some of the variables     501
are not time variant and thus reflect the household situation at the time of the survey.     502
Time-varying and area-specific indicators of wealth and access to services would     503
certainly provide better estimates of the effect of a change in residential area. For     504
rural-to-urban migrants, the net effect of migration on the mortality of the children     505
shows urban advantage in only 3 of the 18 countries. Migration from urban to rural     506
areas results in lower mortality after migration in 2 of the 18 countries, but higher     507
mortality in two other countries.     508

## Discussion     509

Our study of 18 African countries confirms some of the findings in the literature     510
with regard to urban-rural differences in under-5 mortality and yet also provides     511
contrasting evidence in some aspects. Our analysis confirms the generally held view     512
that under-5 mortality is lower in urban areas than in rural areas. The departure of     513
our findings from many studies that do not control for migration status is that we     514
find that the urban-rural difference disappears in most countries after controls for     515
migration status of the mother and compositional effects (i.e., differences in     516
socioeconomic status, sanitation, and individual child characteristics). The implica-     517
tions for policy are that if rural households have access to sanitation and services,     518
and if their economic well-being improves, rural childhood mortality can decline to     519
levels that cancel out the so-called urban advantage.     520

Comparing rural-to-urban migrants with urban natives, we find that migrants     521
fare worse than natives in less than one-half of the countries. Thus, we conclude     522
that the disadvantage in child survival of urban migrants relative to natives that     523
has been observed by a number of scholars (Brockerhoff 1990, 1995; Konseiga et     524
al. 2009; Van de Poel et al. 2007) is not universal. Many scholars have argued that     525
because many migrants to urban areas live in slums, which lack basic sanitation     526
and access to social services, their children experience worse health outcomes than     527
children of established migrants and natives of the cities (Fotso et al. 2007; Madise     528
et al. 2003; Montgomery and Hewett 2005; National Research Council 2003;     529
Ndugwa and Zulu 2008). In our study, we are unable to establish exactly whether     530
indeed migrants end up in such poor areas; however, there is support in our study     531

that migration is not random and that those moving from rural to urban areas 532
generally appear to have better health outcomes while in rural areas than do other 533
rural families. Those moving from rural to urban areas may be families that are 534
relatively well-off or those with better access to health and social services than 535
other rural inhabitants. Thus, it is possible that such families are able to 536
compensate for hardships that they experience when they first arrive in the cities. 537
Further research is needed to understand why, in countries such as Gabon, Malawi, 538
Tanzania, and Togo, urban under-5 mortality of rural-to-urban migrants is much 539
lower than that of urban natives. 540

Mothers who migrate from urban to rural areas while they are still in the 541
childbearing ages appear to be a highly select group, too. Although the sample is 542
small in almost all the countries we examine, there is evidence to show that children 543
of urban dwellers who migrate to rural areas have very high mortality while in urban 544
areas relative to other urban inhabitants. The people leaving urban areas for rural 545
areas may be mostly those who have failed to achieve their economic goals. These 546
could include the poorest slum dwellers, those with no access to services, and people 547
whose children consequently bear the worst of urban poverty (APHRC 2002). Many 548
studies that have looked at intra-urban differences in child health outcomes report of 549
very high mortality or poor health of children of the poorest urban dwellers (Fotso 550
2006; Madise et al. 2003; Van de Poel et al. 2007). 551

An important question is whether it is more advantageous for child survival to be 552
poor in urban areas than in rural areas. Research published by the National Research 553
Council (2003) that examined child mortality in more than 80 developing countries 554
found evidence of higher mortality among the urban poor compared with rural 555
inhabitants in 25 of 87 countries but the reverse in more than 50 countries. In our 556
study, where we compare child mortality of the same families while they are in urban 557
areas and when they migrate to rural areas, we find evidence of higher mortality 558
before migration from urban areas in 10 of 18 countries (although the difference is 559
statistically significant only in two countries). Few migrate from urban to rural areas, 560
but for those who do, the survival chances of their children may be better or at least 561
no worse when they migrate to rural areas. Thus, for families with the highest risks 562
of child loss in urban areas, relocating to rural communities may be a good option to 563
improve their children's survival chances. 564

A limitation of our study is that we do not control for causes of death that might differ 565
by place of residence and migration status. As an example, HIV/AIDS in sub-Saharan 566
Africa might affect both child mortality rates and the patterns of urbanization. In the 567
majority of sub-Saharan African countries, adult HIV prevalence is higher in urban than in 568
rural areas (Dyson 2003). This can lead to higher urban childhood mortality because of 569
mother-to-child transmission of the HIV virus, such that differences between urban and 570
rural childhood mortality become smaller (Nicoll et al. 1994). However, a study using 571
1999 data from 39 sub-Saharan African countries found that HIV-attributable deaths 572
accounted for less than 10% of under-5 mortality in these countries, indicating 573
that HIV/AIDS may not be the main contributor to trends in under-5 mortality 574
(Walker et al. 2002). HIV/AIDS may also alter the patterns of migration. As an 575
example, if people migrate to rural areas because of illness, or if surviving HIV-576
infected members of a family migrate to rural homes, this would have an impact of 577
increasing rural mortality (Dyson 2003). Assessing the impact of HIV/AIDS 578

correctly would require time-dependent information on HIV status, which is not    579
available in DHS data. Furthermore, not all the DHS data sets that we use have     580
information on HIV status, and where HIV status is available, it is available only  581
for the mothers and only at the time of the survey. Community-based longitudinal   582
studies that include HIV testing are probably the best for disentangling the linkages  583
between migration, HIV/AIDS, and child survival.                                   584

## Conclusion                                                                      585

Urban-rural differences in child health outcomes have received renewed attention   586
because of the rapid migration from rural to urban areas that is taking place in the  587
majority of African countries. This study has shown that taking into account the   588
migration status of the mother when calculating urban-rural under-5 mortality      589
differences refines the estimation of the differences, but the urban advantage remains  590
in most countries. However, this difference declines or disappears in many countries  591
after we control for socioeconomic and reproductive behavior factors. The results  592
suggest, therefore, that it is not necessarily the place of residence but access to amenities,  593
health and social services, and economic opportunities that matters for child survival.  594

## Appendix: Differences Between Actuarial (DHS) and Kaplan-Meier Mortality        595
## Estimates in the Presence of Age Heaping                                        596

To better understand the differences between the estimates, we illustrate with the  597
help of a Lexis diagram, shown in Fig. 3.                                          598

For a given age-specific mortality rate, the computation of the DHS estimate       599
is as follows:                                                                     600

$$DHS = {}_{a+1}q_a^{(e-t) \to (e)} = \frac{\left(\dfrac{d_{(e-t-1) \to (e-t)}^{(e-t) \to (e-t+1)}}{2}\right) + d_{(e-t) \to (e-1)}^{(e-t+1) \to (e)} + d_{(e-1) \to (e)}^{(e) \to (e)}}{\left(\dfrac{s^{(e-t-1) \to (e-t)}}{2}\right) + s^{(e-t) \to (e-1)} + \left(\dfrac{s^{(e-1) \to (e)}}{2}\right)},$$

with $d_{\alpha \to \beta}^{\tau \to \upsilon} = \sum 1_d(i,j)$, $i$ (calendar time: $i \in (\alpha \to \upsilon)$), and $j$ (age or observation time:  602
$(i - \alpha) \geq j > (i - \beta)$) representing the coordinate of each death counted in the Lexis  603
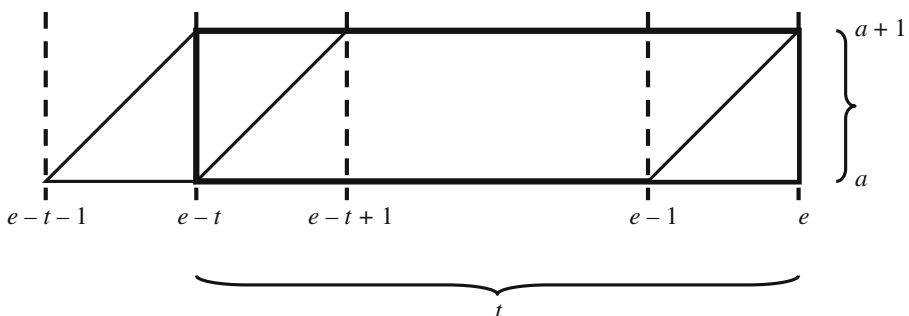


Fig. 3 Lexis diagram for age $a$ and period $t$ before time at survey $e$

diagram in a given calendar-time interval $t$ and age interval $(a, a + 1)$; and  604
$s_{\alpha \to \beta} = \sum 1_s(i)$, counting the survivors of a given cohort at age $a$. Note that the  605
expressions $\alpha \to \beta$ and $\tau \to \upsilon$ represent segments on the Lexis diagram, respectively,  606
at age $a$ and $a + 1$. A segment reduces to a point when the two arguments are the  607
same (e.g., $\beta \to \beta$).  608

In the DHS, an approximation of the deaths occurring in the calendar time  609
interval $(e - t) \to (e - t + 1)$ is done by dividing the number of deaths experienced by  610
the cohort $S_{(e - t - 1) \to (e - t)}$ by 2, with an hypothesis of equal distribution of the  611
deaths in the age interval $(a, a + 1)$. This approximation in the numerator is mirrored  612
in the denominator by adding one-half of the cohort $S_{(e - t - 1) \to (e - t)}$ to one-half of  613
the cohort $S_{(e - 1) \to (e)}$.  614

Using the same notation, the computation of the KM estimate for the same time  615
intervals is:  616

$$KM = {}_{a+1}q_a^{(e-t) \to (e)} = \frac{d_{(e-t) \to (e-t)}^{(e-t) \to (e-t+1)} + d_{(e-t+1) \to (e-1)}^{(e-t+1) \to (e)} + d_{(e-1) \to (e)}^{(e) \to (e)}}{\left(S_{(e-t-1) \to (e-t)} - d_{(e-t-1) \to (e-t)}^{(e-t) \to (e-t)}\right) + S_{(e-t) \to (e-1)} - d_{(e-1) \to (e)}^{(e) \to (e)}} .$$

To compute the KM estimates with left-truncation, only the deaths dated in the  618
interval $(e - t) \to (e - t + 1)$ are counted for the cohort $S_{(e - t - 1) \to (e - t)}$; at the  619
denominator, only the survivors at time $(e - t)$ are counted. Survivors at time $(e - t)$  620
are included in the analysis from the beginning of the age interval even if they  621
spent on average only half the time in the interval. As for right-censoring,  622
among the cohort $S_{(e - 1) \to (e)}$, only those who died in the interval $(e - 1) \to (e)$ are  623
counted, both in the numerator and the denominator. The right-censored  624
individuals are discarded from the analysis at the beginning of the age interval,  625
except for those who died. In other words, the left-truncated are supposed to  626
compensate for the right-censored. The hypothesis is of constant death rate over the  627
time interval $t$.  628

What are the consequences of age heaping in the computation of the two  629
estimates? In large age intervals where age heaping occurs at the end of the interval,  630
the approximation of deaths for the left-censored cohort by $\left(\frac{d_{(e-t-1) \to (e-t)}^{(e-t) \to (e-t+1)}}{2}\right)$ in the  631
DHS equation, following the hypothesis of equal distribution of deaths in the age  632
interval, will tend to underestimate the estimate as compared with the KM estimate  633
computed at exact month. Dividing the deaths of the left-censored cohort by 2  634
underestimates the actual number of deaths recorded in the reference period $t$—in  635
particular, in the 6- to 12-months' age bracket, where most deaths are declared in the  636
eleventh month.  637

Age heaping has the opposite effect for child mortality estimation when age at  638
death is rounded in years: that is, recorded at the 24th, 36th, 48th, and 60th months.  639
Compared with the DHS estimate, the KM estimate computed using monthly  640
interval will overestimate the person-years at risk over the yearly age interval  641
because all deaths are recorded at the end of the interval while the time at risk runs  642
over the entire interval.  643

To sum, although the DHS is not sufficiently precise when it comes to left-  644
censoring in the presence of age heaping, the KM monthly estimate is  645
unnecessarily precise when deaths are recorded at only round ages. However,  646

the two effects compensate for each other for the estimation of the overall under-5 mortality rate.

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