Demography (2011) 48:531–558
DOI 10.1007/s13524-011-0019-2

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

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Published online: 18 May 2011
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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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Keywords Sub-Saharan Africa · Child mortality · Migration · Urban, rural · Rural-Urban

Introduction

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

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

Background

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

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

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

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

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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

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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

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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

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who are classified as rural residents in the DHS country report having 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

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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)

		Infant Mortality Rate			Child Mortality Rate			Under-5 Mortality Rate		
			KM Estimate			KM Estimate			KM Estimate	
Country and Survey Year	Area	DHS Report	Not Adjusted	Migration Adjusted	DHS Report	Not Adjusted	Migration Adjusted	DHS Report	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.	*	*

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Gabon	Urban	60.7	64.7	64.2	29.5	25.7	27.1	88.4	88.8	90.0
2000	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	Urban	42.6	47.5	54.3	35.7	32.2	34.8	76.8	78.2	87.9
1998	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	Urban	55.4	62.1	66.9	34.8	28.2	21.7	88.3	88.5	87.2
1998	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	Urban	82.5	90.8	89.6	71.3	63.1	66.4	147.9	148.1	150.1
2000	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	Urban	105.9	123.5	125.2	88.1	70.2	69.7	184.6	185.0	186.1
2001	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-	Urban	100.8	106.8	101.4	55.2	52.7	58.1	150.4	153.8	153.6
bique	Rural	159.7	175.7	177.2	91.9	77.7	76.2	236.9	239.7	239.9
1997	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	Urban	79.9	89.4	86.1	106.8	97.4	96.0	178.1	178.1	173.8
1998	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		
			KM Estimate			KM Estimate			KM Estimate	
		DHS Report	Not Adjusted	Migration Adjusted	DHS Report	Not Adjusted	Migration Adjusted	DHS Report	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.	*	*

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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 computation of the infant and under-5 mortality uses the same formula,

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

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

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

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

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

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

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

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

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

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

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

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

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

		Infant Mortality Rate			Child Mortality Rate			Under-5 Mortality Rate		
Country and Survey Year	Area	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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	Total	65.6	71.0	57.0	27.0	39.7	18.7	90.8	107.9	74.6
	Signif. u-r			*						*
Ghana	Urban	44.2	85.4	67.4	27.8	48.8	55.7	70.7	130.0	119.4
1998	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	Urban	62.9	101.0	52.1	19.1	19.9	30.9	80.8	118.9	81.3
1998	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	Urban	82.3	132.8	55.4	65.8	88.0	46.1	142.7	209.1	98.9
2000	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	Urban	118.0	167.5	133.4	64.4	90.7	80.3	174.9	242.0	203.0
2001	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	*						*		
Mozam-	Urban	95.5	122.8	111.7	47.8	166.7	56.6	138.7	269.1	162.0
bique	Rural	177.5	161.6	201.2	76.4	64.1	92.7	240.3	215.4	275.3
1997	Total	164.1	148.0	132.1	71.3	97.8	63.6	223.7	231.3	187.3
	Signif. u-r	*		*		*		*		*
Niger	Urban	77.5	108.9	109.9	89.3	123.0	112.2	159.8	218.5	209.8
1998	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	Urban	71.7	76.3	59.4	41.3	64.6	55.7	110.1	136.0	111.8
1999	Rural	92.6	83.2	83.1	59.8	42.0	20.2	146.9	121.7	101.6

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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	*						*		

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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.

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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:

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

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

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

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

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

For all models, only the coefficient of interest—β_{nm}, β_{ru}, and β_{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

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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*
Cameroon	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
Mozambique	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
Tanzania	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.

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

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

Urban and Rural Mortality Estimates Adjusted for Migration Status

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

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

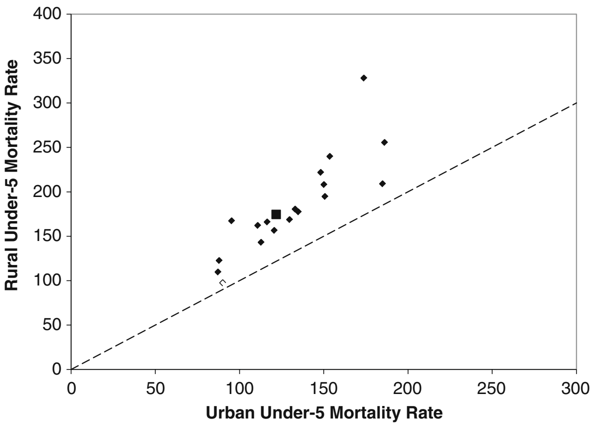

Fig. 1 Urban and rural under-5 mortality rates after controlling for migration status of the mother. Black diamonds denote a significant difference; the black square represents the weighted average for 18 countries; and the dotted line represents equality between urban and rural mortality rates

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

Table 3 presents infant, child, and under-5 mortality estimates by migration status of the mother: nonmigrants (i.e., mothers who did not change residence across the rural-urban boundary during the 10-year period), rural-to-urban migrants, and urban-to-rural migrants. For the sake of brevity, we confine our discussion to the under-5 mortality rates only, starting with the mortality of children to mothers who moved from rural to urban areas.

In 11 of the 18 countries, the children of rural-to-urban migrant families experience lower under-5 mortality before migration than do children of nonmigrant rural mothers, confirming the hypothesis that out-migrants from rural areas tend to be a select group, often with better outcomes than nonmigrants. For example, in Benin, the pre-migration under-5 mortality rate for rural-to-urban migrants is 113.9 deaths per 1,000 live births compared with 181.6 for rural inhabitants who never migrated. Generally, there is an advantage to migrating from rural to urban areas. In the majority of countries, childhood mortality was lower *after* migration of the mother to urban areas. However, this urban advantage is statistically significant at 5% level in only six countries (Gabon, Malawi, Mozambique, Niger, Tanzania, and Togo). In 8 of the 18 countries, urban under-5 mortality of rural-to-urban migrants is significantly higher than the mortality of urban natives; in four countries (Gabon, Malawi, Tanzania, and Togo), migrants' children have significantly lower mortality; and in six countries, there is no statistical difference in urban under-5 mortality rates for migrants and natives.

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

In some countries, the children of urban-to-rural migrants experience high mortality before their mothers' migration relative to other groups in urban areas (e.g., rural-to-urban migrants or urban natives). Also, comparison of mortality risks of the same children *before* and *after* the mother's migration shows that in 11 of the 18 countries, urban-to-rural migrant families experience lower under-5 mortality *after* migration (even though these results are not statistically significant at 5% level). Thus, mothers' migration to rural areas appears to reduce the mortality risk for their children. The small number of women who moved from urban to rural areas may explain the lack of statistical significance, but the results still point to strong peculiarity of the mortality risks of children of urban-to-rural migrants. Only in Chad do we find that families of urban-to-rural migrants experience higher mortality *after* migration, and this effect is statistically significant.

We used weighted averages for all the 18 countries to compare the mortality of the six subgroups by migration status. As Fig. 2 shows, children of rural nonmigrants have, on average, higher mortality than the children of urban nonmigrants (176 versus 116 deaths per 1,000 live births). The figure also shows that the average under-5 mortality of urban nonmigrants is only slightly lower than that of children of rural-to-urban migrants after the migration of their mothers (116 compared with 121 per 1,000). The pre-migration under-5 mortality rate for children of urban-to-rural migrant mothers is also much higher than that for children of urban nonmigrant mothers (162 versus 116 per 1,000). The post-migration under-5

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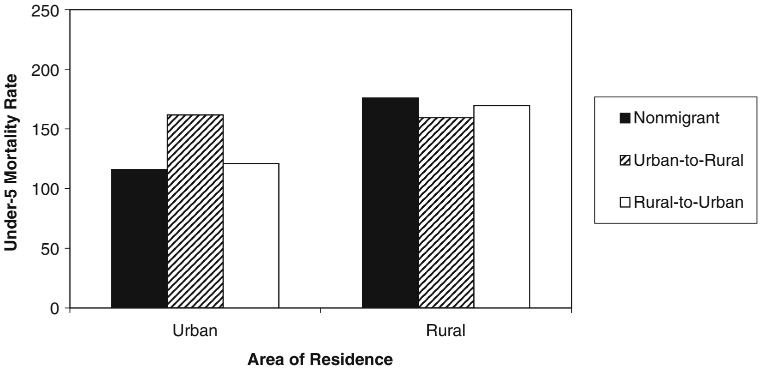

Fig. 2 Under-5 mortality rates by area of residence and migration status of the mother (weighted average of 18 countries)

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

Net Differences in Urban and Rural Under-5 Mortality

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

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

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

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

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

Discussion

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

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

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

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

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

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

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

Conclusion

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

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

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

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

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

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

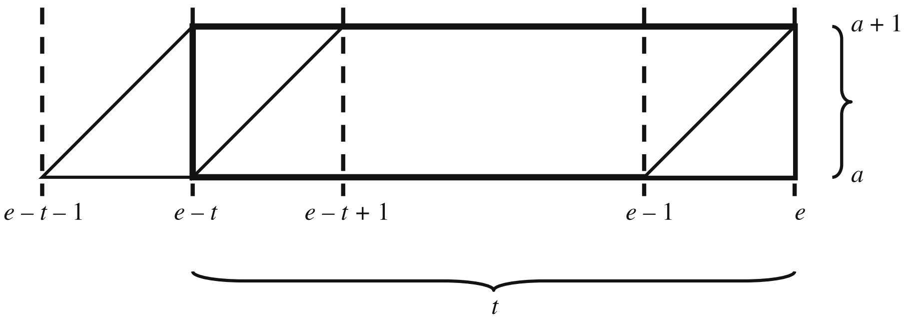

Fig. 3 Lexis diagram for age *a* and period *t* before time at survey *e*

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

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

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

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

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

What are the consequences of age heaping in the computation of the two estimates? In large age intervals where age heaping occurs at the end of the interval, the approximation of deaths for the left-censored cohort by $\left(\frac{d_{(e-t-1)\rightarrow(e-t)}^{(e-t)\rightarrow(e-t+1)}}{2}\right)$ in the DHS equation, following the hypothesis of equal distribution of deaths in the age interval, will tend to underestimate the estimate as compared with the KM estimate computed at exact month. Dividing the deaths of the left-censored cohort by 2 underestimates the actual number of deaths recorded in the reference period t—in particular, in the 6- to 12-months age bracket, where most deaths are declared in the 11th month.

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

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

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

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