USAID
FROM THE AMERICAN PEOPLE

DHS WORKING PAPERS

Child Stunting Across Schooling and Fertility Transitions: Evidence from Sub-Saharan Africa

Sarah C. Giroux

2008 No. 57

DEMOGRAPHIC AND HEALTH RESEARCH

August 2008

This document was produced for review by the United States Agency for International Development.

The *DHS Working Papers* series is an unreviewed and unedited prepublication series of papers reporting on research in progress based on Demographic and Health Surveys (DHS) data. This research was carried out with support provided by the United States Agency for International Development (USAID) through the MEASURE DHS project (#GPO-C-00-03-00002-00). The views expressed are those of the authors and do not necessarily reflect the views of USAID or the United States Government.

MEASURE DHS assists countries worldwide in the collection and use of data to monitor and evaluate population, health, and nutrition programs. Additional information about the MEASURE DHS project can be obtained by contacting Macro International Inc., Demographic and Health Research Division, 11785 Beltsville Drive, Suite 300, Calverton, MD 20705 (telephone: 301-572-0200; fax: 301-572-0999; e-mail: reports@macrointernational.com; internet: www.measuredhs.com).

Child Stunting Across Schooling and Fertility Transitions:

Evidence from Sub-Saharan Africa

Sarah C. Giroux*

Macro International Inc.

August 2008

**Corresponding author*: Sarah C. Giroux, Department of Development Sociology, Cornell University, 434 Warren Hall, Ithaca, NY 14850; Tel: 607-280-2336: Email: sh104@cornell.edu.

ACKNOWLEDGEMENTS

Author thanks Vinod Mishra, Sarah Bradley, Simona Bignami-Van Assche, and Parfait Eloundou-Enyegue for their helpful comments. This research was made possible by a fellowship from the United States Agency for International Development (USAID) through the MEASURE DHS project at the Macro International Inc.

ABSTRACT

Study Objectives. Two concurrent social changes in sub-Saharan Africa have the potential to improve the health of children in these countries. First, the dilution effect of fertility declines may result in the availability of more resources per child. Second, improvements in women's education may additionally translate into improved child outcomes. This study estimates the human capital dividends associated with these dual transitions, especially those in the realm of child stunting.

Data and Methods. This study uses data from six sub-Saharan countries. It examines the relationship between fertility change and stunting at both the macro- (cross-sectional and historical correlation) and micro- (regression) levels. Methodologically, it uses an analytical framework that permits aggregation of micro-level evidence and decomposition of dividends into the specific effects of fertility and educational transitions.

Main Results. First, the cross-sectional findings suggest a relationship between stage in the fertility transition and stunting; however, the historical country-specific trends are less clear. This is partially due to the fact that in three of the six country periods, the number of children competing for resources within the household increased even as fertility declined. Second, the regression results suggest the importance of maternal education and sibsize in the majority of study settings. Lastly, the decomposition shows that changes in the baseline socioeconomic conditions and the effect of sibsize and maternal education are the dominant drivers of change. However, when the prevalence of stunting declines, changes in maternal education and sibsize play an important role. When the prevalence of stunting increases, changes in maternal education make a small, but still significant, contribution.

Conclusions and Implications. The findings suggest that little reduction in stunting can be expected from fertility declines per se, but dividends are more likely when the actual numbers of children residing in households declines. In addition, the findings suggest that recent gains and reversals in women's schooling are contributing to changes in the prevalence of stunting. Policies that promote women's schooling, family-planning programs, and initiatives that channel resources to families with many children may thus help to reduce the prevalence of stunting.

INTRODUCTION

Researchers and policymakers alike are interested in the impact that dual transitions in fertility and women's schooling will have on Africa's children. With regards to fertility transitions, as predicted by demographic transition theory, (Notestein 1945, Caldwell et al. 2006) fertility decline has started in nearly every corner of the globe. Over the past two decades, declines in the total fertility rate (TFR) have been registered in south-central Asia (36 percent), Southeast Asia (29 percent), Latin America and the Caribbean (30 percent), and sub-Saharan Africa (20 percent) (United Nations [UN], 2004).

With these substantial declines in fertility, theory predicts the emergence of a "demographic dividend" (Bloom et al. 2002). The essence of the demographic dividend argument is that, as fertility declines, the age structure of the population shifts to improve dependency ratios; more simply, there are fewer child dependents to be supported by each working-age person. Thus, more resources are available per child, which could improve outcomes related to child health, nutrition and schooling. However, the window of time to capitalize upon the dividend is relatively short because the dependency ratio begins to worsen over time as older workers retire and the proportion of elderly dependents expands. Moreover, even though fertility may be declining at the aggregate (TFR) level, this decline does not necessarily translate into declines in family size at the microlevel. This may partially be the result of practices such as fosterage, which has been historically prevalent in sub-Saharan Africa and is also linked to the high rates of HIV/AIDS in many countries. Increases in family size can also happen if fertility becomes concentrated among certain groups of women. Thus, TFR can actually decrease while the number of children living in a household, and thus competing for resources, increases. Hence, countries many not automatically garner a dividend when TFR decreases. Studies have begun to explore the potential dividends of fertility transitions in terms of human capital but the focus has been on schooling rather than child health outcomes (Knodel et al., 1990; Anh et al., 1998; Bhat, 2002; Lam and Marteleto, 2005; Eloundou-Enyegue and Giroux, 2008[1]). With the exception of the study by Eloundou-Enyegue and Giroux, these studies have focused on Asian and Latin American countries.

In many countries, the fertility decline has been accompanied by long-term gains in women's schooling, both in terms of the overall percentage of women receiving schooling and women achieving higher levels of schooling. Although they still lag behind boys' enrollments in school, girls' enrollments in sub-Saharan Africa have been rising in recent years (Eloundou-Enyegue and Williams, 2006; Lloyd and Hewett, 2003). Between 1990 and 2000, gender parity- the ratio of enrollments of boys to girls- in primary school in sub-Saharan Africa increased from 0.83 to 0.88, and from 0.65 to 0.82 in secondary school (UNESCO 2003. Despite these gains, however, recent research has documented both stalls and reversals in girls' school enrollments in many sub-Saharan countries (Derose and Kravdal, 2007; Lloyd and Hewett, 2003).

Understanding the relationship between the fertility decline and women's schooling trends is important because the concurrent transformations in fertility and women's education could also affect children's outcomes, such as health and nutrition. Maternal education is inversely associated with the prevalence of stunting in their children (Bicego and Boerma, 1991; Wamani et al., 2004), and thus the impact of the fertility decline is likely to be greater among women with higher levels of education. Similarly, the dividend is likely to be larger in societies in which a greater proportion of women have completed primary and secondary school.

[1] Eloundou- Enyegue, P., and S. Giroux. 2008. The schooling dividends from African transitions: Extending the dilution model. Manuscript under review at *Demography*.

Furthermore, if there are declines in women's educational attainment, the dividend is likely to be smaller or nonexistent.

The UN established a Millennium Goal of halving the proportion of people who suffer from hunger and reducing the prevalence of childhood malnutrition between 1990 and 2015. A better understanding of the implications of the fertility decline and educational transitions in sub-Saharan Africa for children's health is therefore warranted. By addressing childhood malnutrition, African nations can indirectly address a host of other development outcomes. For example, child malnutrition is an underlying factor in more than half of all deaths in children under age five in developing countries (Black et al., 2003) and is the single leading cause of the global burden of disease (Murray and Lopez, 1996). Moreover, child malnutrition affects children's mental health, behavioral development, timing of school entry, and educational attainment (Chang et al., 2002; Glewwe and Jacoby, 1993; Glewwe et al., 2001; Weinreb et al., 2002).

This study thus fills at least two gaps in the previous research on the human capital dividends from fertility and educational transitions. The first substantive gap is filled by addressing the human capital dividends in terms of child *stunting* thereby complementing research on the economic and schooling dividends of fertility and educational transitions. The second, geographic, gap is filled by locating this research in *sub-Saharan Africa*, a region in the early stages of both fertility and educational transitions and where the potential dividends from transitions are of key policy interest.

This study uses multiple waves of Demographic and Health Surveys (DHS) survey data from six Sub-Saharan countries. The replications of DHS surveys in many sub-Saharan countries provide historical and comparative data that make it possible to consider how dividends vary across national contexts. Evidence on the magnitude and distribution of these dividends will help public health officials and policymakers target policy in these areas more effectively.

Key Literature

Fertility Transitions. Much of the previous sociological research examining the link between sibsize and children's human capital outcomes has been grounded in dilution theory (Blake, 1981). According to this perspective, declines in fertility result in the spreading of family resources among fewer children, thereby increasing the resources available for each child and improving individual child outcomes. With a few exceptions (Chernichovsky, 1985; Gomes, 1984), most of the evidence from developing countries suggests that having more siblings is disadvantageous for a child's well-being with respect to both education and health. For example, Lalou and Mbacke (1992 found that having more siblings increased the likelihood that children would experience malnutrition in Mali.

Dilution theory has been criticized for a variety of reasons. First, this theory does not take into consideration the distribution of resources within the family. Even as families have fewer children, the potential for discrimination within households means that all children may not benefit equally (Behrman, 1997). Second, even if the TFR declines, the number of children in households can remain stable or even increase. This can happen either when fertility declines are concentrated among certain groups (Giroux et al., 2008) or when the prevalence of fosterage increases. Because of the high rates of HIV/AIDS in many sub-Saharan countries, many families in this region take in extra children, who must then compete with the existing children in their foster families for limited resources. A third criticism of dilution theory relates to the fact that this theory often neglects the relevance of the broader social and economic context. This is an important omission in light of evidence from Lloyd (1994) and Desai (1992) that the relationship between family size and children's outcomes is likely to depend on context. For example, the culture of the family, subsidization of childrearing costs, and stage in the demographic transition can all have an impact on children's outcomes.

Much empirical research has relied on microlevel investigations. However, policymakers, — as is the case of those working towards achieving the MDGs — need aggregate level evidence on how national fertility transitions will affect national outcomes for children. Such evidence requires detailed aggregation of microlevel findings in ways that consider distribution issues. Even if declines in family size do lead to improvements in child health, this does not mean that all children will experience identical improvements in nutritional outcomes, if only because fertility declines at different rates among various groups. Research by Shapiro and Tambashe (2001), for example, showed that the fertility decline in rural areas lagged far behind the decline in urban centers, whereas work by Kirk and Pillet (1998) found substantial variations in fertility declines by family socioeconomic status. Other research has also shown a concentration of reproduction among less educated women in sub-Saharan Africa (Giroux et al., 2008).

In sum, the relevance of dilution theory to policy in general and UN millennium development policy in particular requires methods that address these various critiques. The framework proposed in this paper addresses some of these critiques, notably the importance of examining both the relationship between stunting and TFR and the relationship between stunting and the actual number of children competing for resources within the household.

Educational Transitions. The impact of the fertility decline in sub-Saharan Africa on stunting will also be shaped by the concurrent educational transitions among girls that have been documented throughout the region (Derose and Kravdal, 2007; Lloyd and Hewett, 2003). Although school enrollments for boys have remained stagnant over the past two decades, steady improvements in both school attendance and completion among girls have been noted, despite recent stalls and declines (Derose and Kravdal, 2007; Lloyd and Hewett, 2003).

Gains in girls' education may play an important role in the prevalence of stunting. Research from Uganda found that the children of noneducated mothers were 2.5 times more likely to be stunted than the children of mothers who had completed primary school or higher levels of education (Wamani et al., 2004). Even after analyses control for socioeconomic characteristics, they show that children of noneducated mothers are still 2.1 times more likely to be stunted than children of educated mothers (Wamani et al., 2004). Similarly, Bicego and Boerma (1991) found that mothers' education was a strong predictor of child stunting and that, even after they controlled for socioeconomic status, children of noneducated women in Colombia, the Dominican Republic, and Thailand were twice as likely to be stunted as children of women with secondary schooling.

It should be noted that not all of the research in this area has found evidence of links between maternal education and stunting. Desai and Alva (1998), for example, found evidence of a positive and significant link between height for age and maternal education at the primary level in 6 of 15 sub-Saharan countries and at the secondary level in 13 of the 15 countries. However, controlling for socioeconomic characteristics reduces the magnitude of these coefficients by one third and causes many to drop out of significance. Such mixed findings warrant further investigation to reconcile the disparate evidence.

Various mechanisms have been cited to explain the relationship between maternal education and child health outcomes. Caldwell (1979) noted that beyond improvements in socioeconomic status, higher levels of education have a positive impact on child health through a "shift from 'fatalistic' acceptance of health outcomes towards implementation of simple health knowledge; an increased capability to manipulate the modern world, including interaction with medical personnel; and a shift in the familial power structures, permitting the educated woman to exert greater control over health choices for her children" (Caldwell quoted in Hobcraft, 1993:159). Additional pathways for improving child health as a result of increased maternal education have been identified,, including improved cleanliness (Cleland, 1990; Lindenbaum, 1990), the increased likelihood of using health services (Cleland, 1990), the increased desire among more educated women for higher quality children (LeVine et al., 1991; Chavez et al., 1975), and higher levels of female empowerment (Cleland, 1990).[2] Although this paper does not test these mechanisms, such evidence does suggest the importance of considering the shifting educational composition of populations when trying to understand the nature and magnitude of human capital dividends across fertility transitions.

Although family size and maternal education have separate implications for the health outcomes of children at the microlevel, fertility declines themselves can lead to a concentration of fertility among less educated women at the macrolevel. A recent analysis of DHS data for 31 sub-Saharan countries fielded over the past 16 years shows that the decline in TFR is associated with an increase in the concentration of reproduction among less educated women (Giroux et al., 2008).

National Context. Given the same decline in fertility, some countries might reap greater nutrition dividends than others, depending on the social, economic, and political context under which the declines in fertility occur. The impact of family size on child investment will vary, depending on "1) the level of socioeconomic development, 2) the role of the state, 3) the culture of the family,

[2] See Hobcraft (1993) for an excellent review of this literature.

and 4) the phase of the demographic transition" (Lloyd, 1994). Similarly, work by Desai (1992) found that the relationship between sibsize and height for age is heavily dependent on the extent to which parents bear the cost of child welfare. Thus, even if similar declines in fertility occur across counties, this does not necessarily translate into reductions in stunting in all countries. Instead, the influence of these factors can augment or dampen the dividend, as proposed by dilution theory. The use of data from a few sub-Saharan countries with varying infrastructures and health policies will help clarify the extent to which the context of fertility declines matters for child health outcomes.

Research Questions

Overall, this project uses three complementary methods of quantitative analysis to answer two broad sets of research questions:

1. Is there evidence of a macrolevel health dividend? If so, what is the magnitude of the dividend? How does this dividend vary across countries? How does the understanding of the dividend change when the focus is on TFR or the number of children in the household?
2. Is the dividend shared evenly within national populations? How does the magnitude of the dividend vary by the number of children in the household and the mother's educational attainment? What role do socioeconomic context and changes in the impact of family size and maternal education play?

Conceptual and Analytical Framework

Much of the previous work grounded in dilution theory allows only limited inferences at the macrolevel. Attempts to extrapolate from micro to macrolevel relationships have often resulted in three related ecological, temporal, or distributional fallacies (Eloundou-Enyegue and Giroux, 2008). The (reverse) ecological fallacy arises when microlevel results are used to infer a macrolevel impact. The temporal fallacy arises when the health impacts of fertility declines are inferred from cross-sectional studies, an interpretation that amounts to "reading history sideways" (Thornton, 2001).

Finally, the distributional fallacy arises when microlevel evidence is used to infer macrolevel outcomes, which ignores the distribution of sibsize and educational groups within the population. Knodel et al. (1990) recognized and accounted for this distribution conundrum by using multilevel approaches that involve a double shift, from macro- to microlevel and back. The macro-microlevel shift makes it possible to distill the implications of fertility transitions into the sibsize experiences of children, whereas the reverse shift permits aggregation of microlevel relationships between family size and human capital. This strategy has advanced the understanding of the dividend. However, as the authors acknowledge, the strategy does not account for the potential influence of changing dilution and socioeconomic environments on the dividend.

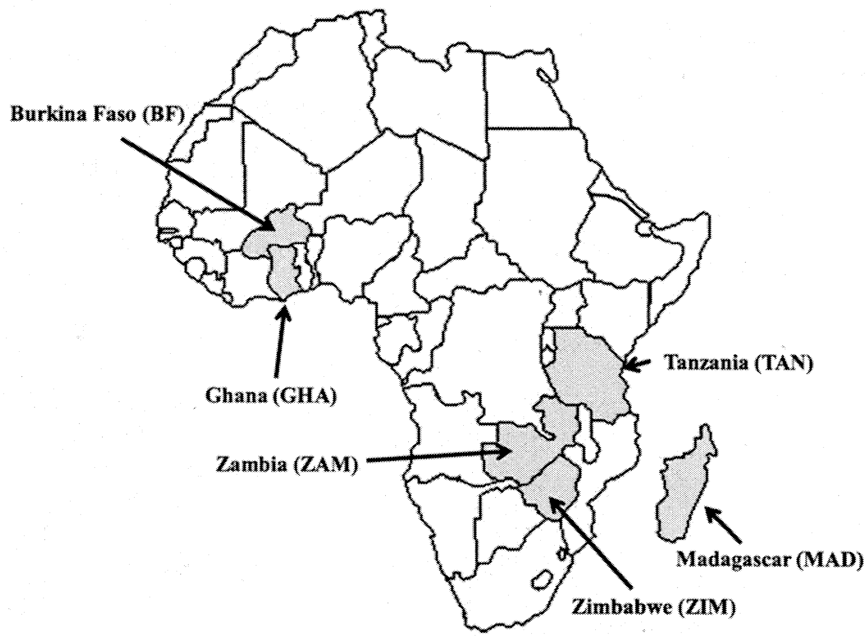
This project builds upon the advancements of Knodel et al. (1990) and also accounts for the potential influence of changing dilution and socioeconomic environments on the dividend. Thus, although this project starts with a dilution theory framework, it expands it in three ways. First, it considers the variations in health dividends that depend on the mother's educational attainment. Second, it examines contextual variability in the dividend. Third, this project mitigates the problems of ecological fallacies by using methods that aggregate microlevel evidence.

To explore the relationship between fertility declines and children's nutrition, three analyses of increasing complexity are deployed. The first, most basic analysis is simply an examination of aggregate correlations of the relationship between TFR and child stunting from cross-sectional and historical perspectives. At this point, we also consider whether or not TFR is an adequate proxy for resource competition. If TFR is an adequate proxy, then trends in the number of children residing in households and in TFR should be similar. The second analysis uses logistic regression to estimate the microlevel effects of family size—the number of children under age 15 years in households—and of the mother's educational background on the children's nutrition. The third analysis uses decomposition methods to apportion changes in health inequality into four components: (1) the influence of the magnitude and evenness of the decline in the number of children in the household; (2) the influence of the changing educational composition of women; (3) the influences of baseline changes in health under the general influence of policy and socioeconomic changes; and (4) the devolution environment, i.e., the extent to which the effects of the number of children in households, mothers' education levels, or both have changed over time.

DATA AND METHODS

This project uses DHS data from sub-Saharan Africa. The main analyses cover six countries at different stages in their fertility and educational transitions. These countries are Burkina Faso, Ghana, Madagascar, Tanzania, Zimbabwe, and Zambia. This country list captures a diverse range of economic and social conditions and transitions. However, the preliminary analyses cover a wider sample of 31 sub-Saharan African countries and 59 country periods.

Figure 1. Country characteristics



Country and DHS Survey Year	BF 1993	BF 2003	GHA 1998	GHA 2003	MAD 1992	MAD 2003	TAN 1992	TAN 2004	ZAM 1992	ZAM 2001	ZIM19 1999	ZIM 2006
Prevalence of stunting in children under age 15 (%)	33.3	38.6	25.9	29.4	54.1	47.3	43.2	37.1	39.8	46.8	26.5	28.1
Total fertility rate	6.5	5.9	4.4	4.4	6.1	5.2	6.2	5.7	6.5	5.9	5.9	5.4
GNI/Capita	810	1,120	1,750	2,140	710	830	410	650	680	790	2,570	1,950
Women 15-49 with no schooling (%)	84	80	30	30	20	22	33	24	16	12	7	4

Data sources: DHS and Food and Agriculture Organization of the United Nations

Figure 1 shows the countries examined in the main analyses. For most, the recent socioeconomic changes would seem to favor reductions in the prevalence of stunting. Economic conditions, as captured by gross national income (GNI) per capita, improved during the survey periods in all of these countries, with the exception of Zimbabwe, which had the highest GNI of any county in its first survey year. These counties also experienced widespread declines in TFR, with the exception of Ghana, where the initially remarkable decline began to stall in the late 1990s. Four of the countries (Burkina Faso, Tanzania, Zambia, and Zimbabwe) experienced a decline in the proportion of women with no schooling. However, despite improvements in these indicators, the prevalence of stunting declined only in Madagascar and Tanzania.

From these observations, two sets of questions emerge. First, for countries where the prevalence of stunting declined, what is the main driver of this decline—increases in the education of women, declines in family size, or other socioeconomic trends? Second, why do the other four countries not show a similar pattern? Might it be partially due to the fact that declines in fertility in sub-Saharan Africa are not homogenous and may vary by education groups? Indeed, are the numbers of children residing within households increasing as fertility declines?

To further address these questions, microlevel data on child stunting and family information from the DHS child files are used. These files contain anthropometric data for children age 5 years and under, as well as information on their mothers (age 15-49 years) and their mothers' partner's characteristics.

Two limitations should be noted. First, the sample of children only includes those who live with their biological mother. Therefore, fostered children, who are probably more disadvantaged, are excluded from the analysis. In addition, only children of women age 15-49 years are included in the survey. Nevertheless, given the limited levels of childbearing that occur in women younger than 15 years or older than 49 years, the sample includes the vast majority of children in the countries included in this analysis.

Measures

Child Malnutrition: The dependent variable in this analysis is child malnutrition status, as indicated by stunting. Essentially, children who are stunted are too short for their age and have suffered from a reduced rate of linear growth (Bronte-Tinkew and De Jong, 2004; Desai, 1992; Kostemans, 1994). Although weight for height (wasting) and weight for age (underweight) are other common measures of child malnutrition status, height for age is most appropriate for this analysis because it is dependent on children's nutritional status, which can be influenced by both food shortages and chronic or recurring diseases. Stunting is thus a "long-run measure of nutritional status which tends to be better explained by socio-economic variables that are also long run in nature" (Bronte-Tinkew and De Jong, 2004). Moreover, as a measure, stunting is less affected by temporary illnesses like diarrhea or by the initiation of weaning foods (Desai, 1992).

As seen in Figure 1, the proportion of children who are stunted (that is, have a height for that is two standard deviations below the median height for children of the same sex and age in an internationally standard index) varies widely across countries and time, from a high of 54 percent in Madagascar in 1992 to a low of 9 percent in Ghana in 1998 (DHS, 2008). Similarly, the change between the first and last survey year has varied as well, with an increase of nearly 15 percent in Burkina Faso to a 14 percent decline in Tanzania. Children whose height for age is less than two standard deviations from the mean height for age are considered to be "stunted" in this analysis and are coded as 1. All others are coded as 0.

Again, it should be noted that it was not possible to calculate the sibsize for orphans and foster children, due to fact that anthropometric data were collected only for children living with their biological mothers.

Sibsize. The first main independent variable of interest is sibsize. For the initial analysis, for all countries, this is simply captured by maternal TFR. However, for the regression and decomposition, a more precise measure is used, the number of children under age 15 years that live in the household, including both biological siblings and other children. Although other measures of family size could be used, such as the number of children ever born, the number of children under age 15 residing in the household arguably best reflects the number of individuals with whom the child competes for resources.

Maternal Education. Maternal education is the second main independent variable. The mother's education level is dummy coded into three categories: no schooling, primary schooling, and secondary schooling and higher. The last category serves as the reference group because this category is assumed to be the most advantageous.

Individual and Household Controls: Controls are introduced for the confounding influences of individual factors that play a role in stunting. These factors are the child's age, child's age squared, child's sex, whether the child had an acute respiratory infection (ARI) in the two weeks prior to the survey, and whether the child had diarrhea in the two weeks prior to the survey. To account for family-level effects, terms are introduced to account for variations in family SES. Specifically, SES is constructed using characteristics of the home's floor, source of drinking water, toilet facilities, access to a radio, electricity, access to television, and ownership of a private car. Children are assigned to various categories as follows: 1= poor floor, poor drinking water, and poor toilet; 2 = two of the following: poor floor, poor drinking water, and poor toilet; 3 = one of the following: (poor floor, poor drinking water & poor toilet) and no radio; 4 = one of the following: (poor floor, poor drinking water, and poor toilet) and a radio; 5 = one of the following: (poor floor, poor drinking water, and poor toilet) and electricity; 6 = one of the following: (poor floor, poor drinking water, and poor toilet) and a television; 7 = one of the following: (poor floor, poor drinking water, and poor toilet) and a refrigerator; 5 = one of the following: (poor floor, poor drinking water, and poor toilet) and a car. Additional family level controls included rural residence, parental marital status, whether the mother has skilled employment, whether the father has skilled employment, sex of the household head, age of the household head, and maternal body-mass index.

Analyses

Cross-sectional and Historical Trends. The analysis simply examines cross-country correlations of the relationship between TFR and child health. This makes it possible to determine if, at the broadest level, there is any discernable relationship between the country's stage in the fertility transition and its prevalence of child stunting. This preliminary analysis gives a panoramic overview of the cross-sectional relationship between national fertility levels and the prevalence of child stunting. The second step is to determine if there is any pattern in the relationships between historical trends in TFR and child stunting.

Logistic Regression. The third step in the analyses is the use of logistic regression to examine the microlevel relationship between the number of children under age 15 years residing in the household and child stunting while controlling for the individual and household characteristics listed above.

Estimating the Dividend and Decomposition. The framework further addresses distributional issues through a consideration of how the health dividends are unevenly distributed across maternal education groupings. Thus, the macrolevel prevalence of stunting (*R*) at time *t* is calculated as:

$$R_t = \sum_j w_{jt} X_{jt}$$

Where j is a variable defined by an exhaustive set of mutually exclusive maternal education groups, wjt is the proportion of children within each maternal education group, and xjt is the prevalence of stunting associated with each maternal education group.

The macrolevel dividend in stunting is then a function of changes in both within-group prevalence of stunting and changes in group size:

$$\Delta R \approx \left[\sum \bar{X}_j * \Delta w_j\right] + \left[\sum \bar{w}_j * \Delta X_j\right]$$

Where $\bar{X}$ and $\bar{w}$ represent the averages of t and t+1.

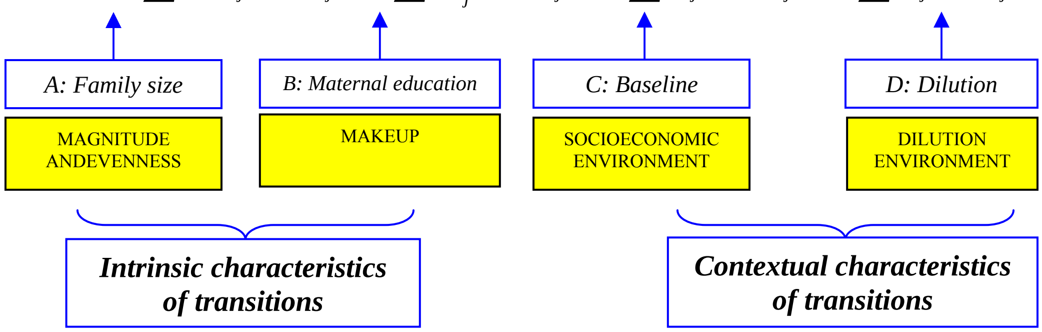
If a linear dilution is assumed— which is arguably appropriate in this case because the outcome is dichotomous and is expressed in logit units—it is then possible to further decompose the second component of the above decomposition into:

$$X_{jt} = \alpha + \left(\beta_{St} S_{jt} + \beta_{jt} * j\right)$$

Where α, the baseline, indicates the group-specific rate of stunting for an only child; Sjt is the impact of family size; and βSt and βjt are dilution coefficients associated with family size and maternal education group (j), respectively.

Changes in *R* can then be decomposed into four components: (1) the influence of the magnitude and evenness of the decline in family size; (2) the influence of educational transitions; (3) the influences of baseline changes in health under the general influence of policy and socioeconomic changes; and (4) the devolution environment, i.e., the extent to which dilution from family size, maternal education, or both has changed over time. The decomposition framework used in this paper is discussed in detail in Eloundou-Enyegue and Giroux (2008) and can be summarized as follows:

$$\Delta R \approx [\sum \bar{\beta}_s \bar{w}_j * (\Delta S_j)] + [\sum \bar{X}_j * (\Delta w_j)] + [\sum \bar{w}_j * (\Delta \alpha_j)] + [\sum \bar{w}_j * ((\bar{S}_j \Delta \beta_s) + \Delta \beta_j)]$$



Where j indexes different subpopulations, w represents their relative size, and S is the average sibsize within each subpopulation. βs and βj represent the dilution associated with family size and maternal education, respectively.

FINDINGS

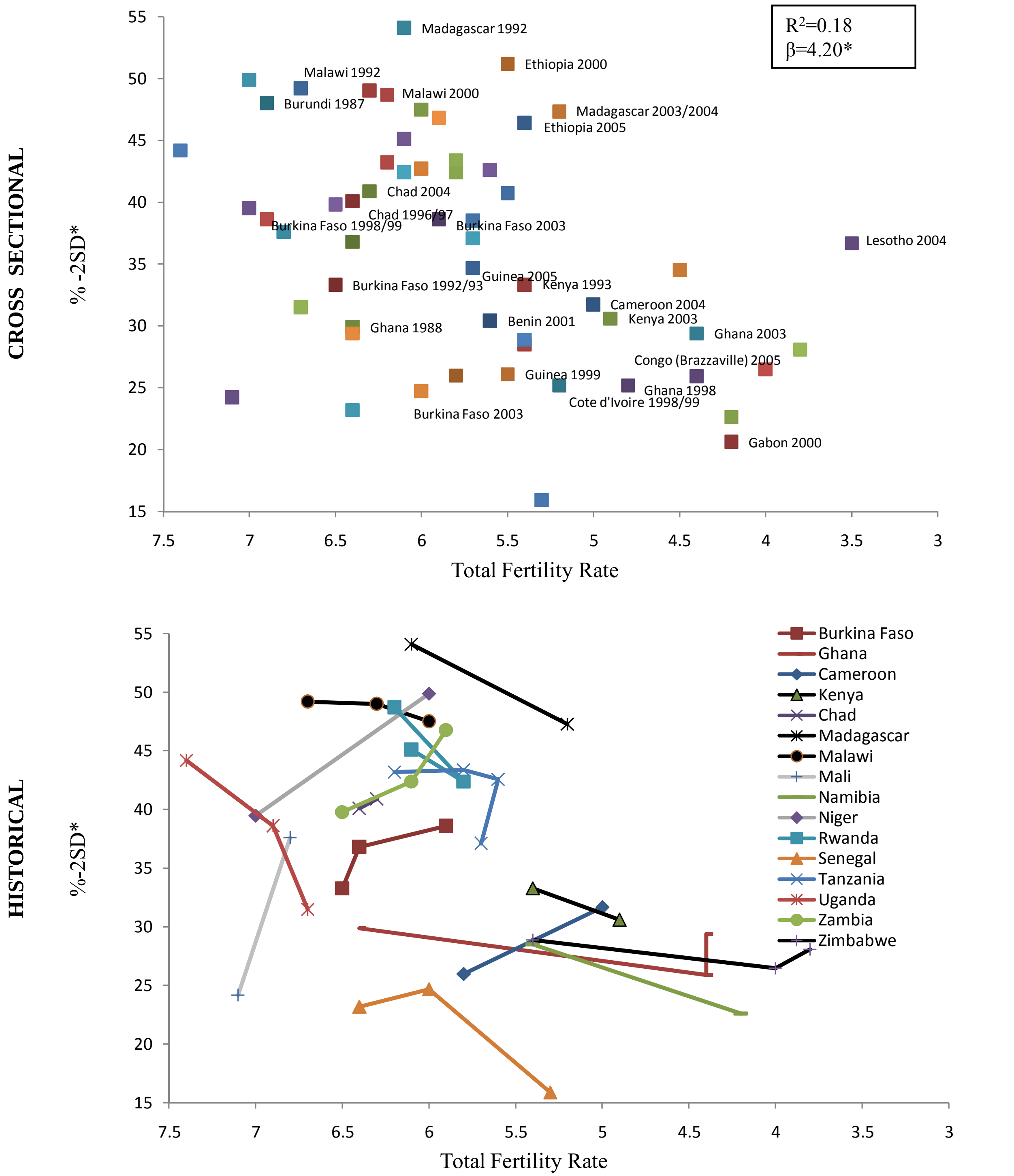
Cross-country Correlations

Figure 2 shows the historical and cross-sectional findings for the relationship between stunting and fertility transitions at the macrolevel. As seen in the top frame, the cross-sectional perspective suggests support for the resource dilution hypothesis. The prevalence of severe stunting declines as fertility levels decline. Indeed, national TFR explains 18 percent of the variance in severe stunting. With each unit decline in stunting, countries can expect a 4.20 unit decline in stunting.

However, although this cross-sectional picture may hint at the presence of a demographic dividend in child nutrition, the historical perspective shown in the bottom frame of the figure tells a different story. Some countries, such as Madagascar and Uganda, follow the expected pattern, with a decline in the prevalence of stunting across the fertility transition. However, other countries, such as Cameroon and Burkina Faso, have experienced an increase in stunting during the fertility decline. Moreover, other countries, like Ghana, show little evidence of a relationship between their fertility decline and stunting levels.

To better understand these historical relationships, the analysis shifts to a consideration of whether they may be due to the fact that the TFR may not adequately reflect the actual number of children competing for resources within households. Table 1 provides data that can be used to assess whether the TFR is an acceptable proxy for resource competition in the rest of the analysis.

Figure 2. Relationship between prevalence of child stunting and stage in fertility transition: cross-sectional and historical perspectives, DHS, selected sub-Saharan countries, 1987-2006



* -2 SD refers to the proportion of children whose height is two standard deviations below the median height of children of the same sex and age in an internationally standard index.

Table 1. Changes in the educational composition of women and the average number of children under the age 15 in the household, 1992-2006

	YEAR 1		YEAR 2	
	1992-93		2003	
Burkina Faso	Women	Children under age 15 (N)	Women	Children under age 15 (N)
No schooling	83%	5.35	87%	5.39
Primary	12%	4.66	9%	4.40
Secondary or higher	5%	3.54	4%	3.45
Weighted average		*5.18*		*5.23*
	1998		2003	
Ghana	Women	Children under age 15 (N)	Women	Children under age 15 (N)
No schooling	47%	3.72	47%	3.92
Primary	19%	3.05	22%	3.01
Secondary or higher	34%	2.63	30%	2.83
Weighted average		*3.22*		*3.39*
	1992		2003-04	
Madagascar	Women	Children under age 15 (N)	Women	Children under age 15 (N)
No schooling	19%	3.79	21%	3.47
Primary	57%	3.63	50%	3.31
Secondary or higher	24%	3.25	29%	2.79
Weighted average		*3.57*		*3.19*
	1992		2004	
Tanzania	Women	Children under age 15 (N)	Women	Children under age 15 (N)
No schooling	37%	4.95	28%	4.24
Primary	60%	3.89	65%	3.44
Secondary or higher	3%	3.49	7%	3.05
Weighted average		*4.27*		*3.64*
	1992		2001	
Zambia	Women	Children under age 15 (N)	Women	Children under age 15 (N)
No schooling	18%	3.84	16%	3.52
Primary	65%	4.03	66%	3.57
Secondary or higher	17%	3.90	18%	3.50
Weighted average		*3.97*		*3.55*
	1999		2006	
Zimbabwe	Women	Children under age 15 (N)	Women	Children under age 15 (N)
No schooling	8%	3.89	4%	4.17
Primary	49%	3.20	41%	3.33
Secondary or higher	43%	2.66	55%	2.82
Weighted average		*3.02*		*3.08*

As noted in Figure 1, fertility declined in all countries during the survey period, with the exception of a stall in Ghana. However, it is clear in Table 1 that declines in fertility do not always translate into declines in the average number of children under age 15 living in a household. Although there was a decline during the study period in the average number of children living in households in Madagascar, Tanzania, and Zambia, the number increased in Burkina Faso, Ghana, and Zimbabwe.

Thus, TFR is not an adequate proxy for resource competition among children and using TFR as a proxy for resource competition among children may muddy the understanding of the implications of dilution theory for the relationship between changes in family size and the prevalence of stunting. Thus, the next series of analyses uses the number of children under age 15 who reside in a household as the main independent variable of interest.

Logistic Regression

Logistic regression is used next to understand the relationships between sibsize and stunting. Table 2 shows some interesting results. The effect of sibsize is only significant (at the 0.10 level) in seven of the 12 country-years. In five of these seven cases, the coefficient is in the expected direction, with children from larger families being more likely to experience severe stunting. However, in Tanzania in 2004 and Zambia in 1992, children from families with more children in the household under age 15 were less likely to be stunted. In Tanzania, this may be due to the impact of socialist welfare policies that mitigate the negative impacts of family size. The positive impact of sib size on stunting could also be due to the increased number of children under age 15 years who are employed and thus help improve the welfare of households. Nevertheless, on the whole, it appears that in 50 percent of countries, declines in family size lead to important reductions in the likelihood of stunting.

Table 2. Logistic regression results for the effects of family size and maternal education on child stunting, DHS, six sub-Saharan African countries, 1992-2006

	Burkina Faso				Ghana				Madagascar			
	1992-93		2003		1998		2003		1992		2003-04	
Variables	B	$e^{(B)}$	B	$e^{(B)}$	B	$e^{(B)}$	B	$e^{(B)}$	B	$e^{(B)}$	B	$e^{(B)}$
Children under age 15	0.02	1.02	0.03 ***	1.03	0.06 +	1.06	0.05 +	1.05	0.04 *	1.04	0.00	1.00
Maternal education												
None	0.77 **	2.17	0.68 ***	1.98	0.26 *	1.30	0.30 *	1.35	-0.12	0.89	0.17	1.19
Primary	0.38	1.46	0.38	1.46	0.24 +	1.27	-0.21	0.81	0.17 +	1.18	0.25 *	1.28
Secondary or higher	*ref*		*ref*		*ref*		*ref*		*ref*		*ref*	
Individual and family characteristics												
Child age	1.45 ***	4.25	1.57 ***	4.81	1.31 ***	3.70	1.10 ***	2.99	1.31 ***	3.71	0.87 ***	2.38
Child age squared	-0.26 ***	0.77	-0.30 ***	0.74	-0.21 ***	0.81	-0.21 ***	0.81	-0.24 ***	0.78	-0.16 ***	0.85
Child is female	-0.11	0.90	-0.09	0.92	-0.33 ***	0.72	-0.27 **	0.76	-0.14 *	0.87	-0.11	0.90
Age of household head	0.00	1.00	0.00 +	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00
Household head is female	0.20	1.23	-0.16	0.85	0.16	1.18	-0.01	0.99	-0.13	0.88	-0.03	0.97
Parents are married or cohabiting	0.06	1.07	-0.01	0.99	-0.23	0.80	-0.26	0.77	-0.29 *	0.75	0.01	1.01
Family lives in rural area	0.45 ***	1.57	0.23 *	1.26	0.31 *	1.37	0.14	1.15	0.27 *	1.31	0.00	1.00
Mother has skilled employment	-0.08	0.92	-0.14	0.87	-0.16	0.85	-0.15	0.86	-0.07	0.93	-0.18	0.84
Father has skilled employment	-0.07	0.93	-0.20 *	0.81	0.00	1.00	-0.07	0.93	0.19 +	1.21	0.03	1.03
Family socioeconomic status	-0.12 **	0.89	-0.16 ***	0.85	-0.19 ***	0.83	-0.18 ***	0.84	-0.13 ***	0.88	-0.15 ***	0.86
Maternal and child health												
Maternal body mass index (BMI)	0.00 +	1.00	0.00 **	1.00	0.00	1.00	0.00 +	1.00				
Child had acute respiratory infection (ARI) in the two weeks prior to survey	0.04	1.04	0.04	1.04	0.16	1.18	-0.13	0.87	0.15	1.17	-0.02	0.98
Child had diarrhea in the two weeks prior to survey	0.10 +	1.10	0.09 **	1.10	0.10 +	1.11	0.06	1.06	0.00	1.00	0.11	1.12
Constant	-2.54		-1.58		-1.48		-0.46		-0.71		-0.62	
-2 Log Likelihood	-2499.99		-5190.12		-1329.52		-1618.91		-2744.75		-3507.21	
N	4115.00		8749.00		2701.00		3123.00		4048.00		4690.00	

(Cont'd)

Table 2 – cont'd

Variables	Tanzania 1992 B	Tanzania 1992 $e^{(B)}$	Tanzania 2004 B	Tanzania 2004 $e^{(B)}$	Zambia 1992 B	Zambia 1992 $e^{(B)}$	Zambia 2001 B	Zambia 2001 $e^{(B)}$	Zimbabwe 1999 B	Zimbabwe 1999 $e^{(B)}$	Zimbabwe 2006 B	Zimbabwe 2006 $e^{(B)}$
Children under age 15	-0.02	0.98	-0.05 ***	0.95	-0.04 *	0.96	0.03	1.03	0.06 +	1.06	0.05 +	1.05
Maternal education												
None	0.65 **	1.91	0.54 **	1.72	0.21	1.23	0.33 **	1.40	0.43 *	1.53	-0.04	0.96
Primary	0.51 *	1.67	0.45 *	1.57	0.24 *	1.27	0.28 **	1.32	0.10	1.10	-0.10	0.91
Secondary or higher	ref		*ref*		*ref*		*ref*		*ref*		*ref*	
Individual and family characteristics												
Child age	1.15 ***	3.15	1.06 ***	2.88	1.43 ***	4.20	1.36 ***	3.89	0.99 ***	2.69	0.90 ***	2.47
Child age squared	-0.21 ***	0.81	-0.19 ***	0.83	-0.28 ***	0.75	-0.26 ***	0.77	-0.20 ***	0.82	-0.19 ***	0.83
Child is female	-0.11 +	0.90	-0.11 +	0.90	-0.13 *	0.88	-0.14 *	0.87	-0.18 +	0.84	-0.12	0.89
Age of household head	0.00	1.00	0.00	1.00	0.00	1.00	-0.01 **	0.99	0.00	1.00	0.00	1.00
Household head is female	-0.02	0.98	0.03	1.03	-0.06	0.94	-0.22 *	0.80	0.16	1.17	-0.11	0.90
Parents are married or cohabiting	-0.13	0.88	-0.34 **	0.71	-0.19 +	0.83	-0.24 *	0.79	0.17	1.18	-0.45 ***	0.64
Family lives in rural area	0.15	1.16	0.36 ***	1.43	0.05	1.05	0.23 *	1.25	0.07	1.07	0.20	1.22
Mother has skilled employment	-0.44 +	0.65	-0.27	0.76	-0.05	0.95	-0.10	0.91	-0.10	0.91	-0.06	0.94
Father has skilled employment	-0.08	0.93	-0.39 ***	0.68	-0.24 **	0.79	-0.17 *	0.85	-0.20 +	0.82	0.02	1.02
Family socioeconomic status	-0.09 **	0.92	-0.11 ***	0.90	-0.16 ***	0.85	-0.08 ***	0.92	-0.02	0.98	-0.04	0.96
Maternal and child health												
Maternal body mass index (BMI)	0.00 ***	1.00	0.00 ***	1.00	0.00	1.00	0.00 **	1.00	0.00 ***	1.00	0.00	1.00
Child had acute respiratory infection (ARI) in the two weeks prior to survey	0.04	1.04	0.05	1.05	0.08	1.09	0.13	1.14	-0.07	0.93	-0.04	0.96
Child had diarrhea in the two weeks prior to survey	0.06	1.06	0.19 ***	1.21	0.13 **	1.14	0.16 ***	1.17	0.14 *	1.15	0.05	1.05
Constant	0.31		0.14		-0.83		-0.23		-0.51		-1.00 **	
-2 Log Likelihood	-4024.42		-4483.45		-3016.21		-3414.11		-1440.74		-2319.96	
N	6404		7274		4999		5597		2807		4158	

B=coefficient; e(B)=exponentiated beta or odds ratio; ref=reference group; $*p < .05$. $**p < .01$. $***p < .001$

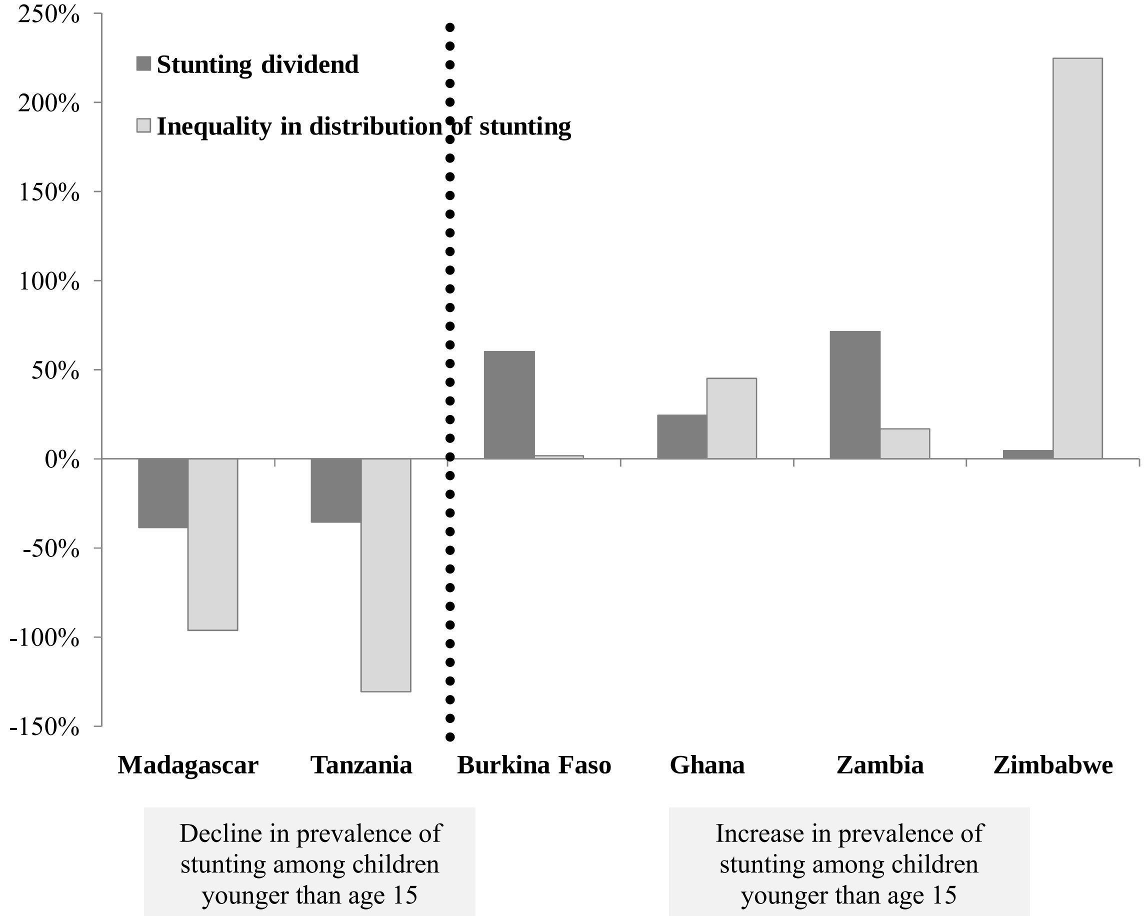
Mothers' education, however, plays an important role in child stunting in all countries included in the analysis, with the exception of Zimbabwe. In the five countries in which mothers' education plays an important role, children of mothers with no schooling are generally the most disadvantaged with regards to stunting. The relevance of education to children's stunting, however, has shifted over time. In Burkina Faso, Ghana, and Tanzania, the benefit conferred by mothers' education has declined over time. This may be related to the fact that the proportion of women with no schooling declined in Burkina Faso and Tanzania and remained relatively low (30 percent) in Ghana. However, in Zambia and Madagascar, mothers' education matters more during the last survey year. In Madagascar, this may be connected to the slight increase in the proportion of women with no schooling (from 20 to 22 percent). However, this relationship is unclear, especially given that Zambia experienced a decline in the proportion of women with no schooling (from 16 to 12 percent).

The effects of the additional family and individual controls are in the expected directions. Child age is positively associated with stunting, whereas family SES reduces the changes in stunting in all models. In some countries, living in a family headed by a woman, having married parents, and having employed parents reduce the odds that a child will be stunted. In other countries, rural residence increases the likelihood of severe stunting. The effects of maternal and child health controls are significant in about 50 percent of countries and are in the expected direction.

Dividends & Decomposition

Figure 3 displays the changes in dividends and inequality- or how the prevalence of stunting was distributed by maternal education- between the first and last survey years in the six countries studied.

Figure 3. Changes in the odds of stunting among children age 15 and distribution of stunting by maternal education (inequality), by country, DHS, six sub-Saharan African countries, 1992-2006

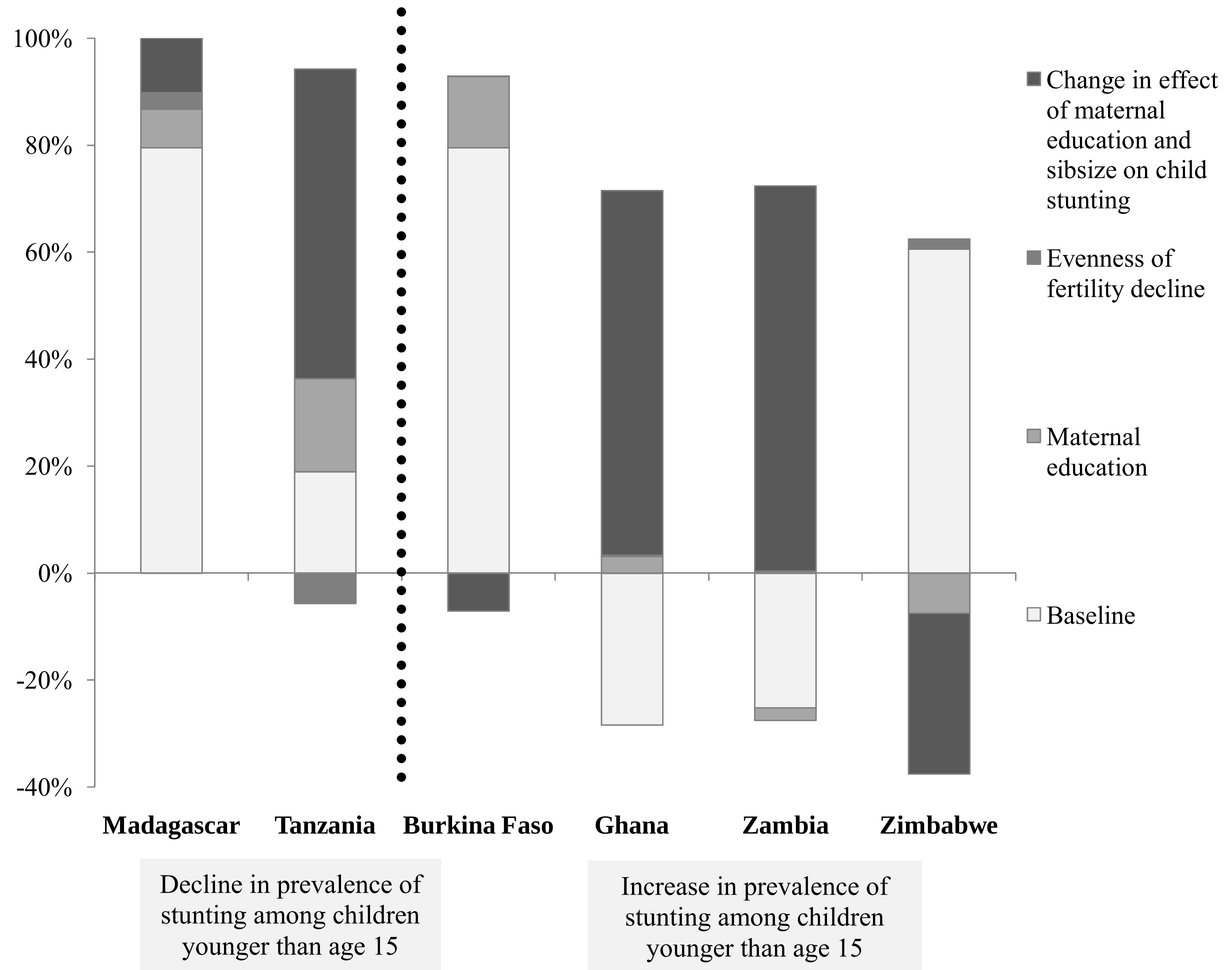


Only two counties, Madagascar and Tanzania, experienced a decline in the prevalence of stunting, from 54 to 47 percent in the former and 43 to 37 percent in the latter. These countries also experienced declines in inequality, by 62 percent in Madagascar and 126 percent in

Tanzania, suggesting a convergence in outcomes by maternal education groups. The prevalence of stunting increased in Burkina Faso (from 33 to 39 percent), Ghana (26 to 29 percent), and Zambia (42 to 47 percent); the prevalence of stunting also increased slightly in Zimbabwe (27 to 28 percent). However, although Ghana and Zimbabwe experienced an increase in inequality, suggesting divergence among educational groups, the prevalence of stunting increased in Burkina Faso and Zambia in the presence of declining inequality between maternal education groups (see Appendix Table 2 for exact values). It should be noted that the countries with the highest prevalence of stunting were the only ones that experienced a decline in stunting.

To help clarify the driving forces behind the changes in the prevalence of stunting and the relative contributions of family size and maternal education, Figure 4 displays 100 percent bar charts that show the relative influence of socioeconomic conditions (or baseline effects), changes in the distribution of women among education groups (maternal education), the evenness of the fertility decline (evenness), and the changes in the effects of maternal education and family size on child stunting (dilution) (see Appendix Table 1 for input data used to calculate and Appendix Table 2 for exact values).

Figure 4. Decomposition of stunting dividend by county, DHS, six sub-Saharan countries, 1992-1996



The results suggest that in half of the countries studied, socioeconomic context (at baseline) explains a majority of the change in the prevalence of stunting This is perhaps unsurprising and future research is needed to address more precisely the nature of these contextual variables, especially because all countries studied experienced a growth in GNI per capita (Figure 1). However, the findings also suggest that in the other 50 percent of countries, dilution plays a major role. Essentially, this means that changes in the effects of family size and maternal education have a substantial impact on the incidence of stunting. Maternal education and, to a lesser extent, family size play a smaller but arguably still important role in many of the countries

In Madagascar, improvements in dilution accounted for 80 percent of the reduction in stunting, whereas an increase in maternal education and an increasing convergence in family size accounted for 7 percent and 3 percent of the reduction, respectively. Interestingly, the dilution effect also improved the dividend by 10 percent, probably because the effects of family size and secondary schooling on stunting increased during this period, when enrollment was increasing and family size was declining. The results in Tanzania are similar, but dilution appears to be the dominant driver in this country, predominantly because the relevance of family size declined during this period (see Table 2 for documentation of changes in the betas). Improvements in the socioeconomic context (baseline) and maternal education reduced stunting by 19 and 21 percent, respectively. Interestingly, the results suggest a concentration of reproduction among women with lower levels of education, and the dividend was reduced by 6 percent as a result.

In countries in which the odds of stunting increased, it appears that the socioeconomic context and dilution were the main drivers of this change. However, the odds of stunting would have been higher without the gains in maternal education in Zambia (-5 percent) and Zimbabwe (-30 percent). In Burkina Faso and Ghana, changes in maternal education led to a slight increase in the prevalence of stunting (by 15 percent and 7 percent, respectively); this seems reasonable, given that enrollments decreased during this period (see Table 1).

In all four countries, changes in family size play a minor role in the prevalence of stunting. In Zimbabwe, changes in the number of children under age 15 living in households led to increases in the prevalence of stunting because family size increased during this period. Interestingly, in Burkina Faso and Zimbabwe, the change in the effect of family size and maternal education (dilution) on the prevalence of stunting served to reduce the rate of growth in the prevalence of stunting, while it magnified the rate of growth in Ghana and Zambia (see Appendix Table 1 for more information). However, there does not appear to be a relationship between the direction of changes in family size and schooling and the impact of dilution on the prevalence of stunting.

CONCLUSIONS

The goal of this paper was to estimate the human capital dividends associated with childhood malnutrition that stem from fertility declines and educational transitions in sub-Saharan Africa. The study is based on dilution theory, but a new analytical framework is used that helps translate microlevel findings into more policy-relevant trends at the macrolevel.

Although the cross-sectional correlations between TFR and stunting give some support to the notion of a demographic dividend that could provide a demographic "fix" for such problems as child malnutrition, historical evidence suggests that such a fix is suspect. Despite fertility declines in nearly all of the countries studied,[3] only three countries experienced a decline in the number of children under age 15 living in households. Moreover, only two of these three countries, Madagascar and Tanzania, experienced a drop in the prevalence of severe stunting at the macrolevel. These two countries also experienced a reduction in the level of inequality between maternal education groups. Nevertheless, in the four other countries, the prevalence of stunting increased, and the level of inequality between maternal education groups also increased in Burkina Faso and Zambia.

[3] Ghana is an exception; this country experienced a stall in its fertility decline but also had the lowest TFR (4.4) of all countries studied.

The results suggest that the effect of baseline factors (or socioeconomic context) and dilution appear to be the predominant determinants of the macrolevel prevalence of stunting. Further research in the specifics of the health care systems and food security status of each of the six countries would help identify some of the relevant socioeconomic context factors. The results also demonstrate that macrolevel transitions in women's schooling have played a larger role than declines in family size.

Thus, policymakers should take heed of the evidence of changes in women's schooling (DeRose and Kravdal, 2007) as these may have important implications for the prevalence of child stunting. Indeed, future research that can simulate the effects of varying levels of increases in maternal education levels could be useful for policymakers seeking to understand the role that educational expansion might play in reductions in child malnutrition. In addition, changes in the number of children under age 15 years residing in households played a non-negligible role in decreasing the prevalence of stunting in countries in which this prevalence declined, suggesting that programmatic efforts to target children in large families might be fruitful in some circumstances. Moreover, even though sibsize may not have a large impact on child malnutrition in all of the study countries, sibsize may have implications for other aspects of child health, such as immunizations. Thus, future work to consider other aspects of human capital gains across fertility and educational transitions is warranted.

REFERENCES

Anh, T.S., J. Knodel, D. Lam, and J. Friedman. 1998. Family size and children's education in Vietnam. *Demography* 35: 57-70.

Behrman, J.R. 1997. Intrahousehold distribution and the family. *Handbook of Population and Family Economics* 1: 125-187.

Bhat, P.N. 2002. Demographic transition, family size and child schooling. *National Council of Applied Economic Research Working Paper Series* No. 86. New Delhi, India: National Council of Applied Economic Research.

Bicego, G.T., and J.T. Boerma. 1991. Maternal education and child survival: A comparative analysis of DHS data. *Proceedings of the Demographic and Health Surveys World Conference, Washington D.C.,1991, Vol I.* Columbia, Maryland: IRD/Macro International Inc.

Black, R., S. Morris, and J. Bryce. 2003. Where and why are 10 million children dying every year? *Lancet* 361(9376): 2226-2234.

Blake, J. 1981. Family size and the quality of children. *Demography* 18: 421-42.

Bloom, D., D. Canning., and J. Sevilla. 2002. *The demographic dividend: A new perspective on the economic consequences of population change*. Santa Monica, California: Rand Corporation.

Bronte-Tinkew, J., and G.F. De Jong. 2004. Children's nutrition in Jamaica: Do household structure and household economic resources matter? *Social Science and Medicine* 58(3): 499-514.

Caldwell, J.C. 1979. Education as a factor in mortality decline: An examination of Nigerian data. *Population Studies* 33(3): 395-413.

Caldwell, J. C., D. Caldwell, P. Caldwell, P. McDonald, and T. Schindlmayr. 2006. *Demographic Transition Theory*. Dordrecht, The Netherlands: Springer.

Chang, S.M., S. Walker, S. Grantham-McGregor, and C. Powell. 2002. Early childhood stunting and later behaviour and school achievement. *Journal of Child Psychology and Psychiatry* 43(6): 775-783.

Chavez, A., C. Martinez, and T. Yaschine. 1975. Nutrition, behavioral development and mother-child interaction in young rural children. *Federation Proceedings* 34(7): 1574-1582.

Chernichovsky, D. 1985. Socioeconomic and demographic aspects of school enrolment and attendance in rural Botswana. *Economic Development and Cultural Change* 33(2): 319-332.

Cleland, J.G. 1990. Maternal education and child survival: Further evidence and explanations. In J. Caldwell, S. Findley, P. Caldwell, G. Santow, J. Braid, and D. Broers-Freeman (eds.), *What we know about the health transition: The cultural, social and behavioural determinants of health. Vol. I*. Canberra, Australia: Health Transition Centre, The Australian National University, pp. 400-419.

DeRose, L.F., and O. Kravdal. 2007. The effects of educational reversals on first births in sub-Saharan Africa: A dynamic multi-level perspective. *Demography* 44: 59-77.

Desai, S. 1992. The impact of family size on children nutritional status: Insights from a comparative perspective. In C. Lloyd (ed.), *Fertility, family size, and structure: Consequences for families and children*. New York, New York: Population Council, pp. 155-192.

Desai, S., and S. Alva. 1998. Maternal education and child health: Is there a strong causal relationship? *Demography* 35: 71-81.

United Nations Educational, Scientific and Cultural Organization. (2003). *Education for All Global Monitoring Report 2003/4: Gender and Education for All – The leap to equality*. Paris: UNESCO.

Eloundou-Enyegue, P., and L. Williams. 2006. The effects of family size on child schooling in sub-Saharan settings: A reassessment. *Demography* 43(1): 25-52.

Giroux, S., P. Eloundou-Enyegue, and D. Lichter. 2008. Trends in reproductive inequality in sub-Saharan Africa: A micro-macro distinction. *Studies in Family Planning*, in press.

Glewwe, P., and H. Jacoby. 1993. Delayed primary school enrollment and childhood malnutrition in Ghana: An economic analysis. *Living Standards Measurement Study Working Paper* No. 98. Washington, DC: World Bank.

Glewwe, P., H. Jacoby, and E. King. 2001. Early childhood nutrition and academic achievement: A longitudinal analysis. *Journal of Public Economics* 81: 345-368.

Gomes, M. 1984. Family size and educational attainment in Kenya. *Population and Development Review* 10: 647-660.

Hobcraft, J. 1993. Women's education, child welfare and child survival: A review of the evidence. *Health Transition Review* 3(2): 179-193.

Kirk, D., and B. Pillet. 1998. Fertility levels, trends, and differentials in sub-Saharan Africa in the 1980s and 1990s. *Studies in Family Planning* 29: 1-22.

Knodel, J., N. Havanon, and W. Sittitrai. 1990. Family size and the education of children in the context of rapid fertility decline. *Population and Development Review* 16: 31-62.

Kostemans, K. 1994. Assessing the quality of anthropometric data: Background and illustrated guidelines for survey managers. *Living Standards Measurement Study Survey Working Paper* No. 101. Washington, DC: World Bank.

Lalou, R., and C. Mbacke. 1992. The microconsequences of high fertility on child malnutrition in Mali. In C. Lloyd (ed.), *Fertility, family size and structure*. New York: Population Council, pp. 193-223.

Lam, D., and L. Marteleto. 2005. Small families and large cohorts: The impact of the demographic transition on schooling in Brazil. In C. Lloyd (ed.), *Growing up global: The changing* *transitions to adulthood in developing countries*. Washington, DC: National Academy Press, pp. 56-83.

LeVine, R.A., S.E. LeVine, A. Richman, F.M.T. Uribe, C.S. Correa, and P.M. Miller. 1991. Women's schooling and child care in the demographic transition: A Mexican case study. *Population and Development Review* 17(3): 459-496.

Lindenbaum, S. 1990. Maternal education and child care processes in Bangladesh: The health and hygiene of the middle classes. In J. Caldwell, S. Findley, P. Caldwell, G. Santow, J. Braid, and D. Broers-Freeman (eds.), *What we know about the health transition: The cultural, social and behavioural determinants of health, Vol. I*. Canberra, Australia: Health Transition Centre, Australian National University, pp.425-440.

Lloyd, C.B. 1994. Investing in the next generation: The implications of high fertility at the level of the family. *Research Division Working Papers* 63. New York, New York: Population Council.

Lloyd, C., and P. Hewett. 2003. Primary schooling in sub-Saharan Africa: Recent trends and current challenges. *Policy Research Division Working Paper* 176. New York, New York: Population Council.

Murray, C., and A. Lopez. 1996. Evidence-based health policy: Lessons from the Global Burden of Disease Study. *Science* 274: 740-743.

Notestein, F. W. 1945. "Population — The Long View," in Theodore W. Schultz, Ed., *Food for the World*. Chicago: University of Chicago Press.

Shapiro, D., and B.O, Tambashe. 2001. Fertility transition in urban and rural sub-Saharan Africa: Preliminary evidence of a three-stage process. *Journal of African Population Studies* 7 (2 and 3): 111-135.

Thornton, A., 2001. The developmental paradigm, reading history sideways, and family change. *Demography* 38(4): 449-465.

United Nations. 2004. *World population prospects: The 2004 revision*. New York, New York: United Nations.

Wamani, H., T. Tylleskär, A. Astrøm, J. Tumwine, and S. Peterson. 2004. Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural Uganda. *International Journal for Equity in Health* 3(1): 9.

Weinreb, L., C. Wehler, J. Perloff, R. Scott, D. Hosmer, L. Sagor, and C. Gundersen. 2002. Hunger: Its impact on children's health and mental development. *Pediatrics*. 110(4): 41.

Appendix Table 1. Input data for calculation of stunting dividend, inequality in distribution of stunting by maternal education, and decomposition of the dividend, DHS, six sub-Saharan African countries, 1992-2006.

Countries	First survey year											Last survey year										
	wj	Sj	Bj		Bs		Baseline		Ejt	Xjt	rjt	wj	Sj	Bj		Bs		Baseline		Ejt	Xjt	rjt
Family types			B	exp(B)	B	exp(B)	B	exp(B)						B	exp(B)	B	exp(B)	B	exp(B)			
Burkina Faso (1992/93-2003)																						
No schooling	0.83	5.35	0.77	2.17	0.02	1.02	-1.47	0.23	-0.58	0.56	1.12	0.87	5.39	0.68	1.98	0.03	1.03	-1.23	0.29	-0.38	0.69	1.08
Primary	0.12	4.66	0.38	1.46	0.02	1.02	-1.87	0.15	-1.40	0.25	0.49	0.09	4.40	0.38	1.46	0.03	1.03	-1.60	0.20	-1.08	0.34	0.53
Secondary +	0.05	3.54	0.00	1.00	0.02	1.02	-2.12	0.12	-2.05	0.13	0.26	0.04	3.45	0.00	1.00	0.03	1.03	-2.09	0.12	-1.98	0.14	0.22
Total	100								-0.75	0.50	0.06	100								-0.50	0.63	0.04
									Logits	Odds	Inequality									Logits	Odds	Inequality
Ghana (1998-2003)																						
No schooling	0.47	3.72	0.26	1.30	-0.04	0.96	-0.93	0.39	-0.82	0.44	0.89	0.47	3.92	0.30	1.35	0.05	1.05	-1.03	0.36	-0.52	0.59	0.94
Primary	0.19	3.05	0.24	1.27	-0.04	0.96	-1.20	0.30	-1.08	0.34	0.68	0.22	3.01	-0.21	0.81	0.05	1.05	-1.31	0.27	-1.36	0.26	0.40
Secondary +	0.34	2.63	0.00	1.00	-0.04	0.96	-1.36	0.26	-1.47	0.23	0.46	0.30	2.83	0.00	1.00	0.05	1.05	-1.44	0.24	-1.29	0.27	0.43
Total	100								-1.09	0.35	0.39	100								-0.94	0.42	0.49
									Logits	Odds	Inequality									Logits	Odds	Inequality
Madagascar (1992-2003/04)																						
No schooling	0.19	3.79	-0.12	0.89	0.04	1.04	-0.15	0.86	-0.11	0.90	1.80	0.21	3.47	0.17	1.19	0.00	1.00	-0.12	0.89	0.07	1.07	1.69
Primary	0.57	3.63	0.17	1.18	0.04	1.04	-0.06	0.94	0.27	1.30	2.61	0.50	3.31	0.25	1.28	0.00	1.00	-0.27	0.77	0.00	1.00	1.58
Secondary +	0.24	3.25	0.00	1.00	0.04	1.04	-0.06	0.94	0.08	1.09	2.18	0.29	2.79	0.00	1.00	0.00	1.00	-0.51	0.60	-0.50	0.61	0.96
Total	100								0.15	1.18	-0.85	100								-0.13	0.90	-0.32
									Logits	Odds	Inequality									Logits	Odds	Inequality
Tanzania (1992-2004)																						
No schooling	0.37	4.95	0.65	1.91	-0.02	0.98	-0.66	0.52	-0.11	0.90	1.79	0.28	4.24	0.54	1.72	-0.05	0.95	-0.67	0.51	-0.33	0.72	1.13
Primary	0.60	3.89	0.51	1.67	-0.02	0.98	-0.77	0.46	-0.34	0.71	1.43	0.65	3.44	0.45	1.57	-0.05	0.95	-0.86	0.42	-0.57	0.56	0.89
Secondary +	0.03	3.49	0.00	1.00	-0.02	1.00	-1.19	0.31	-1.19	0.31	0.61	0.07	3.05	0.00	1.00	-0.05	0.95	-1.22	0.29	-1.37	0.25	0.40
Total	100								-0.28	0.77	-0.41	100								-0.56	0.59	0.11
									Logits	Odds	Inequality									Logits	Odds	Inequality
Zambia (1992-2001)																						
No schooling	0.18	3.84	0.21	1.23	-0.04	0.96	-0.12	0.89	-0.05	0.95	1.90	0.16	3.52	0.33	1.40	0.03	1.03	-0.36	0.70	0.08	1.08	1.70
Primary	0.65	4.03	0.24	1.27	-0.04	0.96	-0.36	0.70	-0.27	0.76	1.53	0.66	3.57	0.28	1.32	0.03	1.03	-0.46	0.63	-0.08	0.92	1.45
Secondary +	0.17	3.90	0.00	1.00	-0.04	0.96	-0.68	0.51	-0.82	0.44	0.88	0.18	3.50	0.00	1.00	0.03	1.03	-0.66	0.52	-0.55	0.57	0.91
Total	100								-0.33	0.74	-0.37	100								-0.14	0.88	-0.31
									Logits	Odds	Inequality									Logits	Odds	Inequality
Zimbabwe (1999-2006)																						
No schooling	0.08	3.89	0.43	1.53	0.06	1.06	-1.15	0.32	-0.50	0.60	1.21	0.04	4.17	-0.04	0.96	0.05	1.05	-0.90	0.41	-0.73	0.48	0.76
Primary	0.49	3.20	0.10	1.10	0.06	1.06	-1.23	0.29	-0.96	0.38	0.77	0.41	3.33	-0.10	0.91	0.05	1.05	-0.99	0.37	-0.92	0.40	0.63
Secondary +	0.43	2.66	0.00	1.00	0.06	1.06	-1.38	0.25	-1.24	0.29	0.58	0.55	2.82	0.00	1.00	0.05	1.05	-1.10	0.33	-0.95	0.39	0.61
Total	100								-1.04	0.36	0.34	100								-0.93	0.39	0.48
									Logits	Odds	Inequality									Logits	Odds	Inequality

NOTES: wj=the proportion of children within each maternal education group; Sj=the average number of children under the age 15 residing in the household for each maternal education grouping; Bj=group specific coefficient for the effect of maternal education on stunting; Bs= coefficient for the impact of the number of children under the age of 15 living in the household on stunting; Baseline=calculated by 1) multiplying the group mean for each education group for a given variable by the regression coefficient for that same variable (i.e. mean value of socioeconomic status for women with no schooling times the coefficient for socioeconomic status) then, 2) summing the values for all variables (excluding maternal education and average number of children under the age 15 residing in the household) by maternal education grouping; Ejt= log of Xjt (used for calculation of rjt); Xjt= prevalence of stunting for children under age 15; rjt= inequality in distribution of stunting by maternal education.

Appendix Table 2. Decomposition results for the divergence in children's stunting, DHS, six sub-Saharan African countries, 1992-2006.

		Survey Specific Values						Total Change		Decomposition of Dividend			
		Time 1			Time 2			Dividend	Inequality				
	Countries	Prevalence of stunting in children under age 15	Odds of stunting in children under age 15	Inequality in distribution of stunting	Prevalence of stunting in children under age 15	Odds of stunting in children under age 15	Inequality in distribution of stunting	Change in Odds of Stunting	Change in the inequality in distribution of stunting	Baseline	Maternal education	Evenness	Dilution
Declines	Madagascar (1992-2003/04)	54%	1.18	-0.85	47%	0.90	-0.32	-23%	-62%	80%	7%	3%	10%
	Tanzania (1992-2004)	43%	0.77	-0.41	37%	0.59	0.11	-24%	-126%	21%	19%	-6%	65%
Increases	Burkina Faso (1992/93-2003)	33%	0.50	0.06	39%	0.63	0.04	27%	-23%	93%	15%	0%	-8%
	Ghana (1998-2003)	26%	0.35	0.39	29%	0.42	0.49	20%	24%	-66%	7%	1%	158%
	Zambia (1992-2001)	42%	0.74	-0.37	47%	0.88	-0.31	19%	-15%	-56%	-5%	1%	161%
	Zimbabwe (1999-2006)	27%	0.36	0.34	28%	0.39	0.48	9%	38%	243%	-30%	8%	-121%