Determinants of the Rise in Early Childhood Mortality in Kenya: Adversity or Shift in the Structure of Relationships?[♣]

Abstract
This study explores the determinants of the rise in early childhood mortality rate in Kenya after 1990. In particular, it examines the role of adversity – changes in the values of explanatory variables – versus shift in the structure of relationships, or changes in the relative importance of the explanatory variables. Analysis is based on data from the four Kenyan DHSs conducted in 1989, 1993, 1998, and 2003. Cox hazards model is used to analyze the pooled records of 45,690 children born during the period 1979-2003. Results show significant changes in both values and relative importance of explanatory variables after 1990. The changes were associated with a variety of factors including reductions in income, vaccination coverage, and breastfeeding duration, on one hand, and changes in the relative importance of income, education, maternal age, fertility, and marital status, on the other hand.

INTRODUCTION

Childhood mortality rates increased in Kenya from the 1990s after three or so decades of decline. Under-five mortality rate, for instance, increased from 91 per 1000 live births in the late 1980s to 115 per 1000 in early 2000s (ROK 2004). This contrasts sharply with the scenario witnessed during the preceding period in which the same dropped from 250 to 100 per 1000 live births between mid-1940s and mid-1980s (Hill 1993). The reversal begs the question: what changed, or rather, what led to the increase in the early childhood mortality rate in Kenya after decades of fairly impressive decline? Many studies have explored this question – not only in Kenya but in other similarly affected Sub-Saharan countries as well. The studies attribute the rising trends to contemporary deterioration in living standards and high prevalence of HIV/AIDS in the affected countries (Adetunji 2000; Amouzou and Hill 2005; Hill et al. 2004; Ikamari 2004; Mahy 2003; National Research Council 1993; UN 2003; Zuberi et al. 2003). But, while this argument remains popular in the public domain, sound empirical evidence is generally lacking. Therefore, we must look farther afield for other explanations, in line with the assertion that more than handful explanations are necessary to clarify this phenomenon (Rutstein 2000).

This study explores the determinants of the recent rise in the risk of early childhood mortality in Kenya. In particular, it seeks to examine the roles of changes in both values and relative importance of individual explanatory variables in accounting for the increased risks of under-5 deaths after 1990. No study in Kenya has quantitatively assessed the dynamics of the recent rise in early childhood mortality in light of these potential explanations. This amounts to an undesirable research gap, given evidence from other developing countries showing that shifts in the structure of relationships explain a substantial portion of the contemporary changes in childhood mortality rates (see Preston 1975, 1980; Da Vanzo and Habicht 1986; Arriaga and Davis 1969; Caldwell 1986).

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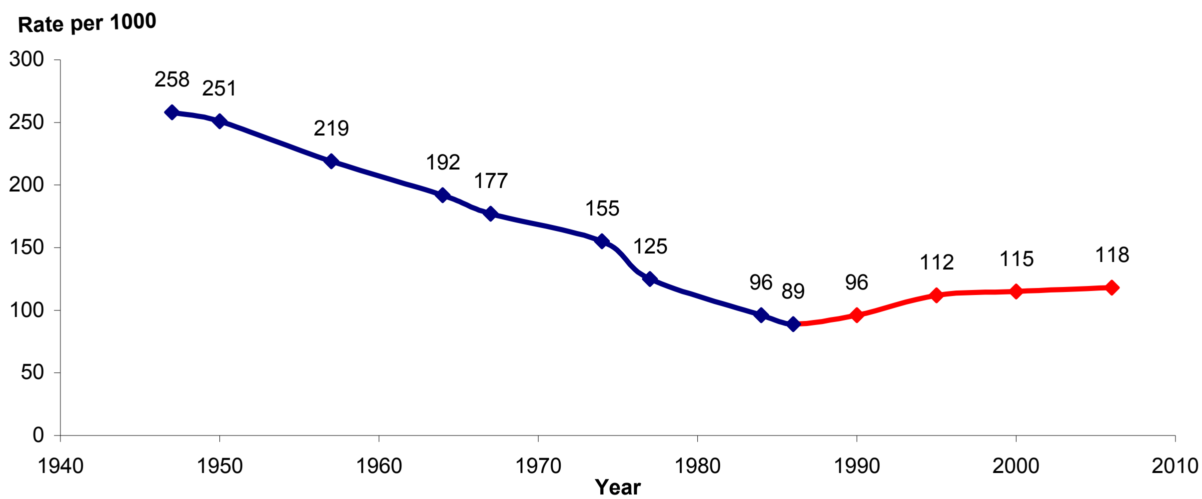
BACKGROUND

Achieving optimal human welfare and survival remains the greatest development challenge of all time. The challenges are more formidable in developing countries, more so Sub-Saharan Africa where many children continue to die of causes that are preventable. Globally, more than 10 million children still die before their fifth birthday. Sub-Saharan Africa accounts for half of these deaths in spite of being home to only about 20 percent of the world's young children (United Nations 2006). Even within the sub-region huge disparities abound, not only with respect to child survival trends and prospects, but also relating to socio-economic growth (Hill 1993; National Research Council 1993). Thus, country specific studies add enormous knowledge on child survival trends and prospects.

The optimism that a child survival revolution was in the offing in Sub-Saharan Africa was shattered in mid-1980s when the rate of childhood mortality decline decelerated in many countries, stalled in some, and even reversed in others (Hill 1993; Hill and Pebley 1989; Zuberi et al. 2003). The deterioration is observed mainly in countries with relatively high prevalence of HIV/AIDS (Adetunji 2000; Amouzou and Hill 2005), and among those experiencing major economic reversals (National Research Council 1993). Soon after becoming a Republic, the Kenyan government put in place pragmatic social and economic policies that culminated in fairly appreciable economic growth and relative success in the performance of the social, economic, and health sectors (Brass and Jolly 1993; Hill et al. 2004). An elaborate public health infrastructure provided preventive and curative services, while other measures put in place improved food security, water supply, and sanitation (ROK 1984 1989). Kenya's child health record following these reforms was considered impressive (Brass and Jolly 1993; Caldwell 1986; Hill 1993; Hill et al. 1999; Hill et al. 2004). However, evidence shows that it deteriorated from the 1990s (Hill et al. 2004; ROK 1994, 1999, 2001, 2004).

Figure 1. Trends in under-5 mortality in Kenya



The upsurge in early childhood mortality rate is not unique to Kenya as similar patterns are observed elsewhere in sub-Saharan Africa. Many studies suggest that high prevalence of HIV/AIDS and falling living standards are culpable (Hill et al. 2004; Adetunji 2000; Timaeus 1998; Mahy 2003; United Nations 2003; Zuberi et al. 2003; Amouzou and Hill 2005; Ikamari 2004). But others contradict this popular notion, asserting that the impact of HIV/AIDS on early childhood mortality can be minute and ambiguous (Mahy 2003), often with tenuous causal pathways (Zaba, Marston, and Floyd 2003). Thus, the evidence on HIV/AIDS remains largely inconclusive. On the other hand, the demographic impact of economic reversals in Sub-Saharan Africa – especially on early childhood mortality – is inconsistent across countries, although there is a general notion that it is negative (National Research Council 1993). In addition, some scholars encourage exploration of further explanations, arguing that more than handful explanations are warranted (Rutstein 2000). Altogether, these arguments provide sufficient grounds to challenge the widespread notion that the recent deterioration in child survival in Sub-Saharan Africa is driven mainly by high prevalence of HIV/AIDS and falling living standards.

In the case of Kenya, an outstanding issue is whether the upsurge in early childhood mortality affects all sub-groups given recent notable changes in population dynamics. Preliminary evidence reveals non-negligible temporal and sub-group differentials in early childhood mortality patterns. Even more intriguing are the huge intra-country differentials, particularly what drives the 20-year difference in life expectancy between regions (ROK 2002). In a nutshell, the underlying causes of the recent increase in early childhood mortality clearly have temporal and structural (or sub-group) dimensions.

THEORETICAL PERSPECTIVE

It is posited in this study that early childhood mortality in Kenya increased after 1990 due to adversity and/or shift in the structure of relationships.

Adversity

Adverse trends in the values of key determinants of childhood mortality could increase the general risk of death in early childhood. For example, the deterioration in socio-economic circumstances and inadequate access to child health services witnessed in Kenya in the recent past (Brass and Jolly 1993; Hill 1993; Hill et al. 2004) could potentially reverse the gains hitherto made regarding child survival. Also, contemporary population dynamics may increase death clustering among certain sub-groups (Hill 1991; Hill and David 1998). For instance, the dramatic fall in birth rates among higher socioeconomic status sub-groups (Brass and Jolly 1993) has disproportionately shifted births to sub-groups with above-average mortality risks, which could potentially increases childhood mortality rates.

Shift in the structure of relationships

Perhaps, the relative importance of the individual determinants of early childhood mortality changed over time. For example, the health transition literature asserts that the relative contribution of medical technology to overall mortality decline surpassed that of socio-economic factors in many developing countries (Arriaga and Davis 1969; Caldwell 1986; Gwatkin 1980; Preston 1975, 1980). It is argued that socio-economic status is a more important determinant of health under conditions of absolute material deprivation. However, the importance wanes as societies become more modern and the general socio-economic circumstances of the populace improve (Mammot 2002). In the case of Kenya the high risk of neonatal and post-neonatal mortality compels us to conjecture that socio-economic factors possibly lost their relative prominence to factors related to family formation and child care. Lastly, changes in disease patterns without a parallel shift in policy focus may present new and formidable challenges in disease management and treatment. High HIV/AIDS prevalence, for instance, has been associated with the re-emergence of resistant strains of infectious diseases hitherto controlled – such as tuberculosis. This may accentuate risks associated with certain diseases and, consequently, change the interrelationships between the determinants of mortality.

DATA AND METHODS

Data

The study is based on individual-level data from the four Demographic and Health Surveys (DHS) conducted in Kenya in 1989, 1993, 1998, and 2003. The surveys were conducted in collaboration with ORC-Macro as part and parcel of the DHS series undertaken in developing countries to assess their demographic and health situation. Data was collected on – inter alia – the background characteristics of households and their members. More importantly for this study, the data include maternity histories of all women of reproductive age and a variety of maternal, child health, and household variables associated with child survival. The DHS data are publicly available on ORC-Macro's website [http://www.measuredhs.com]. We pooled these individual data sets, and considered only singleton births occurring within 10-years of each survey. Thus, this analysis is based on 45,690 records of children born during the period 1979-2003.

Methods of analysis

The analytical strategy is adapted from studies by Preston (1975) and Da Vanzo and Habicht (1986). The first – involving many developing countries – showed the relationship between income and economic development had shifted upwards after 1960s, compared to 1930s. The second, probably adapted from the first, also showed that structural shifts played a significant role in the decline of infant mortality in Malaysia in 1946-1975.

Survival analysis is the principal analytical technique used in this study. It is deemed pertinent because survival times often follow a skewed, non-normal distribution. *Kaplan-Meier* and *life table* survival analysis procedures are used to estimate overall hazards without covariates, while Cox regression model is used in the multivariate analysis. Cox regression – a proportional hazards model – is particularly appealing due to its ability to fit a large variety of data without imposing a distribution, thereby yielding robust results (Allison 1995; Lee and Go 1997; Cleves, Gould, and Gutierrez 2004). It models the hazard of an individual experiencing a given event – death by age five, in this case – in a multivariate framework. Given a set of k covariates, x_1, x_2, $\ldots x_k$, the hazard of death of individual *i* is given as:

$$h_i(t, x_i) = h_0(t)\exp\{b_1 x_{i1} + \ldots\ldots + b_k x_{ik}\}$$

The above equation implies that the hazard of death for each individual at time *t* is the product of an arbitrary or unspecified but non-negative function of time $h_0(t)$, and an exponential linear function of the covariates. The model is estimated using its 'log hazards' equivalent, thus:

$$\log h_i(t, x_k) = a(t) + b_1 x_{1i} + \ldots\ldots + b_k x_{ki}$$

where $a(t) = \log h_0(t)$.

Cox regression is considered a proportional hazards model because the ratio of the hazards of two individuals does not depend on the baseline hazard, and remains constant over time (Allison 1995; Lee and Go 1997).

Pooling the data permits us to dichotomize the analytical period into the *declining period* (1979-1990) – when early childhood mortality rate was downward-bound – and the *rising period* (1991-2003) – when it was upward-bound. A two-sample t-test is used to compare means of all potential predictors between the two periods to find out which ones changed significantly.

Only variables whose (mean) values changed significantly between the two periods enter the multivariate model. To assess the contributions of individual explanatory variable to the overall change in mortality between 1979-1990 and 1991-2003 we fit a Cox hazard model to the pooled data, and apply the resulting coefficients to the absolute differences in the average values of each explanatory variable between the periods. On the other hand, to investigate structural changes, we use the pooled data, again, but instead estimate a model where each variable is interacted with a period dummy variable for 1991-2003. Thereafter, statistical tests are performed to determine the coefficients that differ significantly between the two periods. Variables whose influence changed significantly between the two periods suggest a shift in the structure of relationships. At this juncture, a re-estimation of the contributions of the individual explanatory variables is necessary – taking into account the changes in both the values and the structure – in order to work out the net roles due to adversity and structure respectively.

Variables for analysis

The choice of predictors is based on three main criteria: established association with childhood mortality; availability; and, significant variation between the two periods. The response variable is death by age five. Explanatory variables include socio-economic factors (maternal education, household income, and urban residence), variables related to family formation and reproduction (maternal age at birth, birth order, previous birth interval, mother's parity and marital status), and those related to child care and services (vaccination coverage, skilled delivery assistance, and medical care for sick children, nutrition, and breastfeeding duration). The variables in the last category are cluster (district) averages – percentages imputed for every child in the district – as they were only available for a subset of children in the original data files. They proxy important intra-country or contextual differences in factors related to child health production, such as accessibility of health services (Frankenberg 1995), competency in childcare (Ewbank and Preston 1990), and the social benefits of public health measures such as immunization, or the consequences of public health concerns such as high prevalence of HIV/AIDS (Behrman and Knowles 1998). HIV prevalence, although important, was not included in the model as the information was only available for the 2003 survey. And – of course – the gender composition of births was included in the analysis, more as a control rather than an explanatory variable, as it hardly changed over the period.

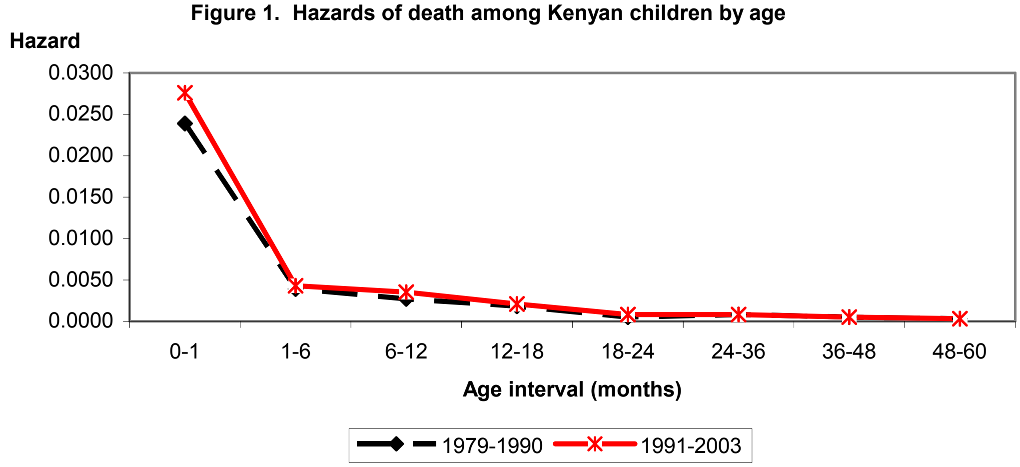
Because DHS-type surveys do not collect income or expenditure data, an asset-based wealth index that serves as a proxy for household income was created using principal components analysis (see Dunteman 1989; Filmer and Pritchett 1999). The index is weighted by the GDP per capita at constant prices to reflect periodic changes in income distribution (Sam Preston, Personal communication). In addition to measuring income, the index absorbs the effect of the physical conditions of the living environment, particularly exposure to pathogenic agents through inadequate water supply and sanitation. Lastly, because length of breastfeeding and child survival are intertwined – potentially leading to reverse causation – the duration of breastfeeding was re-defined by splitting the age interval into small segments and assigning duration according to whether the child was breastfeeding at the beginning of the segment (Palloni and Millman 1986).

RESULTS

Death hazards by age 5

The hazards of dying by age 5 are compared for the *declining period* (1979-1990) and *rising period* (1991-2003) in Figure 1. Clearly, the risks are higher after 1990 for both infants and toddlers. Barring a somewhat erroneous pattern exhibited by the upper panel of Table 1 (estimated using the Life Table survival analysis technique) the results corroborate the observation made from the graph that not much change in hazards of death occurred after age 2. The lower panel suggests that the risks of under-5 mortality increased by 22 percent over the period, and occurred entirely among post-neonates (22%) and neonates (16%).

Figure 1. Hazards of death among Kenyan children by age



The last two columns of Table 1 show the implied age specific probabilities of dying, q(x). The probabilities are estimated using the equation:

$$q(x)=1-l(x) = 1-l(0)\, e^{-\int_0^x \vartheta(a)da}$$

where l(0)=radix=1000, and $\vartheta(a)$ is the hazard or force of mortality (see Preston, Heuveline, and Guillot, 2001, p.60).

Noticeably, the probability of dying by age 5 increased from 85.4 per 1000 during the period 1979-1990 to 98.2 per 1000 in 1991-2003, an increase of 12.8 deaths per 1000, or 15 percent. Similarly, the probability of dying in infancy increased from 57.9 per 1000 in 1979-1990 to 67.7 per 1000 in 1991-2003, an increase of 9.8 deaths per 1000, or 17 percent. These estimates are somewhat lower than those documented in the survey reports, certainly because they refer to broader time periods. At any rate they do provide a good indication of risk patterns during the two periods, which is, more or less, the emphasis of this study.

Table 1. Estimated age specific hazards and probabilities of dying in early childhood: Kenya, 1979-1990 and 1991-2003

Age interval x, x+n	Exact Age x (months)	Period of birth				Change in hazard (%)	Implied probability of dying by age x, q(x) (per 1000)	
		1979-90		1991-03				
		Hazard	SE	Hazard	SE		1979-90	1991-03
0-1	0	0.0239	0.0010	0.0276	0.0012	15.5	-	-
1-6	1	0.0039	0.0002	0.0043	0.0002	10.3	23.6	27.2
6-12	6	0.0027	0.0001	0.0035	0.0002	29.6	42.5	47.9
12-18	12	0.0018	0.0001	0.0021	0.0002	16.7	57.9	67.7
18-24	18	0.0005	0.0001	0.0008	0.0001	60.0	68.0	79.4
24-36	24	0.0008	0.0001	0.0008	0.0001	0.0	70.8	83.8
36-48	36	0.0005	0.0001	0.0005	0.0001	0.0	79.6	92.5
48-60	48	0.0003	0.0000	0.0003	0.0001	0.0	85.2	98.0
	60						85.4	98.2
Summary indicators								
0-1		0.0239	0.0010	0.0276	0.0012	15.5	23.6	27.2
1-12		0.0032	0.0001	0.0039	0.0001	21.9	35.1	41.6
12-60		0.0008	0.0000	0.0008	0.0000	0.0	29.3	32.8
0-12		0.0050	0.0001	0.0060	0.0002	20.0	57.9	67.7
0-60		0.0018	0.0000	0.0022	0.0001	22.2	**85.4**	**98.2**

Fixed Structure analysis

In Table 2 we attempt to estimate the contribution of individual predictors to the overall change in hazard of death by age 5 between 1979-1990 and 1991-2003, assuming the structure remained unchanged during the entire period. Columns (1) and (2) show the average (mean) values of each predictor for each period, while column (3) shows the absolute change in the values of the predictors between the periods. A two-sample t-test, shown in column (4), identifies the predictors that changed significantly between the periods and, therefore, were potentially associated with the change in mortality risk between the periods.

Overall, the values of all predictors – except gender composition of the births – changed significantly over the period, although the magnitude and direction did vary. Among socio-economic factors, the proportional share of births decreased by almost half among uneducated women, but increased among poor households, and in the urban areas. Thus, this group of factors may have acted both to elevate and inhibit risks across the periods. Among family formation variables, the proportion of births associated with sub-groups presumed to exhibit above average mortality risks decreased, save for the never and formerly married women among whom it increased. Remarkable reductions were noted especially among births to high parity women and those with short preceding birth intervals, but a significant increase among first order births.

However, all factors associated with child care and services deteriorated significantly over the period, with vaccination coverage registering the largest drop – of 15 percentage points – followed by medical treatment of sick children, and skilled delivery assistance. Stunting and breastfeeding duration also dropped slightly, but significantly.

Table 2. Cox regression model for decomposing change in hazards of death by age 5 in Kenya between 1979-1990 and 1991-2003: Fixed structure analysis

Predictors	Mean value of predictor 1979-90 (1)	1991-03 (2)	Absolute Change (3)	t-statistic for difference of means (4)	Cox regression coefficient [a] (5)	SE	Change in hazard due to change in variable (6)
Socioeconomic variables							
No education	0.270	0.149	-.121	-31.44***	-.0326	.078	.00394
Secondary+ education	0.184	0.232	.048	12.67***	-.3723***	.056	-.01787
2nd income quintile*	704.78	781.53	76.75	5.75***	-.0000325**	.0000137	-.00249
3rd income quintile*	710.16	725.86	15.70	1.19	-.0000612***	.0000172	-.00096
4th income quintile*	671.60	583.13	-88.47	-7.05***	-.0001138***	.0000191	.01007
5th income quintile*	583.02	512.9	-70.12	-5.90***	-.0001134***	.0000242	.00795
Urban residence	0.158	0.192	.034	9.52***	.1869**	.085	.00635
Family formation variables							
Maternal age 15-19	0.181	0.177	-.004	-1.27	.3141***	.054	-.00126
Maternal age 35-49	0.118	0.111	-.007	-2.36**	.0786	.057	-.00055
First birth	0.188	0.246	.058	15.00***	.2177***	.051	.01263
Short birth interval	0.110	0.074	-.036	-13.19***	.6642***	.052	-.02391
Mother has 5+ children	0.572	0.384	-.188	-40.60***	.2999***	.049	-.05638
Mother never married	0.047	0.062	.015	6.90***	.0012	.085	.00002
Mother formerly married	0.077	0.087	.010	3.84**	.2691***	.056	.00269
Child care and services							
Vaccination coverage (%)	74.30	59.34	-14.96	-95.32***	-.0102***	.003	.15259
Skilled delivery care (%)	47.82	43.14	-4.68	-25.40***	-.0032	.002	.01498
Medical attention (%)	69.21	59.31	-9.90	-49.85***	.0006	.002	-.00594
Breastfeeding (%)	89.32	88.43	-.89	-14.11***	-.0215***	.007	.01914
Stunting (%)	34.46	34.16	-.30	-3.03**	.0034	.005	-.00102
Gender (male)	0.498	0.506	.008	1.61	.1355***	.038	.00108
Probability of dying under-5 (per 1000)	**85.4**	**98.2**	**12.8**				**0.120** [s]

Note: *** p<.01 ; ** p<.05 ; * p<.10

[a] Relative log hazards

[s] Sum of relative log hazards

* Wealth quintiles weighted by GDP per capita at constant prices

Fitting a Cox regression model to the pooled data yields estimates in column (5). As shown in this column all predictors – but delivery and medical care, and stunting – were significantly associated with under-5 mortality risks. Risks were substantially lower among children born to women with higher education. Risks also reduced monotonically with rising income. Longer duration of breastfeeding and high vaccination coverage also significantly lowered risks of death.

However, children born to teenage mothers were predisposed to significantly higher risks of death, as were children of formerly married and high parity women, and among first births and those born within 18 months of the preceding birth, especially the latter. Male children also faced significantly higher risks of death, while children resident in urban areas had higher mortality risks net of other variables.

Applying the “fixed” structure in column (5) to the absolute changes in the values of the variable in column (3) predicts the change in hazards shown in column (6). Because Cox regression only models relative hazards, column (6) cannot be interpreted as absolute hazards but rather as the relative change in hazards over the period. Negative signs on this column imply net reduction in death hazards, and vice versa. The total column sum is 0.120. Thus, assuming that the ‘structure’ remained constant over the entire period, we can argue that overall, the changes in the values of the variables between 1979-1990 and 1991-2003 imply a 12.7 percent [$100(e^{0.120}-1)$] increase in the hazard of death by age 5.

This overall picture, however, masks real differences in the contributions of individual or groups of variables. For instance, among socio-economic factors, the net effect of income and urbanization were positive (increased risk), while that of education was negative (decreased risk). Overall, the net effect of the socio-economic variables was +0.0070, or 0.7 percent increase in risk over the period. Similarly, among family formation variables, changes in maternal age, parity, and birth interval suppressed risks, while changes in birth order and marital status elevated risks. The result is a net change in hazard of -0.0668, or a 6.5 percent reduction in risk over the period. Lastly, among variables associated with child care and services, changes in medical care and nutrition inhibited risk elevation (although not significantly), while changes in vaccination coverage, delivery care, and breastfeeding facilitated it. The net change in death hazards among this group was +0.1797, or 19.7 percent rise in risk over the period, representing the largest effect. Thus, based on the ‘fixed structure’ analysis, changes in the values of the variables related to child care and services largely influenced the increase in hazards of death by age 5 after 1990, while changes in the values of family formation variables acted to reduce it. The net role of socio-economic variables was negligible.

Shifting structure analysis

In Table 3, we explore whether a shift in structure occurred by identifying the variables whose coefficients changed significantly between the two periods. To that end we fit a Cox model using the pooled data and the same variables as before, but this time interact each variable with the 1991-2003 period dummy. The results are shown in columns (1) and (2), while column (3) indicates whether the change is significant.

Evidence shows significant changes in the structure of relationships. The relative importance of six predictors – mother’s education, age at birth, parity, and marital status, household income, and child’s birth order – shifted significantly after 1990 compared to before. Lack of education had a significantly strong negative impact on death hazards after 1990 and a positive impact before, while the beneficial effects of secondary-plus education was greater before 1990.

Household income, especially high income, also had a stronger negative impact before 1990, while first births faced significantly higher death hazards before 1990. However, children of teenage, high parity, and formerly married women were predisposed to higher mortality risks after 1990 than before. In fact the relative risk of under-5 mortality was more than twice as high in the latter compared to the former period for these variables.

The rest of the variables, on the other hand, showed slight differences in effects across the periods but that were not statistically significant. Short preceding birth interval especially showed the strongest positive association with the hazards of death in both periods, but the difference was not statistically significant. Similarly, breastfeeding had a negative and statistically significant effect after 1990 unlike before. But children residing in urban areas faced much greater but non-statistically significant risks of death before 1990. The effects of vaccination and skilled delivery assistance were in the desired direction and remained fairly unchanged across the periods, although the latter was not statistically significant after 1990. Medical care and stunting swapped signs from positive before 1990 to negative afterwards, while the reverse was the case among children of never-married women, although the effects were not statistically significant. It is also noteworthy that the impact of gender, which favors the girl-child, remained unchanged over the period.

Adversity or structural shift?

Last but not least, we explore the roles of adversity (changes in the actual values of individual variables) and a possible shift in structure (changes in the relative importance of individual variables) in accounting for the increase in the hazards of death between 1979-1990 and 1991-2003. Thus, we are interested in establishing how well the overall relative change in death hazards can be predicted by each structure across both periods, and within each period by both structures. This is achieved by alternately holding the period and structure constant, and examining the changes in the predicted overall hazards shown in columns (4) – (7) of Table 3. Columns (4) and (5) are predicted by applying the 1979-1990 structure to the average values of the variables in 1979-1990 and 1991-2003 – shown in Columns (1) and (2) of Table 2 – respectively. Similarly, columns (6) and (7) are predicted by applying the 1991-2003 structure to the average values of the variables in 1979-1990 and 1991-2003 respectively.

Now, based on the 1979-1990 structure, the difference in the predicted overall change in the hazard of death between the two periods [columns (4) and (5)] constitutes the role of adversity. But, based on the variable values for the period 1979-1990, the difference between the overall change in hazard predicted by the 1979-1990 structure and that predicted by the 1991-2003 structure represents the contribution due to changes in structure. A reverse analysis based on the 1991-2003 structure should yield similar results, barring rounding errors. The results are summarized in Table 4.

Table 3. Cox regression model for decomposing the change in hazards of death by age 5 in Kenya between 1979-1990 and 1991-2003: Shifting structure analysis

Predictors	Cox regression coefficients [a] 1979-90 coefficient (1)	SE	1991-03 coefficient (2)	SE	z-test for interaction term (3)	Predicted hazards [b] Based on 1979-90: 1979-90 (4)	1991-03 (5)	Based on 1991-03: 1979-90 (6)	1991-03 (7)
Socioeconomic variables									
No education	.0861	.080	-.289**	.115	-2.89**	.02325	.01283	-.07803	-.04306
Secondary+ education	-.4433***	.072	-.3319***	.094	.90	-.08157	-.10285	-.06107	-.07700
2nd income quintile*	-.0000458***	.0000171	-.0000246	.000021	.79	-.03228	-.03579	-.01734	-.01923
3rd income quintile*	-.0000531**	.0000225	-.0000786***	.0000209	-.90	-.03771	-.03854	-.05582	-.05705
4th income quintile*	-.0001452***	.0000231	-.0000777***	.0000282	2.15**	-.09752	-.08467	-.05218	-.04531
5th income quintile*	-.0001163***	.0000299	-.000103***	.0000343	.32	-.06781	-.05965	-.06005	-.05283
Urban residence	.2166	.139	.1340	.098	-.50	.03422	.04159	.02117	.02573
Family formation variables									
Maternal age 15-19	.2220***	073	.4128***	.076	1.82*	.04018	.03929	.07472	.07307
Maternal age 35-49	.0587	.074	.1166	.084	.53	.00693	.00652	.01376	.01294
First birth	.3281***	.073	.1028	.079	-1.97**	.06168	.08071	.01933	.02529
Short birth interval	.6961***	.072	.6180***	.070	-.78	.07657	.05151	.06798	.04573
Mother has 5+ children	.1866**	.076	.4007***	.057	2.12**	.10674	.07165	.22920	.15387
Mother never married	-.0067	.115	.0092	.149	.08	-.00031	-.00042	.00043	.00057
Mother formerly married	.1689**	.078	.3777***	.083	1.75*	.01299	.01468	.02908	.03286
Child care and services									
Vaccination coverage (%)	-.0109**	.005	-.0106***	.003	.07	-.80987	-.64681	-.78758	-.62900
Skilled delivery care (%)	-.0048*	.003	-.0034	.003	.36	-.22954	-.20707	-.16259	-.14668
Medical attention (%)	.0015	.003	-.0003	.002	-.53	.10382	.08897	-.02076	-.01779
Breastfeeding (6+ months)	-.0215	.013	-.0214***	.007	.01	-1.9204	-1.90125	-1.91145	-1.89240
Stunting (%)	.0063	.005	-.0043	.007	-1.37	.21710	.21521	-.14818	-.14689
Gender (male)	.1365***	.052	.1394***	.052	.04	.06798	.06907	.06942	.07054
Birth period			.2413	1.073				.24130	.24130
Sum of relative log hazards						**-2.5255**	**-2.3850**	**-2.5887**	**-2.4453**

Note: *** p<.01 ; ** p<.05 ; * p<.10

[a] Relative log hazards

[b] Total relative log hazards

* Wealth quintiles weighted by GDP per capita at constant prices

Reading Table 4 horizontally [rows I and II] maintains the structure for the period, but allows the variable values to vary between the periods. This permits assessment of the role of changes in the values of the variables (adversity). However, reading it vertically [columns (1) and (2)] maintains the variable values but allows the structure to vary within each period, thus reflecting the effect of structural changes. Therefore, the predicted overall change in the hazard of death due to changes in the values of the variables between the periods was 0.1419 [(.1405+.1433)/2], while that due to changes in the structure was 0.0617 [(.0631+.0603)/2]. Accordingly, adversity accounts for 15.2 percent [100($e^{.1419}$-1)] of the increase in the hazard of death by age 5 between 1979-1990 and 1991-2003. Structural change, on the other hand, accounts for 6.4 percent [100($e^{.0617}$-1)] of the increase over the same period. Altogether, they explain about 22 percent of the overall change in under-5 mortality risk during the period.

Table 4. Predicted changes in Under-5 mortality risk in Kenya between 1979-90 and 1991-03 (based on Table 3)

Component	Period		Change
	1979-1990 (1)	1991-2003 (2)	(3)
I. Predicted under-5 mortality risk using 1979-90 structure	-2.5255	-2.3850	0.1405
II. Predicted under-5 mortality risk using 1991-03 structure	-2.5887	-2.4453	0.1433
III. Change in under-5 mortality risk due Structure (log hazards)	0.0631	0.0603	

SUMMARY AND CONCLUSION

This study is set up against the backdrop of increasing early childhood mortality rate in Kenya from early 1990s – a scenario which is in sharp contrast to the dramatic drop between mid-1940s and 1980s. In particular, it sought to explore the role of changes in the values versus relative importance of the explanatory variables in accounting for the increase in under-5 mortality after 1990. Past studies have emphasized the role of HIV/AIDS and deterioration in socio-economic circumstances, without much empirical support.

The study was based on individual-level data from the four DHSs conducted in Kenya in 1989, 1993, 1998, and 2003. Only singleton births occurring within 10-years of each survey were considered. The data were pooled, yielding records of 45,690 children born during the period

1979-2003. The study primarily used survival analysis techniques. Cox regression – a proportional hazards model – was used for multivariate analysis owing to its robustness. The following is a summary of the salient findings:

(1) The hazards of death were markedly higher for infants and toddlers after 1990. Overall, the hazards of under-5 death increased by 22 percent between 1979-1990 and 1991-2003. This resulted in a 15 percent increase in the probability of dying under-5, from 85.4 per 1000 live births in 1979-2003 to 98.2 per 1000 live births in 1991-2003. These estimates are consistent with those documented in the survey reports, barring slight differences attributable to use of disparate reference periods.

(2) The values of all variables considered changed significantly between 1979-1990 and 1991-2003, albeit in varied directions.

- The following changes were expected to lower hazards of death: improvements in education; declining birth rates; reductions in the proportional share of births with short preceding interval, and to women aged 15-19 and 35-49 – subgroups known to exhibit above average child mortality risks.

- The following changes were expected to elevate death hazards: reductions in real income, vaccination coverage, medical care for sick children, skilled delivery care, and duration of breastfeeding; increase in proportional share of births to never and formerly married women, and in urban areas.

(3) Assuming a 'fixed" structure over the entire period, changes in the values of the variables between 1979-1990 and 1991-2003 implied a 12.7 percent increase in the hazards of death by age 5. This comprised a net increase of 19.7 percent among variables related to child care and services, net reduction of 6.5 percent among family formation variables, and a net negligible role of socio-economic variables.

(4) Evidence shows significant structural changes as well. Allowing for varying structure between the periods, we estimated that adversity accounts for 15.2 percent of the increase in the hazards of death by age 5 between 1979-1990 and 1991-2003, while change in structure accounts for 6.4 percent of the increase. Altogether, these constitute slightly more than 20 percent of the increase in the hazard of death during the period.

- Adversity was associated with reductions in income, vaccination coverage, and breastfeeding duration, increase in the proportional share of high risk first births and those to formerly married women, and increased mortality risks among children resident in urban areas.

- Structural change was associated with increased death hazards among children of teenage, high fertility, and formerly married women, as well as reduction in the relative importance of higher education and income after 1990. Because divorce rates are fairly low in Kenya, the increased death hazards among children of formerly married women is attributable to increasing prevalence of widowhood precipitated by high prevalence of HIV/AIDS. However, lack of adequate HIV/AIDS data prohibited further investigation of this phenomenon.

To conclude, these results may seem somewhat inconsistent with evidence from similar studies attributing over 70 percent of mortality decline in developing countries to structural changes (Da Vanzo and Habicht 1986; Preston 1975). However, we urge caution in emphasizing the arithmetic value of the crunched numbers, given the inability of Cox regression to model absolute hazards, and the fact that the Kenyan case concerns rising and not declining mortality as was the case with the above-mentioned studies. At the very least, we have adduced evidence that both changes in the values of variables and shifts in the structure of relationships played a role in the recent increase in early childhood mortality in Kenya and – possibly – other similarly affected countries in Sub-Saharan Africa. Needless to overemphasize, a substantial portion of the explanation lies with factors exogenous to our models.

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