Research Paper No. 2007/83

Environmental Determinants of Child Mortality in Kenya

Clive J. Mutunga*

December 2007

Abstract

This paper focuses on the determinants of infant and child mortality in Kenya. It specifically examines how infant and child mortality is related to the household's environmental and socio-economic characteristics, such as mother's education, source of drinking water, sanitation facility, type of cooking fuels and access to electricity. A hazard rate framework is used to analyze the determinants of child mortality. Duration models are easily applicable to the problem of child mortality as this class of models straightforwardly accounts for problems like right-censoring, structural modeling and time varying covariates which traditional econometric techniques cannot handle adequately.

A household's environmental and socio-economic characteristics are found to have significant impact on child mortality. Policies aimed at achieving the goal of reduced child mortality should be directed on improving the household's environmental and or socio-economic status if this goal is to be realized.

Keywords: child mortality, infant mortality, neo-natal mortality, duration model, survival analysis, failure function, duration model, hazard rate

JEL classification: D6, J13, Q59

* Kenya Institute for Public Policy Research and Analysis (KIPPRA): email: cmutunga@kippra.or.ke.

This study is a revised version of the paper presented at the 29-30 September 2006 UNU-WIDER conference on Advancing Health Equity.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme by the governments of Denmark (Royal Ministry of Foreign Affairs), Finland (Ministry for Foreign Affairs), Norway (Royal Ministry of Foreign Affairs), Sweden (Swedish International Development Cooperation Agency—Sida) and the United Kingdom (Department for International Development).

ISSN 1810-2611 ISBN 978-92-9230-036-4

The World Institute for Development Economics Research (WIDER) was established by the United Nations University (UNU) as its first research and training centre and started work in Helsinki, Finland in 1985. The Institute undertakes applied research and policy analysis on structural changes affecting the developing and transitional economies, provides a forum for the advocacy of policies leading to robust, equitable and environmentally sustainable growth, and promotes capacity strengthening and training in the field of economic and social policy making. Work is carried out by staff researchers and visiting scholars in Helsinki and through networks of collaborating scholars and institutions around the world.

www.wider.unu.edu *publications@wider.unu.edu*

UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

Typescript prepared by Anne Ruohonen at UNU-WIDER

1 Introduction

Child mortality, commonly on the agenda of public health and international development agencies, has received renewed attention as a part of the United Nation's Millennium Development Goals. Approximately ten million infants and children under five years of age die each year, with large variations in under-five mortality rates, across regions and countries (Espo, 2002).

Childhood mortality rates have declined all over the world in the last fifty-five years. Between the mid 1940s and early 1970s, child death rates even in the developing countries reduced significantly (see for example, Baker, 1999). A great deal of these gains was achieved through interventions targeted at communicable diseases (diarrhoea, respiratory infections, malaria, measles and other immunizable childhood infections).

However these health gains were short lived. In the mid 1970s the worldwide progress was not maintained and infant mortality rates rose especially in Africa because disease-oriented vertical programmes were not effective alone. Maternal, environmental, behavioural and socio-economic factors were recognized as additional important determinants of infant survival. According to UNICEF (1999), the decline in child mortality in Africa has been slower since 1980 than in the 1960s and 1970s. Of the thirty countries with the world's highest child mortality rates, twenty-seven are in sub-Saharan Africa. The region's under-five mortality in 1998 was 173 per 1000 live borns (UNICEF, 2000) compared to the minimum goal of 70/1000 internationally adopted in the 1990 World Summit for Children. Causes of infant mortality are multi-factorial, especially in developing countries, where there are great variations between social, economic and demographical groups of people even inside one country.

Although enormous literature exists on child mortality, evidence on why infant and child mortality rates remain high in many sub-Saharan African countries despite action plans and interventions made is still scanty.

Environmental risk factors account for about one-fifth of the total burden of disease in low income countries according to recent estimates (World Bank, 2001). WHO (2002) reports that among the ten identified leading mortality risks in high-mortality developing countries, unsafe water, sanitation and hygiene ranked second, while indoor smoke from solid fuels ranked fourth. About 3 per cent of these deaths (1.7 million) are attributable to environmental risk factors and child deaths account for about 90 per cent of the total.

According to Shyamsundar (2002), environmental health risks fall into two broad categories. The first are the traditional hazards related to poverty and lack of development, such as lack of safe water, inadequate sanitation and waste disposal, indoor air pollution, and vector-borne diseases. The second category is the modern hazards such as rural air pollution and exposure to agroindustrial chemicals and wastes that are caused by development that lacks environmental safeguards.

As the world enters into the twenty-first century, debate on childhood mortality remains a big issue for developing countries. Their commitment is reflected in their desire to reduce the level of child mortality by two-thirds of their 1990 levels by the year 2015, as expressed in the Millennium Development Goals. To achieve this goal, it is imperative to determine what factors contribute to the high levels of child mortality in developing countries.

Several studies have been conducted on infant and child mortality in Kenya, most of which have used indirect methods like the Trussell's technique to estimate the child mortality. Some of these studies have also employed multivariate linear and logistic regression to identify the determinants of infant child mortality. However, Ordinary Least Squares (OLS) or binary dependent variable regression models cannot handle very well the aspect of child mortality because of the occurrence of the transition event being the dependent variable because of problems of censoring (and truncation), time varying covariates and structural modeling (Jenkins, 2003). This study introduces survival analysis into child mortality modeling in Kenya. Duration models are the most suited for such analysis because they account for problems like right-censoring, structural modeling and time varying covariates which traditional econometric techniques cannot handle adequately.

2 Background

Although accurate information on cause of death is lacking, the leading cause of under-five mortality in Kenya is pneumonia, malaria, measles and diarrhoeal disease, which are estimated to have been responsible for some 60 per cent of disease burden in the region (Murray and Lopez, 1996). Kenya experienced a dramatical fall in child mortality in the late 1940s and early 1960s. Until around 1980, the under-five mortality rate fell at an annual rate of about 4 per cent per annum. This rate of decline slowed in the early 1980s to about 2 per cent per annum. Data from the 1998 Kenya Demographic and Health Survey (KDHS) (National Council for Population and Development, Central Bureau of Statistics and Macro International, 1989) show that, far from declining, the under-five mortality rate increased by 25 per cent from the late 1980s to the mid 1990s. The recent Kenya Demographic and Health Survey (CBS, 2004) shows that under-five mortality rate is 115 deaths per 1,000 live births (see Table 1).

Table 1: Levels and trends of childhood mortality in Kenya

Years preceding the survey	Neonatal mortality	Postneonatal mortality	Infant mortality	Child mortality	Under-five mortality
0-4	33	44	77	41	115
5-9	32	41	73	40	110
10-14	31	42	73	35	105

Source: CBS 2004. (All rates are expressed per 1,000 live births, except for child mortality, which is expressed per 1,000 children surviving to 12 months of age.)

Table 1 shows the infant and under-five mortality rates for each of the three five-year periods preceding the 1998 KDHS and the 2003 KDHS. The use of rates for five-year periods conceals any year-to-year fluctuations in early childhood mortality. For the most recent five-year period preceding the survey, infant mortality is 77 deaths per 1,000 live births, and under-five mortality is 115 deaths per 1,000 live births. This means that one in every nine children born in Kenya dies before attaining his or her fifth birthday. This pattern shows that 29 per cent of deaths under the age of five occur during the neonatal period while 38 per cent occur during the post neonatal period. In general, both infant and under-five mortality rates are increasing, with the increases being more pronounced during the period between the mid-1980s and mid 1990s.

2.1 Statement of problem

The environment, which sustains human life, is also a profound source of ill health for many of the world's people. In the least developed countries, one in five children does not live to see their fifth birthday, mostly because of avoidable environmental threats to health. This translates into approximately 11 million avoidable childhood deaths each year (WRI, 1999; World Bank, 2004). Hundreds of millions of others, both children and adults, suffer ill health and disability that undermine their quality of life and hopes for the future. These environmental health threats, arguably the most serious environmental health threats facing the world's population today, stem mostly from traditional problems long since solved in the wealthier countries, such as a lack of clean water, sanitation, adequate housing, and protection from mosquitoes and other insect and animal disease vectors.

Poverty also influences health because it largely determines an individual's environmental risks, as well as access to resources to deal with those risks. Throughout the developing world, the greatest environmental health threats tend to be those closest to home. Many in these countries live in situations that imperil their health through steady exposure to biological pathogens in the immediate environment. More than 1 billion people in developing countries live without adequate shelter or in unacceptable housing. A further 1.4 billion lack access to safe water, while another 2.9 billion people have no access to adequate sanitation (World Bank, 2004), all of which are essential for good hygiene. Unable to afford clean fuels, the poor largely rely on biomass fuels for cooking and heating. Inside the smoky dwellings of developing countries, air pollution is often higher than outdoors in the world's most congested cities.

As already mentioned, infant mortality rates in Kenya are still very high compared to other countries and have increased by 30 per cent between 1989 and 2003. Reducing child mortality is the fourth Millennium Development Goal, whose target is to reduce the under-five mortality rate by two-thirds between 1990 and 2015. Despite numerous interventions and action plans, very little evidence exists on why the infant and child mortality rates are increasing in Kenya. If Kenya is committed to achieving the MDG on child mortality, it is prudent to understand clearly the factors that are contributing to the high levels of mortality. This study therefore explores the household's environmental and socio-economic characteristics and their effect on child and infant mortality in Kenya.

2.2 Objectives of the study

The general aim of the study is to explore the relationship between households' environmental and socio-economic characteristics on child mortality. The specific objectives are:

- To assess the relationship between the environment and child mortality in Kenya
- To identify the environmental determinants of child mortality, controlling for other covariates

In order to meet the above objectives, the following hypotheses are tested:

- Household's access to safe water has no effect on child mortality.
- Children born in households without sanitation facilities are more likely to die than those in households without.
- The household's main source of cooking fuel has no effect on child mortality.

3 Literature review

3.1 Theoretical literature

There is a relatively large literature that focuses on the determinants of child mortality (for a survey, see Wolpin, 1997). Theoretical frameworks are often presented as health production functions, which capture the structural relation between health outcomes and the household's behavioural variables, like nutrition, breastfeeding, child spacing, etc. (see Schultz, 1984). In the framework of a health production function, child mortality risks depend on both observed health inputs and unobserved biological endowment or frailty. Not properly taking account of these unobserved characteristics or the relation between children within a family may lead to inconsistent and inefficient estimators (for example, see Ridder and Tunali, 1999).

There are a number of different analytical frameworks through which to view the effects of different determinants on childhood mortality. Demographic research by Mosley and Chen (1984) and by Schultz (1984) made the distinction between variables considered to be exogenous or socio-economic (i.e. cultural, social, economic, community, and regional factors) and endogenous or biomedical factors (i.e. breastfeeding patterns, hygiene, sanitary measures, and nutrition). The effects of the exogenous variables are considered indirect because they operate through the endogenous biomedical factors. Likewise, the bio-medical factors are called intermediate variables or proximate determinants because they constitute the middle step between the exogenous variables and child mortality (Jain, 1988; Mosley and Chen, 1984; Schultz, 1984; UN, 1985).

Mosley and Chen (1984) were among the first to study the intermediate biomedical factors affecting child mortality, labeled 'proximate determinants' They distinguished fourteen proximate determinants and categorized them into four groups: maternal [fertility] factors, environmental sanitation factors, availability of nutrients to the foetus and infant, injuries, and personal illness control factors.

3.2 Empirical literature

Several studies have been carried out on infant and child mortality using census and survey data. In Kenya, all of these studies have used indirect methods, mostly the

Trussel's technique, Preston method and Coale-Demeny model life table to estimate child mortality.

For instance, Jada (1992) and Okumbe (1996) combine the Trussell's technique for estimating child mortality based on the Coale-Demeny model life table with multivariate linear regression; Wanjohi (1996) employs the Trussell-Preston methods and multivariate regression analysis to calculate mortality indices for each woman; Omariba (1993) utilizes the Coale and Trussel technique as well as multiple regression analysis using census data to estimate mortality in Kajiado district; De-Gita (1996) and Ouma (1991) also employ the Trussell's technique while Kamau (1998) uses cross-tabulation and regression analysis. All these studies, which use either the KDHS or census data to measure the effect of socio-economic, environmental or demographic covariates on child mortality, find demographic, socio-economic and environmental factors (type of toilet facility, type of bathing facility, source of drinking water) to be significantly related to infant and child mortality.

In Malawi, Baker (1999) and Espo (2002) use indirect methods to estimate levels and trends of mortality in Malawi. Although the results from former study indicate that owning a pit latrine does not have a significant effect on child mortality (which is explained by the argument that just because a household has sanitation facilities does not mean that it will be used hygienically or by all members of the household), the latter's results indicate that the source of drinking water and sanitation facilities are strong predictors of infant mortality

Woldemicael (1988) employs a logistic regression to examine the effect of some environmental and socio-economic factors that determine childhood diarrhoea in Eritrea, using data from the 1995 Eritrea Demographic and Health Survey (EDHS). The results show that the type of floor material, household economic status and place of residence are significant predictors of diarrhoea. Similarly Timaeus and Lush (1995), in a comparative study of rural areas of Ghana, Egypt, Brazil and Thailand, find out that children's health is affected by environmental conditions and the economic status of the household.

Duration modeling is applied by Hala (2002) to assess the impacts of water and sanitation on child mortality in Egypt. Results show that access to municipal water decreases the risk and sanitation is found to have a more pronounced impact on mortality than water.

The hazard rate framework is elegantly utilized by Klaauw and Wang (2003), in which a flexible parametric framework for analyzing infant and child mortality is developed. Their model predicts that a significant number of deaths, of children under five years, can be averted by providing access to electricity, improving the education of women, providing sanitation facilities and reducing indoor air pollution. In particular, reducing indoor air pollution and increasing the educational level of women might have substantial impacts on child mortality. In a related study, Jacoby and Wang (2003) examine the linkages between child mortality and morbidity, and the quality of the household and community environment in rural China using a competing risks approach. The key findings are that (1) the use of unclean cooking fuels (wood and coal) significantly reduces the neonatal survival probability in rural areas; (2) access to safe water or sanitation reduces child mortality risks by about 34 per cent in rural areas; (3) a higher maternal education level reduces child mortality and female education has strong health externalities; (4) access to safe water/sanitation, and immunization reduce diarrhoea incidence in rural areas, while access to modern sanitation facilities (flush toilets) reduces diarrhoea prevalence in rural areas; (5) significant linkages between Acute Respiratory Infections (ARI) incidence and use of unclean cooking fuels are found using the city level data constructed from the survey.

Wang (2003), using the results from the 2000 Ethiopia DHS examines the environmental determinants of child mortality by constructing three hazard models (the Weibull, the piecewise Weibull and the Cox model) to examine three age-specific mortality rates: neonatal, infant, and under-five mortality by location (urban/rural), female education attainment, religion affiliation, income quintile, and access to basic environmental services (water, sanitation and electricity). The estimation results show a strong statistical association between child mortality rates and poor environmental conditions.

3.3 Overview of literature

There is general consensus in the literature that a household's socio-economic and environmental characteristics do have significant effects on child and infant mortality. This is true for studies which employ both direct and indirect techniques to estimate infant and child mortality.

As observed in most studies, a household's income has a significant effect on the survival prospects of children. Higher mortality rates are experienced in low income households as opposed to their affluent counterparts.

The mother's level of education is strongly linked to child survival. Higher levels of educational attainment are generally associated with lower mortality rates, since education exposes mothers to information about better nutrition, use of contraceptives to space births, and knowledge about childhood illnesses and treatment. Larger differences have been found to exist between the mortality of children of women who have attained secondary education and above and those with primary level of education or less.

On the household's environmental characteristics, safe source of drinking water supply has a significantly negative effect on child mortality. The same holds true for those with sanitation, which in most cases is taken to be access to a flush toilet or a ventilated improved pit latrine.

Differentials by urban/rural residence have commonly been observed, with urban areas having more advantages and therefore better child survival prospects.

As concerns the demographic variables, the patterns of mortality by maternal age and birth order are typically U-shaped. Children born to both relatively old and young women have higher mortality rates than others; the interpretation of the effect of maternal age at birth on infant mortality must be biological, i.e., it depends on reproductive maturity. Moreover, first and higher order births also have higher mortality rates since the birth order reflects the components of the child's biological endowment. As for the child's gender, it is widely believed that male mortality is higher due to biological disadvantages. Twins face a higher mortality risk.

4 Methods

4.1 Theoretical model

In this section, we present the model for estimating infant and child mortality. Our study employs survival analysis, the main concepts of which are the hazard function and the survivor function. The length of a spell for a subject (person, firm, etc.) is a realization of a continuous random variable T with a cumulative distribution function, failure function $F(t)$, and probability density function, $f(t)$. The failure function is given as:

$$F(t) = \Pr(T \leq t) \tag{4.1}$$

where T is the length of a completed spell and t is the elapsed time since entry to the state at time 0. The survivor function is obtained from the failure function and is given as:

$$S(t) \equiv 1 - F(t) \tag{4.2}$$

Thus,

$$\Pr(T > t) = 1 - F(t) \equiv S(t) \tag{4.3}$$

The survivor function $S(t)$ and the Failure function $F(t)$ are each probabilities, and therefore inherit the properties of probabilities. The survivor function lies between zero and one, and is a strictly decreasing function of t. The survivor function is equal to one at the start of the spell ($t = 0$) and is zero at infinity.

Closely related is the concept of hazard rate, which is given as:

$$\theta(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)} \tag{4.4}$$

There is a one-to-one relationship between a specification for the hazard rate and the survivor function, which after some manipulation is given as:

$$S(t) = \exp\left[-H(t)\right] \tag{4.5}$$

where

$$H(t) = \int_0^t \theta(u)\,\mathrm{d}u = -\mathrm{Ln}\left[S(t)\right] \geq 0 \tag{4.6}$$

is the integrated hazard function.

The important result is that, whatever functional form is chosen for (t), one can derive $S(t)$ and $F(t)$ from it (and also $f(t)$ and $H(t)$), and vice versa.

4.2 Empirical model

Our aim is to estimate the hazard ratio of the probability of a child dying within the next day after surviving for *t* days, as a result of environmental factors, among others. In the context of child mortality, the hazard rate is often referred to as the mortality rate (Ridder and Tunali, 1999). The mortality rate at age *t* can be interpreted as the intensity at which a child dies at this age, given that the child survived until age *t*. We focus on children who are born alive and model their mortality probabilities until the age of five.

To check robustness, we implement two models, a parametric (Weibull) and a semi-parametric model (Cox).

4.2.1 Weibull model

The literature contains an abundance of choices for parametric models; but we estimate a popular one, the Weibull model. The hazard function of the Weibull model is defined as $h(t) = \alpha\lambda t^{\alpha-1}$ where $\lambda = \exp(\beta' X)$. α is a scale parameter with α <1 indicating that the hazard falls continuously over time, while α >1 indicates the opposite (see Greene, 2000).

The hazard function $h(t/X)$ will be estimated using Maximum Likelihood estimation. The likelihood function is given as:

$$L = \frac{f_1(t) f_2(t).....f_n(t)}{t, X, \beta, \alpha} \tag{4.7}$$

where $f_i(t)$ $\quad i = 1.....n$ is the probability distribution

$$f(t) = h(t)S(t) \text{ if dead} = \begin{cases} 1 \\ 0 \end{cases} \therefore f(t) = S(t) \tag{4.8}$$

$$L = \prod_{i=1}^{n} [h(t)S(t)][S(t)]$$

$$= \prod_{i=1}^{n} [h(t)S(t)] \tag{4.9}$$

The log-likelihood function is expressed as:

$$\log L = \sum_{i=1}^{n} \log h_i(t) + \sum_{i=1}^{n} \log S_i(t) \tag{4.10}$$

The log of $h(t)S(t)$ is the individual contribution of the likelihood function that we intend to maximize.

4.2.2 Cox model

The distinguishing feature of Cox's proportional hazard model, sometimes simply referred to as the Cox model, is its demonstration that one could estimate the relationship between the hazard rate and explanatory variables without having to make any assumptions about the shape of the baseline hazard function. Hence the Cox model is sometimes referred to as a semi-parametric model. The result derives from innovative use of the proportional hazard assumption together with several other insights and assumptions, and a partial likelihood (PL) method of estimation rather than maximum likelihood.

The Cox model is given as follows:

$$h(t \mid X) = h(t)\exp(X_1\beta_1 + ... + X_m X_m) \qquad (4.11)$$

The model makes no assumptions about the form of $h(t)$ (non-parametric part) of the model but assumes a parametric form of the effects of the predictors on the hazard.

Parameter estimates in the model are obtained by maximizing the partial likelihood as opposed to the likelihood. The partial likelihood is given by:

$$L(\beta) = \prod_{Y_i uncensored} \frac{\exp(X_i\beta)}{\sum Y_j \geq Y_i \exp(X_j\beta)} \qquad (4.12)$$

The log partial likelihood is given by:

$$l(\beta) = \log L(\beta) = \prod_{Y_i uncensored} \left\{ Xi\beta - \log\left[\sum_{Y_j \geq Y_i} \exp(X_j\beta)\right]\right\} \qquad (4.13)$$

The partial log-likelihood can be treated as an ordinary log-likelihood to derive valid (partial) MLEs of β (see, Cox, 1972). However, one of the problems here is the possible existence of unobserved heterogeneity[1] between children from different families since they potentially have a different duration distribution and the control for the effect of the related explanatory variables is incomplete. The result that holds generally about heterogeneity is that it leads to a downward biased estimate of duration dependence. Gail et al. (1984) showed that the unobserved heterogeneity tends to attenuate the estimated coefficients toward zero. On the other hand, standard errors and test statistics are not biased. For this reason, a correction for the unobserved heterogeneity based on the gamma distribution of heterogeneity with mean one and variance θ is used.

4.3 Data

The data used in the empirical analysis was obtained from the Kenya Demographic and Health Survey (KDHS) 2003. The KDHS provides information on fertility, mortality, health issues, socio-economic and environmental conditions. The KDHS 2003 is a nationally representative sample of 8,195 women aged between 15 to 49 and 3,578 men aged 15 to 54 selected from 400 clusters (sample points) throughout the eight provinces in Kenya.

---

[1] Most empirical studies assume that health inputs have constant impacts on child mortality over the age of the child. We will relax these assumptions by accounting for unobserved heterogeneity.

As is often the case with data on child mortality, information comes from surveys among women. A special survey questionnaire for women called the women's questionnaire is administered to capture data on women's birth history. For each live born child the month of birth is recorded and whether or not the child is still alive at the time of the interview. If a child died during the observation period, the age at which the child died is asked. The age of death is observed within intervals, in case a child died within a month after birth, the age of death is recorded in days, if the child died between one month and two years, it is recorded in months, and otherwise it is recorded in years. Because we are only interested in child mortality until age five, we will artificially right-censor at this age. Right-censoring can also occur if a child is alive at the moment of the interview and younger than five years old.

The KDHS also collects information on asset ownership, such as car, radio, television, refrigerator etc. Asset ownership is a proxy for wealth and economic status (e.g. Filmer and Pritchett, 2001). In low-income countries, where household income is often difficult to measure (particularly in rural areas), consumption expenditures are often used in determining poverty (e.g. Deaton, 1997). Although asset ownership is less sensitive to short-term fluctuations than consumption expenditures, asset ownership and consumption expenditures are strongly correlated. Additionally, the KDHS provides information on livestock and land ownership, which are indicators of both economic and social status of a household. Land ownership is also an indicator of income from agriculture.

4.3.1 Limitations of the data

The KDHS data are recorded retrospectively and can therefore suffer from misreporting, for example a child who died at a very young age might not be reported. Several DHS studies show evidence of downward bias in reporting child deaths (Jacoby and Wang, 2003), that is, the longer the recall period, the more likely the possibility of the respondents to misreport the case. The quality of mortality estimates calculated from retrospective birth histories depends upon the completeness with which births and deaths are reported and recorded. Potentially the most serious data quality problem is the selective omission of the birth histories of those who did not survive, which can lead to underestimation of mortality rates. Other potential problems include displacement of birth dates, which may cause a distortion of mortality trends, and misreporting of the age at death, which may distort the age pattern of mortality. When selective omission of childhood death occurs, it is usually most severe for deaths in early infancy. If early neonatal deaths are selectively underreported, the result is an unusually low ratio of deaths occurring within seven days to all neonatal deaths, and an unusually low ratio of neonatal to infant deaths. Underreporting of early infant deaths is most commonly observed for births that occurred long before the survey. An examination of the ratios shows no significant number of deaths omitted in the 2003 KDHS.

4.4 Definition of variables

The variables used in the estimations are defined in this section. The hazard rate, or in our case the child mortality rate, is the dependent variable and is defined as the probability per time unit that a child who has survived to the beginning of the respective interval will fail (die) in that interval.

The explanatory variables are classified into three groups: environmental, socio-economic and demographic. The choice of these variables was guided by the determinants of child mortality literature. The main focus of this study is however, on the environmental variables.

4.4.1 Measurement of variables

Household income is proxied by wealth indices which are calculated by the KDHS on the basis of ownership of household assets. We categorize all the households into rich (richest, rich and medium) and poor (poor and poorest).

Two dummies are constructed for mother's education. These are mothers with education and those without. The former are those having at least primary education.

In this study, households with access to private or public tap water, as well as covered well water are considered to have safe water. Similarly, households that have either a flush or a pit latrine, whether private or shared, are regarded to have sanitation as opposed to those without any facility.

The households' main source of cooking fuel is categorized thus. Households using liquefied petroleum gas (LPG), electricity, kerosene and biogas are considered users of low-polluting fuels. Those using charcoal, firewood and coal are regarded as users of high-polluting fuels.

5 Results

5.1 Descriptive statistics

This sub-section contains a discussion of the characteristics of the study variables.

Table 2 shows that the youngest woman was 15 while the oldest was 49 years of age, resulting in a mean age of 28 years. The mean household size was six members. With regard to educational attainment, about 80 per cent of the women had at least primary education. About 13 per cent of the households had electricity while 62 per cent of them were considered poor. Out of the sample, 3.4 per cent of the children were twins while 50.7 per cent of them were males.

Out of the women interviewed, 73.4 per cent were from a household with a flush toilet or a pit latrine and hence considered to have sanitation. In addition, 74.9 per cent met the study's qualification of having safe water. The majority (87.1 per cent) of the households use high-polluting sources of fuels for their cooking.

Table 2: Variable summary

Variable	Estimation	Obs	Mean	Std dev.	Min	Max	Frequency (%)
Socio-economic							
Household size	*hhsize*	5,949	5.98	2.54	1	24	
Mother with education	*m_educ*	4,739					79.66
Mother without education	*m_noeduc*	1,210					20.34
Household has electricity	*has_elec*	766					12.88
Poor households	*poor*	3,693					62.08
Rich households	*rich*	2,256					37.92
Demographic							
The child is male	*male*	3,015					50.68
The child is a twin	*twin*	201					3.38
Mother's age	*mage*	5,949	28.16	6.65	15	49	
Mother's age squared	*mage2*	5,949	837.34	403.50	225	2401	
Environmental							
Safe water	*saf_water*	4,453					74.85
Unsafe water	*unsaf_water*	1,496					25.15
Low polluting fuel	*fuelLP*	767					12.89
High polluting fuel	*fuelHP*	5,182					87.11
Has sanitation	*has_sani*	4,366					73.39
Has no sanitation	*no_sani*	1,583					26.61

5.2 Empirical results

Table 3 indicates both the Weibull and Cox models' coefficient and hazard rate estimates for child mortality in Kenya. The hazard ratios show the marginal impact of the variable on child mortality. The standard errors are robust and have been adjusted to clustering on the clusters.

Table 3: Coefficient and hazard ratio estimates for Weibull and Cox models

Variable	Weibull Model				Cox Model			
	Coefficient	Z-value	Hazard ratio	Z-value	Coefficient	Z-value	Hazard ratio	Z-value
	(Std error)		(Std error)		(Std error)		(Std error)	
Male	0.285***	3.160	1.330***	3.160	0.291***	3.222	1.338***	3.222
	(0.090)		(0.120)		(0.090)		(0.121)	
Twin	1.182***	7.429	3.260***	7.429	1.171***	7.360	3.225***	7.360
	(0.159)		(0.519)		(0.159)		(0.513)	
Hhsize	-0.146***	-6.319	0.864***	-6.319	-0.146***	-6.312	0.864***	-6.312
	(0.023)		(0.020)		(0.023)		(0.020)	
Mage	-0.094*	-1.915	0.910*	-1.915	-0.086*	-1.745	0.918*	-1.745
	(0.049)		(0.045)		(0.049)		(0.045)	
mage2	0.002**	2.350	1.002**	2.350	0.002**	2.219	1.002**	2.219
	(0.001)		(0.001)		(0.001)		(0.001)	
m_noeduc	0.154***	3.368	1.166***	3.368	0.147***	3.231	1.159***	3.231
	(0.046)		(0.135)		(0.046)		(0.134)	
saf_water	-0.148***	-4.395	0.863***	-4.395	-0.151***	-4.498	0.860***	-4.498
	(0.034)		(0.092)		(0.034)		(0.091)	
has_sani	-0.259	-2.045***	0.772***	-2.045	-0.230	-1.816*	0.794***	-1.816
	(0.127)		(0.121)		(0.127)		(0.125)	
has_elec	-0.312	-3.048***	0.732***	-3.048	-0.296***	-2.900	0.743***	-2.900
	(0.102)		(0.149)		(0.102)		(0.151)	
fuelLP	-0.095**	-2.247	0.909**	-2.247	-0.091**	-2.149	0.913**	-2.149
	(0.042)		(0.169)		(0.042)		(0.170)	
rich	-0.111***	-2.690	0.895***	-2.690	-0.108***	-2.626	0.897***	-2.626
	(0.041)		(0.105)		(0.041)		(0.105)	
Constant	-1.363*	-1.836						
	(0.743)							
p	0.327	23.454	0.327	23.454				
	(0.014)		(0.014)					
LogL	-2710.2				-4198.1			
No. of obs.	5949				5949			
No. failure	502				502			
Wald Chi^2	90.1				93.1			

Notes: *, **, *** significant at 10 per cent, 5 per cent and 1 per cent respectively.

All the variables in both the estimated Weibull and Cox models are significant and have the expected signs. A child born a twin has a significantly lower survival probability than a single born mainly due to biological factors. Male children (boys) have lower survival prospects than female children (girls). There is U-shaped pattern relationship between mother's age and childhood mortality, with children of the youngest and oldest women experiencing the highest risk of death.

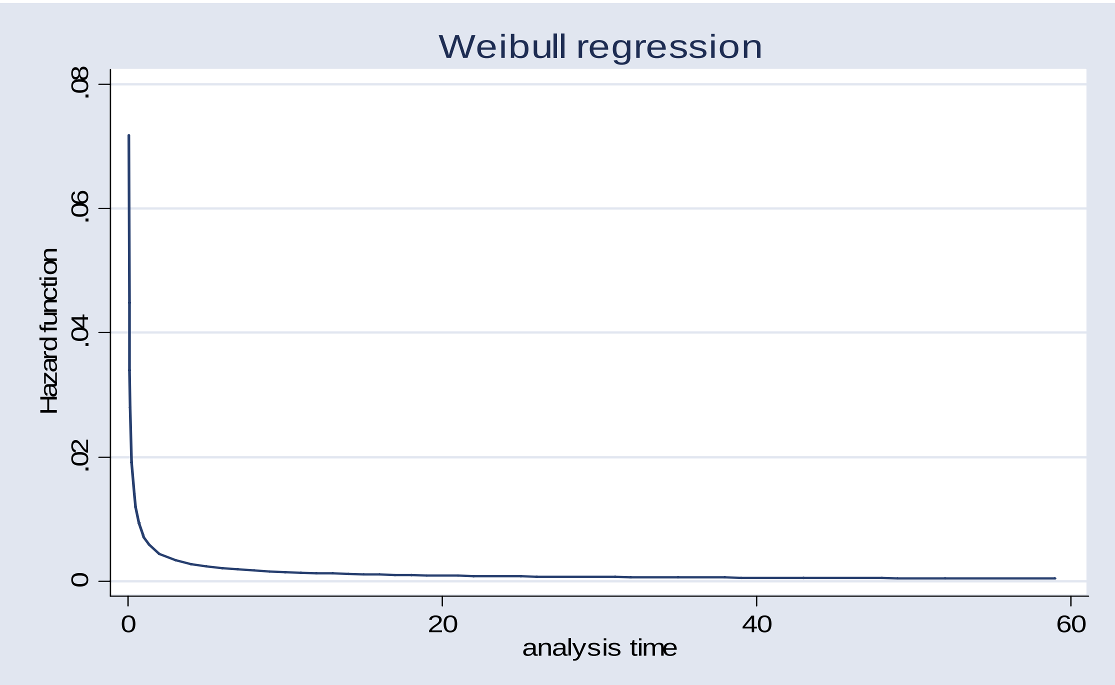
With regard to the socio-economic variables, household size is negatively related to child mortality, meaning that higher child survival prospects are experienced in larger households in Kenya. Lower mortality is experienced in affluent households since they have better child survival prospects. These households have better housing conditions, better nutrition, better education and hence more empowerment and are able to afford better medical attention and care thus significantly enhancing the survival probability of all their members including the children.

Households with access to safe water have significantly lower mortality rates. Access to sanitation facilities is also significantly related to child mortality. Children born in households with either flush toilets or pit latrines have lower mortality rate than those born in households without any toilet facility.

With regard to the source of cooking fuel, children born in households using high polluting fuels as their main source of cooking fuel have higher mortality rates as compared to those using low polluting fuels. Higher incidence of respiratory infections which are responsible for child deaths is expected in households which use 'dirty' fuels as opposed to those using clean cooking fuels.

All these findings are consistent with Hala (2002), Woldemicael (1988), Klaauw and Wang (2003) and Jacoby and Wang (2003).

Figure 1: Weibull hazard function



From the Weibull model estimates, the shape parameter α which is shown as ρ in STATA has a value of 0.3 which implies that the hazard rate is decreasing continuously over time or in other words there is negative time dependence. This means that children face a higher hazard (mortality rate) in the initial days of birth than in later periods. The same is shown by the plotted graph of the hazard function (Figure 1).

6 Conclusions and policy implications

6.1 Summary and conclusions

The paper has empirically examined the environmental determinants of child mortality in Kenya using survival analysis. For purposes of robustness, two models have been implemented. Estimation results from both the Weibull and Cox models have shown that households' socio-economic and environmental characteristics do have significant impact on child mortality.

Of the demographic variables, children born twins, male children and children born of the youngest and oldest women experiencing high risks of death. All of these are mainly due to biological factors.

As for the socio-economic variables, better survival prospects are found to exist for children born in wealthier families. Lower mortality rates have also been found in households with electricity. Household size is negatively related to child mortality, meaning that lower child survival prospects are experienced in smaller households.

As expected, environmental characteristics of the household have been found to be significantly related to child mortality. Lower mortality rates are experienced in households that have access to safe drinking water, those with access to sanitation facilities and those using low polluting fuels as their main source of cooking.

6.2 Policy implications

Since Kenya has committed to the Millennium Development Goals, the fourth of which is the reduction of child mortality, the country should be relentless in its efforts to meet these goals. Of particular importance will be the mainstreaming of the MDGs into the current national policy of economic recovery strategy (ERS). Closely related to this should be the pursuit of pro-poor development strategies, as recognized in various government sessional papers. Sectoral programmes such as the Integrated Mother and Childhood Illnesses (IMCI) programme should also be emphasized in the same regard.

Greater efforts need to be put in place to ensure provision of basic services like water for all. Availability of safe sources of drinking water will significantly reduce child mortality and therefore investments in this sector will be rewarding.

Access to sanitation facilities like constructing toilets entail a private cost but do have significant social benefits. The government should work closely with both the private sector and civil society to ensure that households have universal access to sanitation facilities as this will to a great extend reduce the number of infant deaths. In addition, the proposed housing policy should make it mandatory for each housing unit to have a sanitation facility such that all households have access to sanitation facilities.

Government policy should be focused towards promoting the use of low polluting fuels and in particular discouraging the use of firewood and charcoal which cause deforestation and other environmental problems. Through the use of economic instruments, incentives should be created for promotion of cleaner fuel sources. This would also create employment opportunities that translate into increased earnings and reduced poverty.

References

Baker, R. (1999) 'Differential in Child Mortality in Malawi', Social Networks Project Working Papers, No. 3, University of Pennsylvania.

Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya], and ORC Macro (2004) *Kenya Demographic and Health Survey 2003*, Calverton, MD: CBS, MOH and ORC Macro.

Cox, D.R. (1972) 'Regression models and life-tables', *Journal of the Royal Statistical Society,* Series B, 74: 187-220.

Deaton, A. (1997) *The Analysis of Household Surveys: A Microeconometric Approach to Development Policy*, Baltimore: Johns Hopkins University Press.

De-Gita, S.K. (1996) 'The socio-economic differentials of infant and child mortality in Kenya: Evidence from Kenya Demographic and Health Survey (KDHS) 1993 data', MA Thesis, Population Studies and Research Institute, University of Nairobi.

Espo, M. (2002) 'Infant Mortality and its Underlying Determinants in Rural Malawi', Dissertation, University of Tampere Medical School.

Filmer, D. and L.H. Pritchett (2001) 'Estimating wealth effects without expenditure data—or tears: An application to educational enrollments in states of India', *Demography* 38: 115-32.

Gail, M.H., S. Wieand and S. Piantadosi (1984) 'Biased estimates of treatment effect in randomized experiments with nonlinear regression and omitted covariates', *Biometrika*, 71: 431-44.

Greene, W.H. (2000) *Econometric Analysis*, 4th edn, London: Prentice-Hall.

Hala, A. (2002) 'The effect of water and sanitation on child mortality in Egypt', Environmental Economics Unit, Department of Economics, Gothenburg University.

Jacoby, H. and L. Wang (2003) 'Environmental Determinants of Child Mortality in Rural China: A Competing Risks Approach', Washington DC: World Bank.

Jada, L.F. (1992) 'Determinants of levels and differentials of early childhood mortality in Kenya based on Kenya Demographic and Health Survey (KDHS) 1989' MA Thesis, Population Studies and Research Institute, University of Nairobi.

Jain, A. (1988) ‘Determinants of Regional Variations in Infant Mortality in Rural India’, in A. Jain and L. Visaria (eds), *Infant Mortality in India: Differentials and Determinants*, Bombay: Sage Publications.

Jenkins, S.P. (2003) ‘Survival Analysis’, lecture notes, University of Essex.

Kamau, D.N. (1998) ‘Child survival determinants in the arid and semi-arid lands: A study of Machakos, Kilifi and Taita-Taveta districts’ MA Thesis, Population Studies and Research Institute, University of Nairobi.

Klaauw, van der B. and L. Wang (2003) ‘Child Mortality in Rural India’, World Bank Working Paper, Washington DC: World Bank.

Mosley, W. and L. Chen (1984) ‘An Analytical Framework for the Study of Child Survival in Developing Countries’, *Population and Development Review*, 10: 25-45.

Murray, C.J.L. and A. Lopez (1996) *The Global Burden of Disease: A comprehensive assessment of mortality from diseases, injuries and risk factors in 1990 and projected to 2020*, Cambridge, MA: Harvard University Press.

National Council for Population and Development (NCPD), Central Bureau of Statistics (CBS) (Office of the Vice President and Ministry of Planning and National Development) [Kenya] and Macro International [MI] (1989) *Kenya Demographic and Health Survey 1989*, Calverton, MD: NDPD, CBS and MI.

Okumbe, J. (1996) ‘Demographic and socio-economic correlates of neonatal mortality in Kenya’ MA Thesis, Population Studies and Research Institute, University of Nairobi.

Omariba, D.W.R. (1993) ‘Socio-economic determinants of child survival in Upper Matasia sub-location, Kajiado district, Kenya’ MA Thesis, Population Studies and Research Institute, University of Nairobi, Kenya.

Ouma, F.O. (1991) ‘Environmental risk and socio-economic factors influencing infant and child mortality in Siaya district: A case study of Jera sub-location’ MA Thesis, Population Studies and Research Institute, University of Nairobi.

Ridder, G. and I. Tunali (1999) ‘Stratified partial likelihood estimation’, *Journal of Econometrics*, 92: 193-232.

Schultz, T. (1984) ‘Studying the Impact of Household Economic and Community Variables on Child Mortality’, *Population and Development Review*, 10*:* 215-35.

Shyamsundar, P. (2002) ‘Poverty-Environment Indicators’, World Bank Environmental Department Paper, Washington, DC: World Bank.

Timaeus, I.M. and L. Lush (1995) ‘Intra-urban differentials in child health’, *Health Transition Review* 5(2): 163-90, Canberra: Health Transition Centre.

United Nations (1985) *Socio-Economic Differentials in Child Mortality in Developing Countries*, New York: United Nations.

UNICEF (1999) *The State of the World’s Children 1999*, New York: UNICEF.

UNICEF (2000) *The State of the World’s Children 2000*, New York: UNICEF.

Wang, L. (2003) 'Environmental Determinants of Child Mortality: Empirical Results from the 2000 Ethiopia DHS', Washington DC: World Bank.

Wanjohi, K.P. (1996) 'The influence of environmental factors on infant and child mortality: A study if six districts in Kenya' MA Thesis, Population Studies and Research Institute, University of Nairobi.

Woldemicael, G. (1988) 'Diarrhoeal morbidity among young children in Eritrea: Environmental and socio-economic determinants', Department of Statistics and Demography, Asmara: University of Asmara.

Wolpin, K. (1997) 'Determinants and consequences of the mortality and health of infants and children', in M. Rosenzweig and O. Stark (eds) *Handbook of Population and Family Economics*, Amsterdam: Elsevier Science B.V.

World Bank (2001) 'Health and Environment', Background paper for the World Bank Environment Strategy, Washington, DC: World Bank.

World Bank (2004) World Development Indicators (WDI), *The World Bank Online Database*, Washington, DC: World Bank.

World Health Organization (2002) *The world health report 2002: Reducing risks, promoting healthy life*, Geneva: World Health Organization.

WRI (World Resources Institute) (1999) *World Resources (1998-99): Environmental Change and Human Health*, Washington DC: World Bank.