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UNDER-FIVE CHILD MORTALITY IN BANGLADESH: CLASSICAL AND BAYESIAN APPROACHES TO COX PROPORTIONAL HAZARD MODEL

Shahnaz Nilima*

Department of Statistics, University of Dhaka, Dhaka-1000, Bangladesh

Abstract

This study examines the determinants of under-five child mortality in Bangladesh using the data extracted from the Bangladesh Demographic and Health Survey (BDHS), 2011 and 2014. Product-Limit method and Log-Rank test have been used for bivariate analysis. Cox proportional hazard model has been employed under both classical and Bayesian approaches. Cox regression analysis reveals that region (Barisal and Sylhet), maternal education (higher education), mother's membership of NGO have significant impact on child mortality. The results obtained using Bayesian Cox PH model are almost similar except one key finding. Under Bayesian analysis, child's size at birth appeared as potential determinant of under-five mortality whereas it has insignificant effect on child survival when classical Cox model has been applied.

Key words: Cox Proportional Hazard model, Bayesian Approach, Log-Rank test, Product-Limit Method, Under-five mortality

Introduction

Under-five child mortality rate is widely accepted as an indicator of socio-economic development and a reflection of a country's health care system and quality of life. In order to prevent child deaths and ensure healthy child survival, reducing under-five mortality to at least as low as 25 per 1,000 live births by 2030 is referred as the third Sustainable Development Goals (SDG). Bangladesh is one of the developing countries of Asia with high under-five child mortality rate. In Bangladesh between 1989 and 2014, under-five mortality rate reduced by two-third, from 133 to 46 deaths per thousand live births (BDHS 2014). Despite these prominent gains in reducing child mortality, the progress needs to be accelerated to achieve SDG 3.

Globally sociologists and policymakers pay great concentration on the factors affecting under-five mortality as it is an important indicator for describing standard of living, socio-economic well-being of a country. World-wide several studies have been undertaken that focused on the socio-economic determinants of infant and child mortality. In Kenya, Muriithi and Muriithi (2015) employed Cox regression survival analysis to the 2008 - 09 Kenya Demographic Health Survey data set for children in order to determine the effect of socio-economic and demographic factors on infant and child mortality. Kumar and File (2010) conducted a study to identify the predictors of child mortality using cross-tabulation analysis and found strong significant impact of maternal education, mother's standard of living index and birth order on child survival in Ethiopia. Nasejje *et al.* (2015) examined the determinants of under-five mortality in Uganda by employing Cox

*<s.nilima_du@yahoo.com>.

proportional hazard model with frailty effects under both the frequentists and Bayesian approaches. A multivariate Cox regression analysis has been performed by Nisar and Dibley (2014) to determine the potential risk factors of neonatal mortality in Pakistan.

Like other developing countries, in Bangladesh social scientists and policy makers are also greatly interested on the factors affecting under-five mortality to accelerate socio-economic development and improve quality of life. Karmakar *et al.* (2014) examined the determinants of under-five mortality in Bangladesh using Cox Proportional Hazard model to Bangladesh Demographic and Health Survey 2007 data. Cox regression analysis has been also performed by Chowdhury (2013) and Rahman (2008) to identify the factors affecting child survival in Bangladesh. Islam *et al.* (2013) determined the socio-demographic factors significantly associated with child mortality by running logistic regression model.

The key interest of this paper is to determine the potential determinants of under-five mortality in Bangladesh using Cox proportional hazard model under both classical and Bayesian approaches. This study utilizes the nationally recognized data collected from Bangladesh Demographic and Health Survey conducted in Bangladesh in 2014 and also uses Bangladesh Demographic and Health Survey 2011 data as prior information for Bayesian inference.

Data and Variables

The study utilizes secondary data derived from seventh nationally representative DHS survey conducted in Bangladesh under the authority of the National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare and implemented by Mitra and Associates of Dhaka. The survey followed two-stage stratified cluster sampling design. At the first stage, 600 enumeration areas (EAs) were selected with probability proportional to the EA size (207 EAs in urban areas and 393 in rural areas). The second stage covered selection of 30 households on average using systematic sampling from each of the selected EA that comprises a total of 17989 households. Finally 17863 ever married women aged 15 - 49 are interviewed from the selected households and asked to provide a complete history of their live births, including the sex, month, year of each birth, survival status and age at the time of the survey or age at death and also asked about background characteristics (e.g., age, education, region, media exposure etc.).

The outcome variable in this study is the time to death within five years of a child. A child is considered to be censored if it did not die at or before it's fifth birthday. The censoring time for a child whose current age is more than or equal to 5 years is 1800 days (60 months) and it is considered as the current age for those children who survived less than five years.

Based on some previous studies (Chowdhury 2013, Hossain *et al.* 2015, Islam *et al.* 2013, Karmaker *et al.* 2014, Muriithi and Muriithi 2015, Nasejje *et al.* 2015, Nisar and Dibley 2014, Kumar and File 2010, Rahman 2008), a set of explanatory variables are selected in this study. Mother's age at birth (< 20 years, 20 - 30 years, > 30 years), region (Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur and Sylhet), mother's education (no education, primary, secondary, higher), wealth index (poor, middle, rich) , birth order number (first birth, others), gender of the

child (male, female), place of residence (urban, rural), place of delivery (hospital/clinic, others), mother's membership of Non-Government Organizations (NGO) (member, non-member), child's size at birth (small, average to large), access to media (exposure, non-exposure) are the variables considered to analyze under-five child mortality data in Bangladesh.

In order to determine the factors affecting under-five child mortality, information from 7886 children was collected who were born preceding five years of the survey. Among these children, 319 children died before reaching their fifth birthday, which yields under-five mortality rate 40.45 per thousand live births. This rate underestimates the under-five mortality rate given in BDHS 2014 report (46 per thousand live births). This may happen because this study omits those children, who died within five years of their birth but they were born before preceding five years of the survey. Among the 7886 observations, there are 3158 missing cases for child's size at birth and 3162 missing cases for place of delivery. Child's size at birth and place of delivery (Muriithi and Muriithi 2015, Hossain *et al.* 2015) are the important risk factors for under-five mortality. In order to assess the effect of these two potential variables on under-five mortality in this study, missing cases are excluded for the analysis. After deleting all missing cases, the final data set includes a total of 4723 observations. Among 4723 children, 170 children died within five years of their birth that reveals under-five mortality rate 36 per thousand live births.

Methodology

Product-Limit (P-L) method: Product-Limit method proposed by Kaplan and Meir (1958) is widely used in survival analysis for estimating the survival function and candeal with censored life time data. Suppose the event of interest occurs at k distinct time points $t_1 < t_2 < ... < t_j < ... < t_k$. If n_j and d_j be the number of individuals at risk of failure and the number of individuals failed at time t_j; $j = 1,2 ..., k$, respectively, then the Product- Limit estimate of the survival function $S(t)$ is given by

$$\widehat{S(t)} = \prod_{j:\, t_j < t} \left(1 - \frac{d_j}{n_j}\right)$$

Cox Proportional Hazard (PH) Model: Cox PH model is most commonly used for analyzing censored survival data where distribution of life time is considered as unknown or unspecified. According to Cox (1972), the hazard function for the life time T in presence of a set of covariates $x = (x_1, ..., x_m, ... x_p)'$ takes the form as $h(t|x) = h_o(t) \exp(\beta' x)$

where $\beta = (\beta_1, ..., \beta_m, ... \beta_p)'$ being the $p \times 1$ vector of regression coefficients associated with x and baseline hazard function $h_o(t)$ is left as unspecified or unknown function.

Bayesian Cox Model Formulation: Suppose under an investigation of n individuals, $N_i(t)$ be the process which counts the number of events occurred up to time t for i-th individual (i - *1,2*, ..., n). Following Clayton (1991), the Cox PH model can be formulated using the counting process introduced by Anderson and Gill (1982) and the intensity process for $N_i(t)$ is given by

$I_i(t) = \delta_i(t)h_o(t)exp(\beta' x)$

where $\delta_i(t)$ takes value 1 if the i-th individual is observed at time t and 0 otherwise. If the observed data is $D = \{N_i(t), \delta_i(t), x_i = (N_{i1}, ..., x_{ip})', i - 1,2, ..., n$; then parameter β and $H_0(t) = \int_0^t h_0(u)du$ have to be estimated nonparametrically.

The joint posterior density for the above model is defined by $P(\beta,H_o(\ )|D) \propto P(D|\beta,H_o(\ ))P(\beta)P(H_o(\ ))$

Under the non informative censoring, the likelihood of the data is proportional to

$$\prod_i \left[\prod_{t\geq 0} I_i(t)\right]^{dN_i(t)} exp\left[-\int_{t\geq 0} I_i(t)dt\right]$$

where $dN_i(t)$ be the increment of $N_i(t)$ over the small time interval $[t,t + dt]$ taking value 1 if i-th individual is observed to fail during the interval $[t,t + dt]$ and 0 otherwise. If $dH_o(t)$ is the increment in the integrated baseline hazard function occurring during the interval $[t,t + dt]$, then independent increments prior suggested by Kalbfleisch (1978) is considered as prior for $dH_o(t)$. According to Kalbfleisch, $dH_o(t) \sim Gamma(cdH_{\delta}(t),c)$; where $dH_{\delta}(t)$, is a prior guess for unknown hazard function $H_o(t)$ and c represents the strength of prior guess. The regression coefficients β are assigned the normal prior with the mean and variance obtained from maximum likelihood estimates using previous year 2011 under-five mortality data. The Bayesian analysis has been performed using Open BUGS software and R programming language. R2OpenBUGS package has been used to perform the analysis which provides tools to call OpenBUGS directly after data manipulation in R.

Results and Discussion

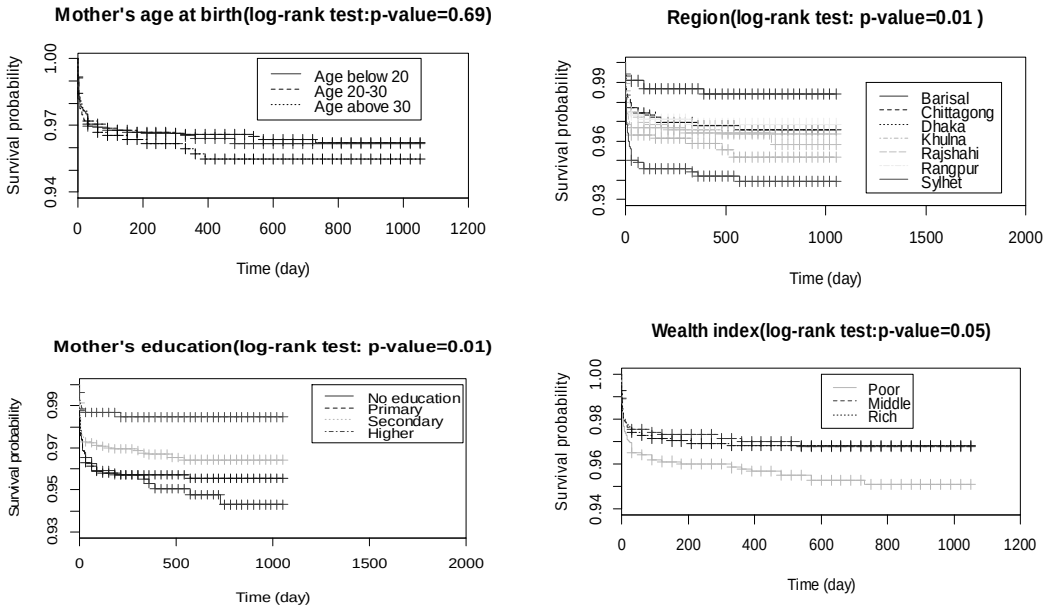
Descriptive statistics: The data used in this study reveal that 2568 (54.3%) children have mothers whose age was between 20 and 30 years when they gave birth to their children. Whereas 1510 (32%) and 645 (13.7%) children have been found to have mothers whose age at birth was below 20 and above 30 years, respectively. It has been observed that 914 (19.4%) children's mothers live in Chittagong which is highest among all children, whereas 838 (17.7%), 548 (11.6%), 551 (11.7%), 574 (12.2%), 564 (11.9%), 734 (15.5%) children's mothers dwell in Dhaka,Barisal, Khulna, Rajshahi, Rangpur and Sylhet, respectively. Among 4723 children, 646 (13.7%) children have illiterate mothers, whereas 1312 (27.8%), 2224 (47.1%), 541 (11.5%) children's mothers completed primary, secondary and higher education, respectively. It has been found that 1909 (40.4%) children were born in poor families, 901(19.1%) in middle-class families and 1913 (40.5%) in rich families. Among all children taken in this study, 1506 (31.9%) are from urban and 3217 (68.1%) from rural areas. The data demonstrate that 1941 (41.1%) children are the first baby of their mothers and 2782 (58.9%) of them are second or other child. 2437 (51.6%) male and 2286 (48.4%) female children are included in this data. It has been also observed that 2873 (60.8%)

children's mothers gave birth to their children in home and 1850 (39.2%) in hospital or clinic. Among 4723 children, 927 (19.6%) children were small sized and 3796 (80.4%) were average or large sized at the time of their birth. 1384 (29.3%) children have been found to have mothers who are NGO members whereas 3339 (70.7%) children's mothers have no membership of NGO. The data also reveal that 2915 (61.7%) children's mothers are exposed to media while 1808 (38.3%) are not.

Bivariate analysis: Product-Limit (P-L) approach has been used for bivariate analysis to estimate the survival probabilities. Log-Rank test has also been employed to test whether the survival probabilities in different categories of a covariate are equal or not.

Figure 1 exhibits the graphical presentation of the survival curves for the selected covariates obtained from P-L method along with Log-rank test p-values. The variables that have been found having significant association with under-five mortality at 5 and 10% level of significance are region, mother's education, wealth index, mother's membership of NGO, child's size at birth, access to media and these variables are considered in the regression analysis.

Semiparametric survival regression analysis: Table 1 gives the estimated hazard ratios obtained using Cox PH model along with p-values to test whether the variables have significant effect on under-five mortality or not. It is clear from Table 1 that the children whose mothers live in Barisal and Sylhet have 60% lower and 52% higher rate of under-five mortality, respectively compared to the children who belong to Dhaka and these results have been found significant at 5% and 10% level of significance, respectively. Table 1 also shows that the children of highly educated mothers have 58% lower rate of mortality compared to the children of illiterate mothers.



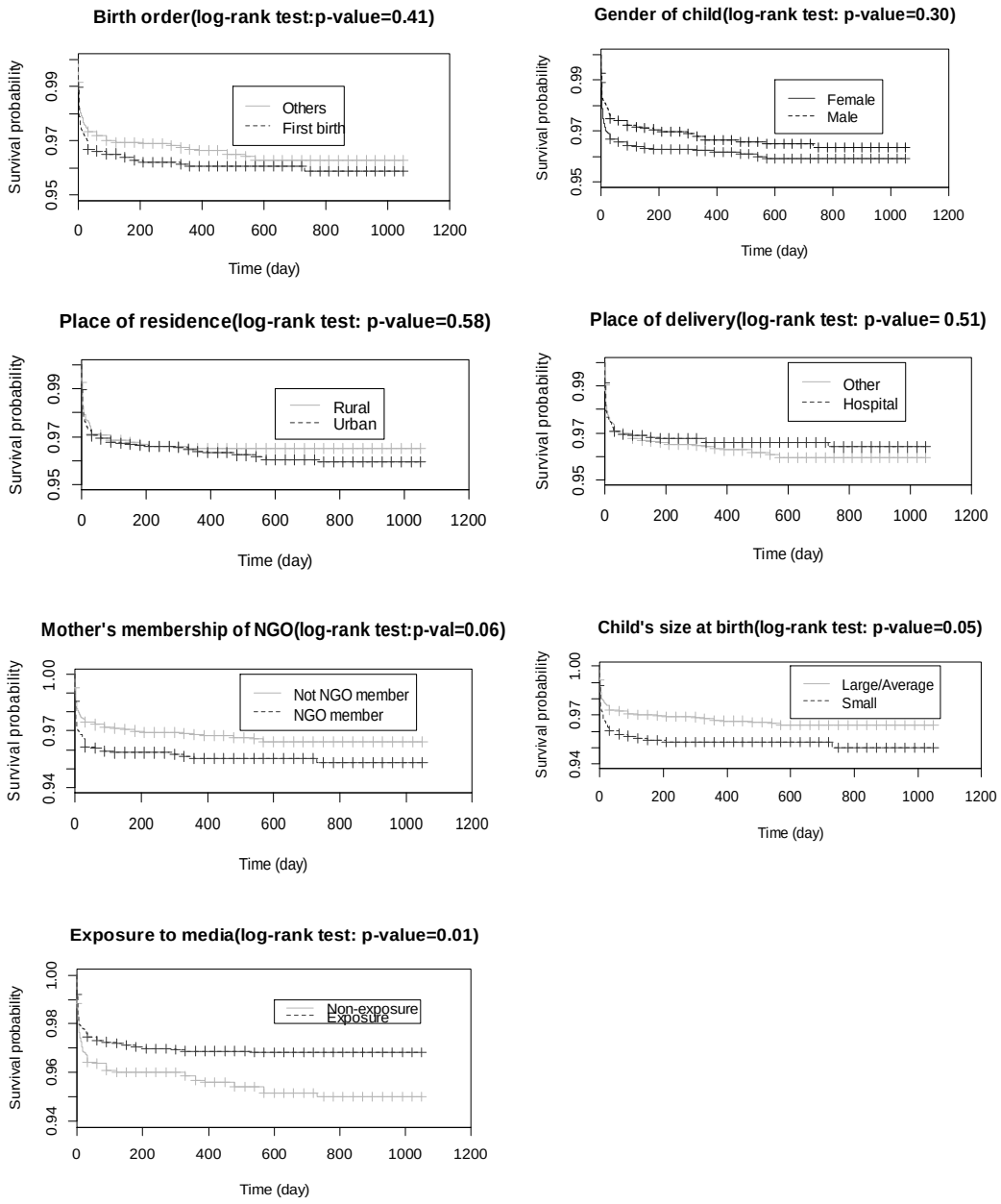


Fig. 1. Survival curves for the selected variables obtained from P-L method along with log-rank test p-values.

It has been also found that higher education has significant impact on child survival (p-value 0.044). It is clear from the analysis that variables wealth index, child's size at birth and access to media have no significant impact on under-five mortality. Mother's membership of NGO has been found to be an important risk factor affecting under-five mortality since the results show that

children whose mothers are affiliated with NGO have significantly 33% higher rate of mortality than those of non-affiliated mothers.

Table 1. Estimated hazard ratios obtained from both Cox PH and Bayesian Cox PH model.

		Model			
		Cox PH		Bayesian Cox PH	
Variable category		HR	P-value	HR	95% CRI
Region	Dhaka (RC)*	-	-	-	-
	Barisal	0.404	**0.025**	0.786	(–0.570, 0.100)
	Chittagong	0.950	0.846	0.868	(–0.476, 0.203)
	Khulna	1.276	0.385	1.012	(–0.323, 0.353)
	Rajshahi	1.058	0.847	1.052	(–0.293, 0.373)
	Rangpur	0.837	0.568	0.835	(–0.535, 0.138)
	Sylhet	1.522	**0.088**	1.436	**(0.030, 0.665)**
Mother's education	No education (RC)	-	-	-	-
	Primary	0.977	0.919	0.907	(–0.375, 0.172)
	Secondary	0.867	0.540	0.817	(–0.467, 0.092)
	Higher	0.425	**0.044**	0.415	**(–1.404, –0.363)**
Wealth index	Poor	1.243	0.357	1.138	(–0.227, 0.438)
	Middle (RC)	-	-	-	-
	Rich	1.219	0.413	1.042	(–0.234, 0.334)
Mother's membership of NGO	Member	1.325	**0.093**	1.293	**(0.002, 0.505)**
	Non-member (RC)	-	-	-	-
Child's size at birth	Small	1.267	0.185	1.431	**(0.119, 0.574)**
	Average/large (RC)	-	-	-	-
Access to media	Exposure	0.794	0.23	0.909	(–0.382, 0.168)
	Non-exposure (RC)	-	-	-	-

*RC: Reference category, HR: Hazard ratio, CRI: Credible interval.

Bayesian survival analysis: Table 1 also reports the estimated hazard ratios obtained applying Bayesian approach to Cox PH model along with 95% credible interval for regression coefficients. It has been found that the rate of under-five morality of the children who belong to Sylhet is significantly 44% higher than the children whose mothers live in Dhaka. Table 1 reveals that highly educated mothers play significant (at 5% level of significance) role in declining child mortality. It has been found from the analysis that the variables wealth index and mother's access to media have no significant effect on child survival. Mother's membership of NGO has been observed to exhibit opposite significant impact on child survival as the result shows that the children of the NGO member mothers have 29% more rate of mortality compared to the children of the mothers who are not engaged with an NGO. Child's size at birth has been found to be a potential determinant for under-five mortality at 5 % level of significance. It is clear from Table 1

that the children born with small size have 43% higher rate of mortality than average to large sized children.

Despite the fact that Bangladesh has made remarkable progress in reducing under-five mortality rate, it is a great topic of interest for the researchers to investigate the risk factors affecting under-five mortality as it reflects a country's socio-economic condition and quality of life. An attempt has been made here to analyze under-five mortality data extracted from BDHS under both classical and Bayesian approaches in order to examine the potential risk factors for under-five mortality in Bangladesh. Under Cox PH model analysis Barisal and Sylhet division have been found to have significant effect on under-five mortality at 5 and 10% level of significance, respectively whereas Bayesian analysis reveals that the children of Sylhet have significantly higher rate of mortality among seven administrative divisions in Bangladesh. According to BDHS report (2014), coverage of child vaccinations of major preventable diseases (tuberculosis, diphtheria, pertussis, tetanus, polio, measles) and vitamin A supplementation is lower in Sylhet which may directly affect the immunity system of the children resulting high child morbidity and mortality. Under both models, maternal education (higher education) has strong inverse relationship with under-five mortality and this results have been found similar to the previous studies (Hossain *et al.* 2015, Chowdhury *et al.* 2010, Rahman 2008) conducted in Bangladesh. This may happen due to the facts that female literacy enhances maternal awareness about child immunization, child nutrition and facilitates their access to modern child health care services (Desai and Alva 1998, Vikram *et al.* 2012). It has been observed from the analysis that the variables wealth index and access to media have no significant impact on child survival. This study examines that children of mothers affiliated with NGO experience lower survival probability compared to the children of mothers who are not engaged with an NGO. This may happen due to the fact that an NGO member mother may not get enough time for breastfeeding since maternity leave is not available in many situations and cannot take proper care of her child due to work loads. Under Cox PH model, child's size at birth shows no significant effect on mortality while Bayesian analysis suggests that child's size at birth is a strong potential risk factor for under-five mortality. These important findings have been observed due to the reason that underweight baby may suffer from severe infections because of impaired immune system which may be responsible for child mortality.

The findings of this study suggest that participation of female education needs to be enhanced because it contributes significantly in declining the rate of under-five mortality. NGOs should pay extra attention to all of the female members who are currently pregnant and have children. The facility of maternity leave with longer duration should be made available for all pregnant women and working pressures should be lessened. Government should take proper initiatives to increase public awareness about maternal health care at the time of pregnancy, newborn care, child immunization and child health care practices in all seven divisions because people's awareness can minimize under-five mortality rate in Bangladesh.

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