Brian Munkombwe
Ph.D Candidate
University of Texas at San Antonio
Department of Demography

Neonatal Mortality in Zambia: A Spatial Analysis

Abstract

In this paper, we have applied a semi-parametric Bayesian approach to model the determinants of neonatal mortality in Zambia using the 2007 Demographic and Health survey. We focus particularly on the influence of the child, maternal, and spatial influences on neonatal deaths. Conventional parametric regression models are not flexible enough to cope with possibly nonlinear effects of the continuous covariates and cannot flexibly model spatial influences. We present a Bayesian semiparametric analysis of the effects of the covariates on neonatal mortality as well as consider spatial effects by employing the Integrated Nested Laplace Approximation (INLA), a new tool for Bayesian inference on latent Gaussian models. We model small scale cluster specific effects using flexible spatial priors. Inference is fully Bayesian and uses Markov chain Monte Carlo techniques.

The fixed effects show the importance of child's birth order, birth weight, previous birth interval and antenatal care on neonatal mortality. We also found a sizeable spatial effect in the models; we are able to pick up a cluster regional pattern of neonatal mortality that is not adequately captured by relying on provincial fixed effects.

Given the limitations of spatial analysis when the data used is a household survey, such as the DHS, an important message emerging from this research is that it would be very worthwhile for census data and other official data sources to undertake such detailed spatial analyses. With such data sources, much more detailed and more precise spatial structures could be uncovered which would be highly relevant for both analytical as well as policy purposes.

Introduction and Background

In recent years health of the neonates has increasingly received attention as a critical component in child survival. Recent publications that focus on neonatal health provide unprecedented evidence of the magnitude and importance of neonatal mortality particularly in the developing countries (Nathan and Mwanyangala 2012). Recent statistics show that of the 130 million babies born every year, about 4 million die in the first 4 weeks of life (Lawn, Cousens et al. 2005) making neonatal mortality not just one of the most tragic or emotionally devastating human experiences (Friabie 2005), but also one of the highest death rates in the human life-span, especially in high mortality populations. (Poston D.L and Bouvier 2010).

Most neonatal deaths occur in developing countries, particularly in Sub-Saharan Africa(Lawn, Cousens et al. 2005) where a vast majority of infants die during the first month of life, when a child's risk of death is nearly 15 times greater than at any other time before his or her first birthday (Anne and Elizabeth 2002). Less than 1% of neonatal deaths arise in rich countries(Lawn, Cousens et al. 2005). These high neonatal mortality rates are hampering the process of meeting the targets of the fourth Millennium Development Goal (MDG)-4 that targets the reduction of under-five mortality by two thirds by 2015 (Lawn, Cousens et al. 2005; Nathan and Mwanyangala 2012).

In despite infant and child mortality declining in recent years in Zambia, neonatal mortality has remained high. The 2007 Demographic and Health Survey (DHS) estimates show a statistically significant decline of under-five mortality from 191 per 1,000 live births in the late 90s to 119 per 1,000 live births in 2003–2007, likewise infant mortality decline from 107 to 70 over the same time period but neonatal mortality only dropped from 43 to 34 in the same period, still remaining above 30 per 1000 live births (ZDHS, 2007). The gains in child survival are mainly attributed to effective interventions such as the Maternal and Child Health clinics that are mostly utilized in the post neonatal periods (ZDHS, 2007).

The aim of this study is to examine the influence of maternal, child and household characteristics, and their spatial effects, on neonatal mortality at a sub district level in Zambia. The study will investigate the effect of the socioeconomic and demographic factors in influencing these high levels of neonatal deaths in Zambia and how the geographical place influences these rates. The results of the study are important in order to identify how area influences mortality in order to well inform policy interventions.

Literature Review:

This study uses the Mosley and Chen's analytic framework for studying child survival in a developing country. Mosley and Chen proposed this analytical framework for the study of child survival, which they referred to as a proximate determinant model (Mosley and Chen, 1984). One of the five premises upon which the framework is based is that social and economic determinants "must operate through more basic proximate determinants that in turn influence the risk of disease and the outcome of disease processes" (Mosley and Chen, 1984), in this case neonatal mortality. Mosley and Chen identified a set of proximate determinants that they preceded to group into five categories: maternal factors, environmental contamination, nutrient deficiency, injury, and personal illness control. They further described the socioeconomic determinants as including community-, household-, and individual-level characteristics that operate on proximate determinants to influence the child's health and well-being. The community level characteristics can be an influence of geographical factors such as rural-urban residence and other regional factors that could influence neonatal deaths. For this analysis we apply this framework by grouping our variables to examine neonatal mortality in Zambia into three groups, maternal factors, household factors and child factors. The variables selected are described in the methods section.

Several studies have documented causes of neonatal mortality in many developing countries, including causes due to neonatal conditions, preterm birth, severe infections, asphyxia, and neonatal tetanus, including low birth-weight as an important indirect cause of death (Lawn, Cousens et al. 2005; UNICEF 2008). Other studies have shown that maternal complications in labor carry a high risk of neonatal death, and poverty is strongly associated with an increased risk (Lawn, Cousens et al. 2005; Gonzalez, Merialdi et al. 2006). Other studies have also shown residential variations with higher levels of neonatal mortality in the rural areas than in the urban areas.(Lawn, Cousens et al. 2005).

Place of delivery has also been an important factor of neonatal mortality were research has shown that most neonatal deaths (99%) that arise in low-income and middle income countries and over half occur to births that took place at home(Lawn, Cousens et al. 2005). Just over 40% of deliveries occur in health facilities and little more than one in two neonatal deaths occur from a birth that took place at home (WHO 2003). A study by Abhay, etal, (1999) found that up to 83% neonates in rural India are born at home(Abhay, Rani et al. 1999). The main influencing factors to births outside the health facilities are lack of accessibility due to long distances to the health facilities, especially in rural areas, and affordability due to high poverty levels.

Sex of the baby has also been found to be one of the main influencers of neonatal deaths. It is evident that girls have a well described biological survival advantage in the neonatal period(De Almeida, Rodrigues et al. 2000; Lawn, Cousens et al. 2005) In Zambia, neonatal mortality was 41 deaths per 1000 for males and 32 deaths per 1000 for females (ZDHS, 2007)

Evidence from most studies on neonatal mortality are that neonatal health is closely linked to that of the mother's socioeconomic and residential factors (Mitra, Al-Sabir et al. 1997; Lawn, Cousens et al. 2005). Studies have documented reduction in infant and child mortality in association with increased levels of maternal education(Victora, Huttly et al. 1992; vanGinneken, LobLevyt et al. 1996) , while other studies have shown that neonatal mortality is lowest among children born to mothers age 20-30 and is much higher for very young and very old mothers (A

Pandey, MK Choe et al. 1998; Rahman and Abidin 2010). Poverty was also found to be highly associated with child mortality. A study on child health inequity in rural Tanzania revealed that at infancy, children in poor household had about 50% higher risk of dying compared to these in least poor household(Ogbolu; 2007; Nathan and Mwanyangala 2012).

The geographic distribution of health problems such as neonatal mortality is not always uniformly distributed, and aggregated factors and health statistics do not often describe the variations in the mortality experienced within regions of the country. The neonatal mortality rates, in particular, can vary significantly between geographic locations, as well as across the urban rural divide (Sartorius, et al, 2011). In Zambia, the neonatal mortality rates are highest in the rural areas at 37 per 1000 births compared with 34 per 1000 births in the urban areas. By province; there is a variation among the nine province with North-Western province having the lowest neonatal rate at 28 deaths per 1000 births, while Western province having the highest rate at 48 deaths per 1000 births. These differentials in neonatal rates may also reflect unequal socioeconomic status (SES) and access to services and facilities that vary widely across the nine provinces. They could also be due to differences in the levels of HIV/AIDS prevalence that vary significantly by province in Zambia, and where in north-western province the prevalence is lowest (ZDHS, 2007).

Investigating the spatial distribution and determinants of neonatal mortality can usefully inform more focused and effective public health interventions (Sartorius etal, 2011). In particular, high risk clusters or sub-districts can be targeted for these interventions in order to reduce the high levels of neonatal mortality. Spatial analysis is an important tool in epidemiology to detect possible sources of heterogeneity and spatial patterns (Sartorius et al, 2011). The potential of spatial analysis is reinforced by the increasing availability of geographically indexed data such as the DHS data, as well as advances in computation methods using GIS systems and other free programs like R. Spatial analysis, moreover, can be applied to health data for disease mapping in small area studies, as well as to imperfect data, often the case in Africa, using advanced statistical methods such as Bayesian analysis (Sartorius etal, 2011).

Data and Methods

Data Source

Data are from the 2007 Zambia Demographic and Health Survey. This survey is a nationally representative survey which serves as the primary source of information on fertility, reproductive health, mortality, HIV/AIDS/health behaviors, and nutrition in the developing countries (ZDHS, 2007). The sample was designed to provide estimates of population and health indicators at the national and provincial levels. The 2007 ZDHS makes use of a representative probability sample of 8,000 households, which were selected using a two-stage stratified design from the 2000 Census of Population and Housing frame. Stratification was achieved by separating every province into urban and rural areas. Therefore, the nine provinces of Zambia were stratified into 18 sampling strata. Samples were selected independently in every stratum by a two-stage selection.

In the first stage, 320 clusters or primary sampling units (PSUs) were sampled from the sample frame. The household listing operation was conducted in all selected clusters, with the resulting lists of households serving as the sampling frame for the selection of households in the second stage. Selected clusters with more than 300 households were segmented, with only one segment selected for the survey with probability proportional to the segment size. In the second stage selection, an average number of 25 households were selected in every cluster, by equal probability systematic sampling. In each selected household, all women between the ages of 15 and 49 all men age 15-59 who were either permanent residents of the household or visitors present in the household on the night before the survey were eligible to be interviewed. Three questionnaires were used for the 2007 ZDHS: the Household Questionnaire, the Women's Questionnaire, and the Men's Questionnaire. The questionnaires were translated and administered into seven major local languages, in addition to English. (ZDHS, 2007)

The overall response rate for the 2007 ZDHS was very high. Of the total of 7,969 households that were selected for the sample, 7,326 were occupied: Of the 7,326 existing households, 7,164 were successfully interviewed, yielding a response rate of 98 percent. In the interviewed households, a total of 7,408 women were identified, of whom 7,146 were successfully interviewed, yielding a response rate of 97 percent.

The analysis of this study uses the responses from the maternity history dataset, relating to births in the five years preceding the interview. Each child born in the last five years had an entry including the twins. A total number of 6,401 births occurred to a sample size of 7,146 women between the ages of 15 and 49 during the five years preceding the survey. Information pertaining to pregnancy care, antenatal, delivery as well as mortality was included to each child born five years prior to the survey. In addition mothers' as well as household information was also included in the dataset.

Measurement of Variables

Table 1 outlines the operationalization of the variables as presented in the framework.

Variable	Coding
Dependent Variable	
Neonatal death	0= No, 1=Yes
Covariates	
Mother's Characteristics	
Mother's Age at Birth	0= 20-33, 1=Under 20, 2= 34-48
Marital Status of Mother	0=Married/Cohabit, 1=Never Married, 2=Separated/widow/divorced
Mother's Education Level	0= No educ., 1=Primary, 2=Secondary, 3=Higher
Child's Characteristics	
Sex of child	0= Female, 1=Male
Birth Order of child	0= bord5+, 1=bord1, 2= bord2to4
Size of child at birth	0= Average/very large, 1=Small/very small
Previous Birth Interval	0=36-47 months, 1=<24 months, 2=24-36 months, 3=48+months
Antenatal care	0=No Antenatal care, 1= Yes
Place of Delivery	0=Home, 1=Public facility, 2=Private facility, 3= Other place
Household Characteristics	
Place of Residence	0= Urban, 1=Rural
Household Wealth Index	0= Poorest, 1= Poor, 2=Middle, 3=Rich, 4=Richest

Table 1: Operationalization of Variables in the Model

Dependent Variable

Our dependent variable was whether the child died in the first 28 days or one month of life. The variable was dichotomous with 0= child alive after 28 days of life,   1=child dead during the first 28 days of life.

The independent variables were grouped in three groups, the mother's characteristics, the child's characteristics and the household characteristics.

Mother's Characteristics

As shown in Table 1, the mother's characteristic variables included: mother's age at birth, marital status, and education attainment. Mother's age at birth was calculated by subtracting the current age of the child during the survey, for a child who was alive, or the age at death for a child who was dead, from the current age of the mother. The variable was categorized as: under 20 years, 20 to 34 and 35 to 49 years. The age group 20 to 34 was the reference group in the analysis. The mother's level of education was a four level categorical variable defined as: no education, primary, secondary, and higher levels. The no education level was used as the reference in the analysis. Marital status was defined as a three level categorical variable of: never-married, married (including those living together), and the divorced, separated and widowed as one group. The married group was the reference group.

Child's Characteristics

The child's characteristics include; sex of the child, child's birth order, size of child at birth, previous birth interval, antenatal care for that child's pregnancy, place of delivery. For the sex of the child, the female was the reference group. The child's birth order birth order measured the order in which children, and was categorized as first order, 2 to 4, and 5 and more as the reference. The previous birth interval was categorized as less than 24 months, 24 to 35 months, 36 to 47 months, and 48 and more months. The 36-47 months category was used as the reference. The place of delivery of the child was categorized as at home, government clinic/hospital, private clinic, or other type, with home as the reference. Antenatal care was defined as whether or not the mother received antenatal care for that birth. The size of the child at birth was defined as whether the child's size at birth was preserved as very large or above average or small/very small, with very large/above average as the reference.

Household Characteristics

The household variables included the place of residence and household wealth index. The place of residence was characterized as rural or urban, and urban was used as the reference group. The household wealth index was create using household's ownership characteristics such as owning a television and car; dwelling characteristics such as housing type; flooring material; type of drinking water source; toilet facilities; and other characteristics that are related to wealth status. This index is created by assigning a weight (factor score) generated through principal component analysis, and the resulting asset scores being standardized in relation to a standard normal distribution with a mean of zero and standard deviation of one. The resulted is a wealth quintiles index broken into five levels as poorest, poor, middle, richer, and richest. The poorest category was the reference category.

Analysis

In this paper we model the determinants of neonatal mortality in Zambia. The important focus of this analysis is to use a flexible approach to model the impact of the mother, child, and household characteristics of neonatal deaths in Zambia, as well as consider spatial effects. The Integrated Nested Laplace approximation (INLA), a new tool for Bayesian inference on latent Gaussian models, is the better model to use for this study because of the following two reasons: First, it is faster to compute than the MCMC, and second it treats Gaussian models in a unified way, thus allowing greater automation of the inference process. It produces similar results with the MCMC at a faster rate, and is free using a free package in R. The results of the study give a refined insight to spatial effects on neonatal deaths. The inference is fully Bayesian with the focus on the posterior marginal distributions.

In modeling our outcome, we assume that neonatal deaths to be conditionally independent Gaussian random variables with unknown mean η_i and unknown precision tz.

$$\eta_i = \mu + \mathbf{z}_i^T \beta + f_s(s_i) + f_u(s_i)$$

Where η_i is the mean parameter and $\mathbf{z}_i^T \beta$ are the covariates in the model and $f_s(s_i) + f_u(s_i)$ are the structured and unstructured spatial components, in this case are the ZDHS clusters.

Three models were built, the first model with only the covariates of the child's characteristics, the second model added the mother's characteristics to the first model, and the third model included the household characteristics to the second model. The Deviance Information Criteria

(DIC) values were extracted from the three models and compared in order to determine the better fitting model.

R statistical package was used with the library (INLA) to run these Bayesian models.
SAS was used for descriptive statistics of the variables in the model and they were adjusted for complex survey designs by applying appropriate weights, strata and primary sampling units in the analysis.

Results

Table 2:

Noenatal Mortality Rate According to the Maternal, Child, and Household Variables

Covariates	*Neonatal mortality rate/per 1000 births*	*P-value*
Mother's Age at Birth		
<20	26.70	0.2219
20-33	37.70	
34-49	39.60	
Mother's Education Level		
No Education	39.10	0.2193
Primary	37.30	
Secondary	30.40	
Higher	62.10	
Marital Status		
Never married	51.10	0.1171
Married	34.50	
Sep/Wid/Div	44.10	
Sex of Child		
Male	38.40	0.4467
Female	34.80	
Birth Order		
1	51.40	0.0066
2-4	33.20	
5+	32.20	
Previous Birth Interval		
<24 months	54.70	
24-35 months	25.40	0.0001
36-47 months	23.50	
48+ months	37.50	
Place of Delivery		
Home	30.50	0.0540
Public Health Facility	42.00	
Private Health Facility	63.80	
Other Places	46.50	
Size of Child at Birth		
Average or Larger	30.30	0.0001
Small/Very Small	86.00	
Antenatal Care		
No	51.80	0.0001
Yes	27.50	
Place of Residence		
Urban	36.60	0.7520
Rural	37.40	
Household Wealth Index		
Poorest	34.70	0.7411
Poor	35.30	
Middle	34.10	
Rich	42.80	
Richest	36.10	

In Table 2, for bivariate analysis, presents the differentials in neonatal mortality rates for the 5-years period preceding the survey by the selected child, mother and household characteristics. According to Table 2 males have a higher neonatal mortality rate than females. Neonatal mortality for boys and girls was about 38.4 and 34.8 deaths per 1000 live births, respectively, though this difference is not statistically significant. As Table 2 shows, in the case of neonatal mortality, children in the first birth order had the highest rate compared to children in the higher birth orders. Also children born after a previous birth interval of less than 24 months had more than twice the rate of neonatal deaths compared to those born after a previous birth interval of 24-35 months or 36-47 months, and the differentials are statistically significant. The results also reveal that children born from a private health facility were more likely to die before age one-month than children born at home or in public health facilities. While children born with a birth-size preserved to be below average or small had more than two and a half time higher risk of dying before age one, than children born preserved to be large or very large in birth size. The rates were 30.3 deaths per 1000 births for the large sized babies compared to 86 deaths per 1000 births for small or very small babies. The table also shows that children born to mothers who attended antenatal care during their pregnancy were about twice expected to die in their neonatal period as compared to children born to mother who did not have antenatal care.

The analysis did not find any statistically significant differentials in neonatal mortality for mothers' characteristics though children born to mothers aged below 20 years had the lowest neonatal mortality rates at 26.7 deaths per 1000 live births, and those born to mothers aged 34 to 49 had the highest rate at 40 deaths per 1000 live births. No statistical differences in neonatal mortality were noted for mother's education, marital status, and the household characteristics of residence and household wealth.

Fig 1: Neonatal Mortality By Province, Zambia 2007

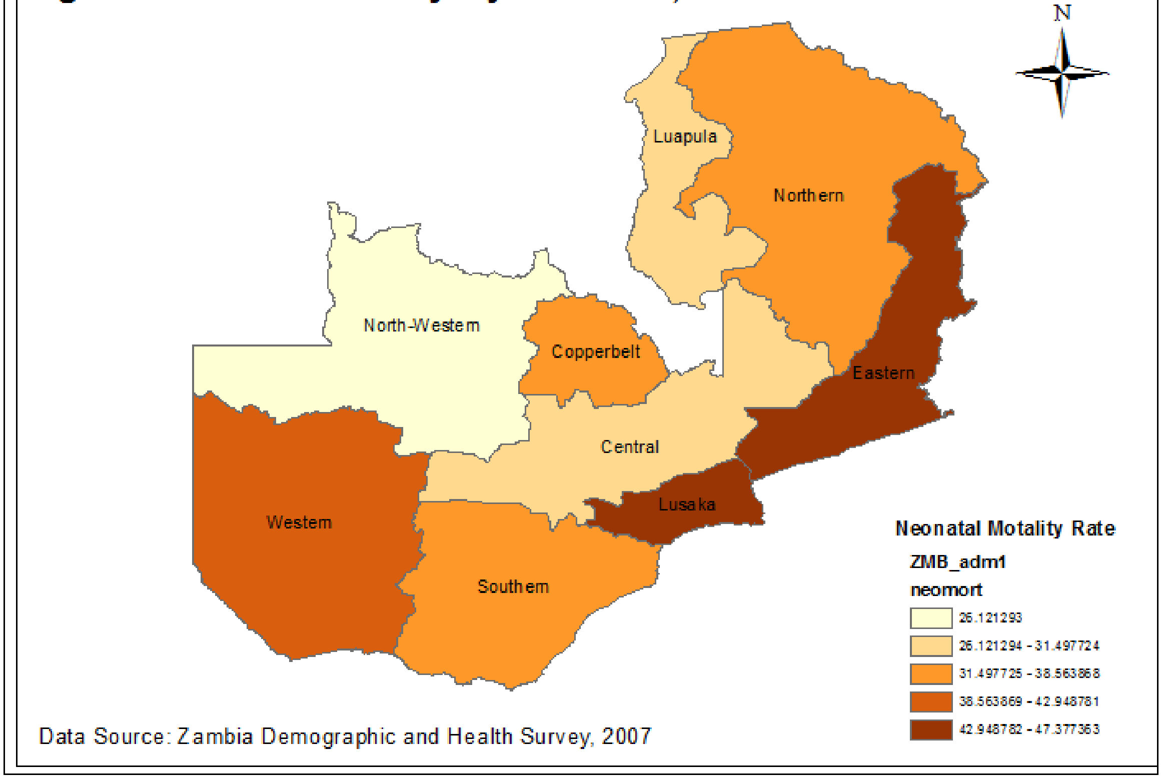

Fig 1 shows the neonatal mortality rates by the nine provinces of Zambia, using data from 2007 ZDHS. For the 5-year period preceding the survey, Lusaka and Eastern provinces had the highest neonatal mortality rates over 43 deaths per 1000 live births, while North-western province had the lowest neonatal death rates of less than 27 deaths per 1000 live births.

Table 3 shows results of the fixed effect parameter of the three INLA models. The posterior mean, together with the standard deviations and the 2.5 and 97.5 posterior percentiles are provided for the main effects in the models. The DICs for three models, shown in Table 4, were compared and model two was the better fitting model. Thus the results interpretation is based on this model.

Table 3: Posterior Means and Standard Deviations together with 2.5% and 97.5% quantiles for the linear Effect parameters in the Models for neonatal mortality in Zambia

	Covariates	*Mean*	*sd*	*0.025quant*	*0.975quant*
Model 1	(Intercept)	-3.7144	0.2420	-4.2039	-3.2534
	Male	0.1398	0.1349	-0.1244	0.4047
	<24 months	0.9350	0.2426	0.4654	1.4177
	24-35 months	0.0949	0.2365	-0.3617	0.5668
	48+ months	0.5214	0.2484	0.0390	1.0138
	Public Health Facility	0.2822	0.1393	0.0092	0.5556
	Private Health Facility	0.7862	0.6168	-0.5436	1.8784
	Other Places	0.0000	31.6228	-62.0090	62.0224
	bord1	-0.2777	0.2266	-0.7183	0.1711
	bord2t4	-0.0466	0.1632	-0.3642	0.2764
	Antenatal	-0.6529	0.1366	-0.9212	-0.3854
	Small/Very Small	1.0263	0.1561	0.7150	1.3275
Model 2	(Intercept)	-5.8945	0.4063	-6.7077	-5.1127
	Male	0.0920	0.1366	-0.1756	0.3603
	<24 months	1.0895	0.2452	0.6147	1.5773
	24-35 months	0.1932	0.2383	-0.2669	0.6684
	48+ months	0.3998	0.2516	-0.0890	0.8982
	Public Health Facility	0.3632	0.1488	0.0713	0.6549
	Private Health Facility	0.7424	0.6468	-0.6417	1.8994
	Other Places	0.0000	31.6228	-62.0090	62.0224
	bord1	0.9742	0.2880	0.4142	1.5444
	bord2t4	0.6590	0.2143	0.2455	1.0868
	Antenatal	-0.7435	0.1428	-1.0243	-0.4643
	Small/Very Small	1.0648	0.1588	0.7484	1.3717
	20-33	1.6126	0.2467	1.1418	2.1105
	34-49	2.8553	0.3322	2.2118	3.5156
	Never married	0.6534	0.2619	0.1181	1.1466
	Sep/Wid/Div	0.0000	31.6228	-62.0090	62.0224
	Primary	-0.0780	0.2036	-0.4664	0.3328
	Secondary	-0.4710	0.2591	-0.9768	0.0396
	Higher	-0.3796	0.4285	-1.2552	0.4284

CONT.

Table 3: Posterior Means and Standard Deviations together with 2.5% and 97.5% quantiles for the linear Effect parameters in the Models for neonatal mortality in Zambia

	Covariates	***Mean***	***sd***	***0.025quant***	***0.975quant***
Model 3	(Intercept)	-6.1926	0.4881	-7.1629	-5.2480
	Male	0.0943	0.1368	-0.1736	0.3630
	<24 months	1.0953	0.2456	0.6198	1.5837
	24-35 months	0.1859	0.2384	-0.2745	0.6614
	48+ months	0.4116	0.2519	-0.0780	0.9107
	Public Health Facility	0.4068	0.1622	0.0879	0.7240
	Private Health Facility	0.9122	0.6605	-0.4963	2.0991
	Other Places	0.0000	31.6228	-62.0090	62.0224
	bord1	0.9829	0.2884	0.4219	1.5539
	bord2t4	0.6553	0.2141	0.2422	1.0827
	Antenatal	-0.7539	0.1434	-1.0359	-0.4736
	Small/Very Small	1.0611	0.1591	0.7441	1.3685
	20-33	1.6419	0.2475	1.1695	2.1412
	34-49	2.8942	0.3330	2.2490	3.5561
	Never married	0.6599	0.2632	0.1294	1.1631
	Sep/Wid/Div	0.0000	31.6228	-62.0090	62.0224
	Primary	-0.0895	0.2050	-0.4809	0.3238
	Secondary	-0.4312	0.2682	-0.9553	0.0970
	Higher	-0.1416	0.4624	-1.0772	0.7392
	Urban	0.2562	0.2360	-0.2075	0.7180
	Poor	-0.0112	0.2121	-0.4271	0.4050
	Middle	0.0118	0.2140	-0.4076	0.4316
	Rich	0.3262	0.2714	-0.2108	0.8538
	Richest	-0.1177	0.3544	-0.8217	0.5685

The results in model 2 show that children born after a previous birth interval of less than 24 months were more than twice more likely to die in the neonatal period compared to children born after a previous birth interval of 36 to 47 months. Compared to children delivery from home; model 2 shows that children who were delivered at the public health facility were about 36 percent more likely to die in the neonatal period. The results also show that children in the fifth and higher birth orders were less likely to die in the neonatal period than children in the first and those in the second to fourth birth orders. Children whose mothers seek antenatal care during pregnancy were 26 percent less likely to die during the neonatal period. While children born with a birth size smaller than average were more than twice likely to die in the neonatal period.

For the mother's characteristics, the results show that children of never married mothers were about 35 percent more likely to die during the neonatal period than children of married mothers.

Table 4:
Random (Spatial) Effect, and DIC values for the three models of neonatal mortality in Zambia

	Model 1	Model 2	Model 3
Mean of the deviance	18663.01	18619.38	18642.29
Deviance of the mean	18400.74	18370.11	18371.12
Effective number of parameters	10.89	16.73	21.56
DIC	1928.73	1849.38	1854.40

Table 4 shows the spatial effects of the three models. From the table the results show that there is spatial variation in neonatal deaths among clusters in Zambia. Controlling for the covariates in the three models, the mean of the deviance of the spatial effect was highest in model 1and lowest in model 3, though the differences do not seem to be too much. The resulting estimates of the space varying regression parameters for the three models are displayed in figure 2 below. We see lower posterior means where children are less likely to die during the neonatal period in the Western and Eastern parts of the country, and higher posterior means in the central and northern parts of the country.

FIG 2:

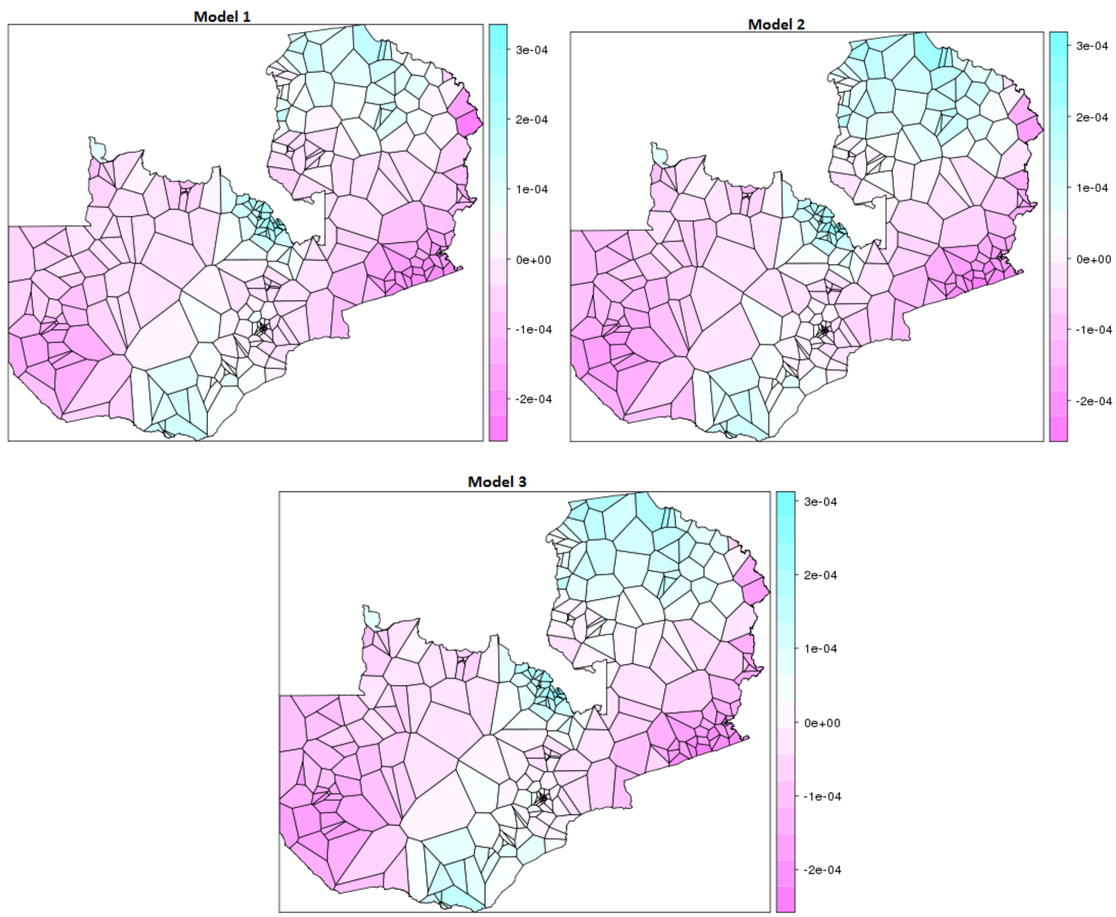

FiG 2: Posterior means of the spatial effect for Zambia

Discussion

Several issues emerged from the analysis and need further discussion. The results did not find a statistical significance of the mother's characteristics as well as the household characteristics, despite literature showing that these are important factors in determining neonatal mortality. The results found that in Zambia, children's characteristics such as birth order, weight at birth, previous birth interval are the important factors explaining neonatal mortality. Other factors are antenatal care and place of delivery. Though it should be mentioned that the results of the place of delivery are a bit surprising because it is expected that children who are born outside the health facility are less likely to survive the neonatal period because they are not attended to by skilled health professions, and that in the case of a complication during delivery, they are less likely to survive.

Though the results shows that children who were delivered at the public health facility were about 36 percent more likely to die in the neonatal period, the possible explanation is the lack adequate medical equipment and other medical supplies in the public health center, that does not provide any advantage to women who deliver from there. The other explanation is the lack of qualified health personnel, especially in rural areas.

However, antenatal care has been found to be very important in neonatal survival. The results show that children whose mothers seek antenatal care during pregnancy were 26 percent less likely to die during the neonatal period. Antenatal care has been found to be important is identifying danger signs during pregnancy are women can be adequately treated to avoid a pregnancy loss or a neonatal death.

The results have also found spatial effects in the neonatal mortality in Zambia. The results show that there is spatial variation in neonatal deaths among clusters in Zambia. This is evidence that neonatal mortality is not evenly distributed in the country, but there are areas with higher levels than other. This is important for interventions programs in order to target those particular areas. We see lower posterior means where children are less likely to die during the neonatal period in the Western and Eastern parts of the country, and higher posterior means in the central and northern parts of the country.

In conclusion, Zambia like many other developing countries has high neonatal mortality rates. A large number of its infant die before the age of one month, which could explain higher levels of infant as well as maternal mortality rates. Spatial variations occur in some areas where children have significantly higher mortality risks than others. These inequalities are hindering the achievements of the Millennium development goals.

Although newborns also have unique needs that need to be addressed in the context of maternal and child health (Nathan and Mwanyangala 2012) to achieve further reductions in infant and child mortality rates, a substantial reduction in neonatal death is of major public health importance (Black et al. 2003).

Reducing neonatal mortality requires understanding of the factors causing it in order to come up with intervention programs. However, reliable mortality data are a prerequisite for planning for these health interventions, yet such data are often not available in developing countries, particularly in Zambia. In the absence of such data, alternate data sources need to be utilized to address these gaps and inform progress towards the Millennium Development Goals.

References

A Pandey, MK Choe, et al. (1998). Infant and Child Mortality in India: National Family Health Survey Subject Reports. National Institute of Population Sciences. Mumbai,.

Abhay, T. B., A. B. Rani, et al. (1999). "Effects of Home-based Neonatal Care and Management of Sepsis on Neonatal Moratlity: Field trial in Rural India." Lancet **354**: 1955-1961.

De Almeida, M. F., L. C. Rodrigues, et al. (2000). "Neonatal mortality by place of delivery in Sao Paulo, Brazil." Journal of Epidemiology and Community Health **54**(11): 879-879.

Friabie, W. P. (2005). Infant Mortality. Handbook of Population. P. D.L and M. M. New York, Kluwer Academic/Plenum.

Gonzalez, R., M. Merialdi, et al. (2006). "Reduction in neonatal mortality in Chile between 1990 and 2000." Pediatrics **117**(5): E949-E954.

Lawn, J. E., S. Cousens, et al. (2005). "4 Million Neonatal Deaths: When?Where?Why/." Lancet **365** (9462): 891-900.

Mitra, S. N., A. Al-Sabir, et al. (1997). Bangladesh Demographic and Health Survey 1996-97., Calverton, Maryland: Ministry of Health and Population [Egypt], National Population Council and ORC Macro

Nathan, R. and M. A. Mwanyangala (2012). "Survival of neonates in rural Southern Tanzania: does place of delivery or continuum of care matter?" BMC Pregnancy and Childbirth **12**(18).

Ogbolu;, Y. (2007). "Neonatal Mortality: A Critical Global Health Issue. ." Neonatal Network; Journal of Neonatal Nursing **26**(6): 357-360.

Poston D.L and L. F. Bouvier (2010). Population and Society: An Introduction to Demography. New York, Cambridge University Press.

Rahman, M. and S. Abidin (2010). "Factors Affecting Neonatal Mortality in Bangladesh." Journal of Health Management **12**(137).

UNICEF (2008). The State of Africa's Child 2008: Child Survival. UNICEF. New York, UNICEF.

vanGinneken, J. K., J. LobLevyt, et al. (1996). "Potential interventions for preventing pneumonia among young children in developing countries: Promoting maternal education." Tropical Medicine & International Health **1**(3): 283-294.

Victora, C. G., S. R. A. Huttly, et al. (1992). "MATERNAL EDUCATION IN RELATION TO EARLY AND LATE CHILD HEALTH OUTCOMES - FINDINGS FROM A BRAZILIAN COHORT STUDY." Social Science & Medicine **34**(8): 899-905.

WHO (2003). Shaping the future; World Health Report 2003. Geneva.