

Spatial Analysis of Child Mortality and Welfare Differentials in South Africa: Evidences from the 2011 Census

Samuel Abera Zewdie¹ & Visseho Adjiwanou²

¹Environment and Climate Research Centre, Ethiopian Development Research Institute,
Addis Ababa, Ethiopia.

samuel_abera@yahoo.com

²Centre for Actuarial Research, University of Cape Town,
Cape Town, South Africa.

Abstract

Context

Welfare differential is a common phenomenon among South African population which can be manifested in terms of various economic and health outcomes. Using child mortality (CM) as one of a key measure of the country's health system, the study attempted to show its spatial distribution and the association with economic disparities in the country.

Data and Methods

Using the 2011 census data, the study primarily aimed to derive estimates of CM rates for the municipalities and provinces of South Africa and assessed the results in relation to poverty and inequality. The estimation of CM rates was achieved through the use of direct synthetic cohort methods with Bayesian spatial smoothing. The smoothing process helped to generate accurate municipal level estimates of CM. The model utilized information from neighboring municipalities by controlling the effects of women's education and HIV.

Results

It was found that there were clear spatial differentials of CM in the country, where at province level under-five mortality (U5M) rate (deaths per 1000 live births) ranges from 26 in Western Cape to 71 in KwaZulu-Natal. At municipal level, it ranges from 24 in City of Cape Town to 109 in uPhongolo. It was also shown that CM was higher in poorer and more unequal areas, although there were cases which had inverse relationship. For instance, several municipalities in Limpopo province scored relatively lower child mortality rates though the level of poverty is very high

Conclusions

The study revealed significant spatial differentials of CM in the country, which were also associated with the level of poverty and income inequality. The findings may help local and national government to implement policies more effectively and make more focused decisions for a better health outcome.

Keywords: Spatial demography; family health; Bayesian smoothing; poverty; inequality.

Introduction

Disparities in health and mortality have been the concern of development agencies, governments and the international public health community for many years. Various declarations were signed by leaders of nations and representatives of key international organizations so that the gap would be reduced to a noteworthy level (WHO, 1978). Child mortality is considered to be one of the key measures of a country's health system, and rates of child mortality of an area have long been believed to be important indicators of health status and socioeconomic development (Kabir et al., 2001, IGME, 2013). This is due to its sensitivity to various changes that affect

the health of the entire population, such as disease epidemics and economic development, and to other changes that affect general living conditions, such as social well-being and the quality of the environment (Reidpath and Allotey, 2003).

According to a United Nations (UN) report, child mortality in South Africa has declined from 61 deaths per 1000 live births in 1990 to 45 deaths per 1000 live births in 2012 (IGME, 2013). The performance, however, is low compared to many other countries' performance. For instance, the world has made substantial progress in reducing the under-five mortality (U5M) rate by 47 % in the period 1990-

2012 while South Africa has attained a reduction of only about 26 %. Although HIV/AIDS is usually quoted as the main reason for this poor performance, the role of poverty and inequality should not be ignored. It has been reported that the health of infants and children in South Africa is largely influenced by social and economic conditions under which they live and approximately 66 % of children in the country live in poverty, with a monthly household income of less than R1200 per month (Whiting, 2013).

Accurate and timely estimates of child mortality at lower geographical units are very important for a country in order to evaluate the effectiveness of intervention programmes as well as for policy planning. Furthermore, child mortality rates in the country have been found to be much higher in certain geographical areas and certain disadvantaged social groups. Many studies in different countries show that the geographic distribution of health problems and their relationship to potential risk factors can be invaluable for cost-effective intervention planning (Freedman et al., 2005, McKinnon, 2010). Addressing inequalities in health status and access to health care services within countries is as important as addressing these issues among countries, and hence, in order to effectively address the problem and work towards further reductions in child mortality in the country it is essential that the efforts be focused more on lower administrative levels as, at municipality level for example, opposed to concentrating only on the level of mortality at national level (Freedman et al., 2005).

In addition, studying this in relation to poverty and inequality will help to make more focused and potentially effective decisions. Many of the researches conducted so far on child mortality in South Africa lack comprehensiveness in that either they focus only on country or province level, or certain specific geographical areas. To the best of our knowledge, there is not any research which attempts to estimate child mortality of the country at municipal level. Besides, very few of these researches tried to analyse the relationship of child survival with poverty and inequality. Thus, this research is unique because it will provide new and comprehensive estimates of child mortality for the country at lower administrative units, specifically for the municipalities of South Africa, and it helps to see how these estimates are related with poverty and inequality.

The primary objective of this research is to estimate infant and child mortality rates for the municipalities and provinces of South Africa using the 2011 South African census and to study the

spatial differentials in relation to poverty and inequality. The hypothesis is that there are significant spatial variations of child mortality, which is associated with socioeconomic differentials in the country, and hence deriving estimates at lower administrative levels helps to achieve faster and greater reduction of child mortality in the country.

Spatial differentials in child mortality in South Africa

Child mortality in South Africa is characterized by large spatial differentials which are strongly associated with the level of socio-economic disparities. Geographically, the country is divided into nine different provinces: Western Cape (WC), Eastern Cape (EC), Northern Cape (NC), Free State (FS), Gauteng (GT), North-West (NW), KwaZulu-Natal (KZN), Mpumalanga (MP) and Limpopo (LP); and 234 municipalities, each reflecting broad differences in geography, environment, population, and development. In the poorer provinces like LP and MP, there are relatively low levels of infrastructure development (housing, water, sanitation, electricity, etc.), education and income, higher unemployment rates, and poor health care services (UNICEF, 2013, HSRC, 2014b). In contrast, in richer provinces like WC and GT there are better infrastructure development, higher income and education levels. Child mortality rates in the poorer provinces are usually estimated to be very high compared to the richer provinces.

In reviewing the studies on spatial differential of child mortality in the country, differentials at province level are better studied by several researchers than differentials at municipal level or other lower geographical units. The work by Dorrington et al. (2004) reports provincial estimated trends of U5M rates from 1986 to 1996 using the 1996 census. Over the period considered, the lowest and highest mortalities were recorded in WC and EC respectively. The estimate for boys per 100 live births varied from 44 in WC to 114 in EC in 1986, while in 1996 it varied from 47 in WC to 102 in EC. Similarly, the estimates for girls, respectively for WC and EC, were 30 and 107 in 1986 and 32 and 87 in 1996. In their review of available empirical data on levels and causes of child mortality in South Africa in the period 1997-2007 Nannan et al. (2012) also show the trends of provincial estimates of infant mortality rates over the time period. It is indicated that in each of the provinces infant mortality was mostly increasing and, in some provinces, such as FS, NW, MP and GT, the rate was much higher (above 50 deaths per 1000 live births).

One comprehensive source of national and provincial estimates of CM is the HIV and

demographic model developed by the Actuarial Society of South Africa (ASSA). The 2008 version of the model shows that U5M rate in EC, FS, KZN and MP had been consistently higher as compared to the rates in the other provinces (ASSA, 2010). One can also note that CM was increasing in 2000 before it has started to decline in 2005 in all the provinces due to the HIV endemic as indicated previously for the national estimates.

Unlike the number of studies at national and provincial levels, the researches on measuring child mortality at lower geographical levels are very limited. One comparable attempt with this research is by Bangha and Simelane (2008), who have used the 2001 census data to map the spatial distribution of U5M mortality at magisterial district (MD) level. They have found a significant extent of differentials in CM among MDs. For instance, based on their computation, U5M rate per 1000 births among MDs ranges from 5.6 to as high as 108.5. However, it seems that they have somehow under-estimated the CM level in general. For example, it is very unlikely that provincial U5M rate in 2001 ranges from as small as 19 deaths per 1000 births in WC to only 66 deaths per 1000 births in EC as they have reported. In another study, marked geographical differentials of infant mortality is observed among provinces, districts and sub-districts (Sartorius et al., 2011). Especially, the Bayesian Poisson model containing only a constant and the conditional autoregressive parameters is fitted to estimate standardised mortality ratio (SMR) of infant deaths in the sub-districts of South Africa using the 2007 community survey data.

Data and methods

Data source

The study uses data from the 10% unit record of the 2011 de facto population and housing census of South Africa. The main objective of the census was to provide statistics on population, demographic, social, economic and housing characteristics (StatsSA, 2014a). Appropriate data quality assessments were carried out before using the data for our analysis.

Methods of estimating child mortality

Direct synthetic cohort method is the only feasible approach to estimate child mortality from the given census data. Reported deaths by households are used to compute infant and U5M rates. This is achieved by calculating a complete life table for children aged 0 to 4. First, infant mortality rate, an approximate estimate of $1q_0$, is calculated by the

ratio of the number of deaths of children under age 1 and the number of births occurred 1 year before the census date.

The number of births occurred 12 months before the census are computed from the census question on day, month and year of the last birth administered to women of age 12-50 years at the census date. Then, the central mortality rate, $1M_x$ for children between ages x and $x+1$ for $x = 1,2,3,4$ are determined by dividing the number of deaths of children aged x by their expected number of children or mid-year population. The mid-year population at age x are computed by first projecting back the number of survivors at the census date by exactly one year before the census using survival factors from ASSA 2008 demographic and AIDS model (ASSA, 2010) to get the population size one year before the census date and then taking the average of these projected numbers and the actual census counts. This implies that the number of children between age x and $x+1$ about six months before the census, $1N_x$ is given by

$$1N_x = \left(P_x^t \times P_x^{t-1} \right)^{1/2} = \left(P_x^t \times \frac{P_x^{t-1}}{1S_x} \right)^{1/2} \quad (1)$$

where P and S respectively denote the census population counts and the ASSA model survival factors. The probability of dying between birth and before reaching their fifth birthdays, $5q_0$ is then calculated as $5q_0 = 1 - \exp\left(-\int_0^5 \mu(x) dx\right)$ where $4q_1$, the probability of dying between age 1 but before reaching the fifth birthday is calculated from the central mortality rates using

$$4q_1 = 1 - \exp\left(-\int_1^4 \mu(x) dx\right) \approx 1 - \exp\left(-\sum_{x=1}^4 1M_x\right) \quad (2)$$

where $\mu(x)$ is the actual force of mortality approximated by the central mortality rate, $1M_x$. Note that in the calculation of $1M_x$, it is assumed that those who die between ages x and $x+1$ do so halfway between the census date and one year before the census date.

In addition to the national estimate, infant and U5M rates for each of the nine provinces of South Africa are computed following the same procedure except that instead of the national level survival factors, provincial survival factors are used from the ASSA model in order to get the respective estimates of the number of children exposed to the risk of death between age x and $x+1$ for $x = 1,2,3,4$ and in each province.

However, for municipal-level estimates a different approach is implemented as it is not feasible to follow the same procedure as the national

or provincial level estimates. First, it is assumed that the ratio of U5M to infant mortality rate in each municipality is the same as the ratio at the respective province and hence the U5M rates are computed by multiplying the infant-mortality rates by these factors (ratios). Second, the infant mortality rates are estimated by fitting a spatial Bayesian smoothing model using the number of infant deaths and births that occurred 12 months before the census in each municipality as inputs (as discussed in the next section). The original or crude mortality rates are used as initial values for the parameter of interest in the smoothing model during MCMC simulation. The smoothing is important because otherwise the estimates become unstable as there are fewer deaths in many municipalities and hence, a few more or less child deaths can greatly impact the estimates especially in less-populated municipalities. The method also helps to obtain mortality rates estimates for those municipalities which have zero observed deaths in the data.

The smoothed municipal-level infant and U5M estimates are aggregated up to give smoothed estimates of the respective rates at national and province levels. It is expected that the difference between the smoothed and unsmoothed estimates at national and province levels is very small. The real advantage of the smoothing is for the municipal-level estimates.

Bayesian Spatial Smoothing

Model specification

A full Bayesian spatial smoothing method is applied to the municipal-level infant mortality rates to improve the quality of the estimates. The parameters of the prior distribution in full Bayesian smoothing are considered to be random variables with their own distributions, resulting in a hierarchical model. The first level of the model is defined by the observed data itself while in the second level the prior distribution defines spatial dependence between nearby areas through its hyper-parameters.

In this study an adjacency matrix is used to identify neighbouring areas. Neighbours are defined as municipalities that are physically connected to one another. There are 234 municipalities and 1244 distinct adjacent pairs of municipalities (neighbours) in South Africa which give an average of 5.3 neighbours per municipality with the smallest number of neighbours being 1 and the largest number of neighbours being 11.

To use prior distributions obtained from neighbouring areas, a hierarchical Bayesian model is employed in which the first level of the model

consists of the level of child mortality in an area in which the number of child deaths reported in each municipality, Y_i , is modelled using a binomial distribution as given below.

$$Y_i \sim \text{Binomial}(p_i, n_i) \quad (3)$$

where p_i is the probability that a child is dying before reaching the first birthday in municipality i and n_i is the total number of children in the municipality. The resulting fitted values of p_i will be used as a smoothed estimate of infant mortality in municipality i . This parameter of interest is modelled using a generalised linear model:

$$\text{logit}(p_i) = \alpha + S_i \quad (4)$$

where α is an unstructured random effect representing the global mean of the log-relative risks for all areas and S_i is a spatially structured random effect representing the municipal-specific effects or the deviation from the global mean (Lunn et al., 2013).

In order to further improve the estimates; it is a good practice to include some important determinants of child mortality in the model specified above. In this regard, two variables are included: level of females' education and the level of HIV in the municipalities. Females' education is known to be a strong predictor of child mortality in many researches. On the other hand, HIV has significantly affected the mortality of children in South Africa. Therefore, the average years of schooling of women aged 15-49 in each municipality and the provincial HIV prevalence rate among adults in the 15-49 age group are included in the model specified above. HIV prevalence rates are taken from the 2012 South African national HIV prevalence, incidence and behaviour survey conducted by the Human Science Research Council (HSRC, 2014a). The revised generalised linear model for the probability of death controlling for these variables becomes:

$$\text{logit}(p_i) = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + S_i \quad (5)$$

Where X_{1i} and X_{2i} are respectively the education and HIV variables as defined above. The inclusion of these two variables in the model helps to effectively use the spatial neighbourhood, females' education and HIV prevalence rate to predict the probability of death for each municipality.

The second level of the hierarchical Bayesian model is the prior distributions for the random effects. An improper uniform prior distribution is assigned for the unstructured random effect, α (Lunn et al., 2013).

$$\alpha \sim \text{dflat}() \quad (6)$$

Since there is very little information available on how much education or HIV impact child mortality occurs

in each municipality, very weak prior distributions for b_1 and b_2 are given by assigning a small value for the precision. In doing so, the data will be guaranteed to be the main determinant of the estimates.

$$\beta_{1i}, \beta_{2i} \sim N(0, 0.001) \quad (7)$$

The spatially structured random effect is assigned a conditional autoregressive (CAR) distribution with parameter

$$S_i \sim CAR(\tau) \quad (8)$$

The CAR model specifies how each S_i is related to the S_j at all other locations via a set of univariate conditional distributions. One of the most commonly used formulations (see Lunn, Jackson, Best et al.) which is applied in this research is

$$S_i | S_{-i} \sim Normal\left(\frac{\sum_{j \neq i} w_{ij} S_j}{w_{i+}}, \frac{\tau^2}{w_{i+}}\right) \quad (9)$$

Where w_{ij} are weights used to express spatial dependence between municipality i and municipality j , with $w_{ij} = w_{ji}$, $w_{ii} = 0$ and $w_{i+} = \sum_j w_{ij}$. Usually w_{ij} is defined as $w_{ij} = 1$ if municipality i and j are neighbours and $w_{ij} = 0$ otherwise. Thus, the conditional mean of S_i is a weighted average of the others. This model is available in WinBUGS software, as

$$S[1:n] \sim \text{car normal}(\text{adj}[], \text{weights}[], \text{num}[], \text{inv.tau.squared}) \quad (3.10)$$

The CAR model also includes the hyper-parameter τ , the precision of the variance, which denotes how similar or variable neighbouring areas should be. Due to uncertainty in the degree of similarity in neighbouring areas, in the third level of the hierarchical model, τ is assigned its own distribution, a hyper-prior distribution, with a very weak gamma distribution.

$$\tau \sim \gamma(0.5, 0.0005) \quad (3.11)$$

To determine the standard deviation of S , τ is normally converted into the form $\zeta \cdot S = \sqrt{1/\tau}$, where w is scalar.

The parameters of the specified Bayesian models are estimated by the use of WinBUGS software which performs Bayesian inference based on the

MCMC sampling scheme. The two models are fitted and compared with DIC (deviance information criterion). The first one is with only spatial structure, and the second model incorporating females' education and HIV prevalence rates. For each model 100 000 iterations are run with the initial 10 000 discarded from the use for parameter estimation. After convergence, the model with the lowest DIC is selected. Convergence is evaluated by inspecting trace and autocorrelation plots of samples for each chain, as well as other numerical summaries as shown below.

For visualisation and further ease of comparison, the estimated U5M rates of the municipalities and provinces are mapped with GIS software. The shape files corresponding to the 2011 census which are used for creating the maps were obtained from Municipal Demarcation Board of South Africa (MDBSA, 2014). They are defined as the GCS WGS 1984 geographic coordinate system and adopted the Africa Albers Equal Conic Area System for projecting the final maps. These options are available in the ArcGIS software.

Methods for measuring poverty and inequality

Two methods of measuring, and one measure of inequality are considered. The measures are determined at national, provincial and municipality levels. The first poverty measurement approach is based on monthly per capita income and comparing it with the national poverty line. As this approach is not the best method to reflect the actual living standard of the population, another measure of poverty is computed by constructing an index from different indicator variables which are supposed to be related with the living standard of people in a better way. It is constructed based on various indicators of wellbeing. Factor analysis (FA) is used to construct the index. The procedure mainly involves extracting the factor(s) by partitioning the total variance in each of the variables into variances which are shared and unique variance. The detail theory and application of FA can be found in any standard multivariate text like Hair et al. (2010). The descriptions of the variables used for constructing the index including some summary statistics of the variables are shown in Table 1 below.

Table 0 Summary of variables used for LSI construction

Variable	Category (code)	Mean	SD	Factor loading	Coefficient
----------	-----------------	------	----	----------------	-------------

Dwelling Type	House (1), Other (0)	0.66	0.48	0.384	0.066
Room per person	Greater or equal to 1 (1), less than 1 (0)	0.69	0.46	0.257	0.030
Roof made of	Tiles (3), Concrete/Block (2) Other (1)	1.98	0.66	0.431	0.058
Wall made of	Brick (3), Concrete/Block (2) Other (1)	1.93	0.60	0.388	0.067
Energy used for lighting	Electricity (1), Other (0)	0.85	0.36	0.631	0.128
Energy used for cooking	Electricity/Gas (1), Other (0)	0.77	0.42	0.674	0.123
Piped water on premises	Available (1), Not available(0)	0.73	0.44	0.667	0.106
Flush Toilet	Available (1), Not available(0)	0.60	0.49	0.717	0.179
Television	Available (1), Not available(0)	0.76	0.43	0.595	0.096
Satellite Dish	Available (1), Not available(0)	0.26	0.44	0.554	0.092
Refrigerator	Available (1), Not available(0)	0.70	0.46	0.641	0.118
Washing Machine	Available (1), Not available(0)	0.32	0.47	0.645	0.120
Vacuum Cleaner	Available (1), Not available(0)	0.17	0.38	0.536	0.097
Computer	Available (1), Not available(0)	0.22	0.41	0.555	0.105
Internet access	Available (1), Not available(0)	0.36	0.48	0.436	0.057
Rubbish collected by local authority	Yes (1), No(0)	0.62	0.49	0.625	0.104

Source: Stats SA census 2011

The first factor is enough to explain about 80% of the variance in the dataset and hence it's used to construct the index. The factor loadings and the coefficients of each variable used to generate the index are given on Table 1. The constructed index is categorized into 5 quintiles which can be used as ranking the level of living standard (LS) of households. A household lying in the first quintile is categorized as to have the poorest living standard while a household lying in the fifth quintile is categorized to have the best living standard. Furthermore, households in the first two quintiles are categorized as poor and LS poverty headcount ratio (LS PHCR) is computed for each area.

Income inequality is expected to be positively correlated with child mortality as greater inequality in income within communities reflects unequal access to healthcare, nutrition and other services which is likely to reduce the health of the poor (Rodgers, 2002, Waldmann, 1992). For this purpose, Gini index (GI) is computed for each province and

municipality of the country from the distribution of their population and income class as reported in the 2011 census.

Results of analysis

Estimates of child mortality from household deaths data

Using the weighted total infant deaths and the number of births that occurred in the country one year before the census, which is calculated as 1 136 387, infant mortality rate or probability of dying before age one (1q0) is estimated to be 37 per 1000 live births. On the other hand, the probability of dying between age one and 5 (4q1) is computed based on the method discussed in Section 3.3 and as shown in Table 2 as 13 deaths per 1000 live births. Combining the estimates of 1q0 and 4q1, the national estimate of U5M rate or the probability of dying before reaching age 5 is 49 deaths per 1000 births.

Table 2 National level child mortality estimates

Age	No of Deaths	Average Population/Births	Central Death Rate	Mortality Rates
0	42 186	1 136 387	NA	1q0 = 37.12
1	7 169	1 147 273	0.0062	

2	3 329	1 147 342	0.0029	${}_4q_1 = 12.76$
3	2 228	1 121 930	0.0020	${}_5q_0 = 49.41$
4	1 851	1 082 251	0.0017	

Applying the same procedure but by disaggregating the census data by province infant and U5M rates are estimated. These estimates are provided in Table 3 together with the smoothed estimates computed by aggregating the municipal level Bayesian estimates.

The spatial distribution of U5M among the nine provinces is shown on Figure 1. The map is created

by categorizing the provinces into 5 classes based on the severity of their U5M rates. WC lies in the first quintile followed by GT and LP while Northern Cape (NC) seized the third quintile. KZN and FS are in the last class preceded by North West (NW), EC and MP.

Table 1 Provincial level estimates of child mortality

Province	Direct Estimates				Smoothed Estimates		
	1q0	5q0	1q4	5q0/1q0	1q0	5q0	1q4
Western Cape	18.86	24.75	6.00	1.31	19.86	26.06	6.33
Eastern Cape	41.69	55.96	14.89	1.34	42.49	57.04	15.19
Northern Cape	40.27	52.55	12.79	1.30	38.50	50.24	12.20
Free State	47.82	68.47	21.69	1.43	47.61	68.17	21.59
KwaZulu-Natal	49.81	68.78	19.96	1.38	51.14	70.61	20.52
North West	44.98	61.79	17.60	1.37	45.15	62.03	17.67
Gauteng	25.95	36.07	10.40	1.39	26.75	37.19	10.73
Mpumalanga	41.29	58.13	17.57	1.41	42.51	59.85	18.11
Limpopo	28.37	39.27	11.22	1.38	28.87	39.98	11.43
ZA	37.12	49.41	14.09	1.34	36.03	49.95	14.45

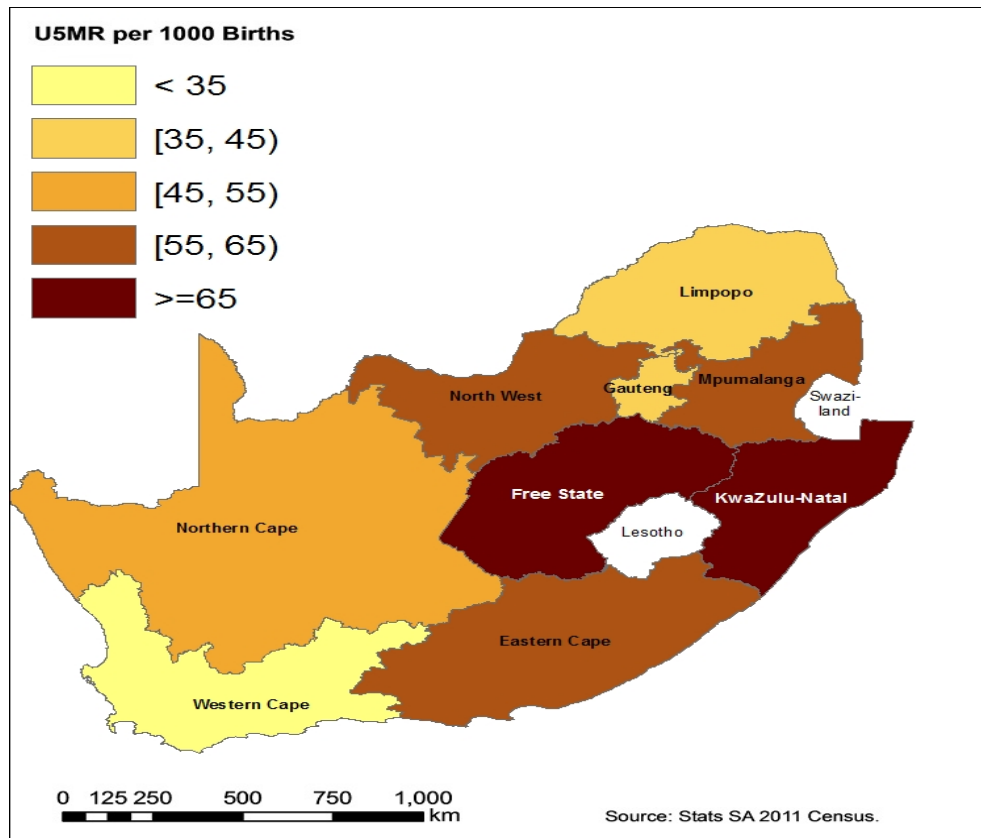


Figure 0 Provincial smoothed estimates of U5M rate

Computing direct estimates of U5M at municipal levels using the same procedure, however, is problematic as the number of deaths at municipal-level are very small in many municipalities to generate stable estimates. First, stable estimates of infant mortality rate for each municipality are computed using Bayesian spatial smoothing technique. Second, it is assumed that the ratio of U5M rate to infant mortality rate in each municipality within a province is the same as the ratio of the two quantities at the respective province. These ratios for each province are as shown in Table 3, which ranges from 1.3 in NC to 1.43 in FS.

Spatially smoothed municipal-level Bayesian estimates of child mortality

Two different Bayesian models are compared. The first model (Model-1) is only with spatial smoothing

– pure conditional autoregressive (CAR) model while the second one (Model-2) incorporates municipal level mean years of women education and provincial HIV prevalence rate for adults aged 15-49. After running each of the models initially for 10 000 iterations and another 100 000 iterations for monitoring stage, the respective models have returned DIC values of 1187.1, and 1164.7 respectively. Hence, the improved model (Model-2) is better to estimate municipal-level child mortality rates. The model is then used to generate estimates of infant and U5M rates to each municipality. The inclusion of the two variables in the CAR model has improved the estimates to some extent. This can be demonstrated by looking at the relationship between the U5M estimates and the variables included as indicated in the plots shown in Figure 2 and 3 below.

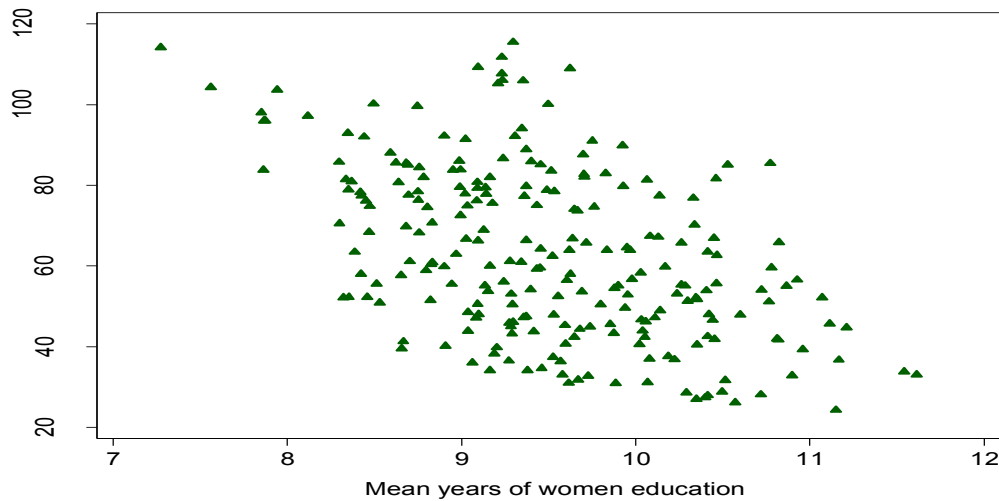


Figure 1 U5M rate and mean years of mothers' education

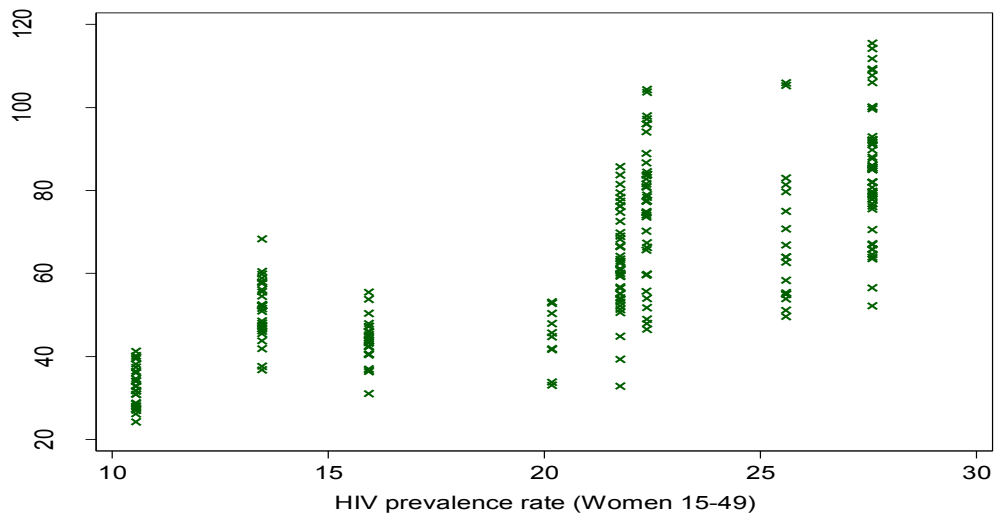


Figure 2 U5M rate vs HIV prevalence rate

Estimates of municipal level infant and child mortality rates

The final municipal level estimates of infant and U5M rates are provided together with other relevant statistics in the appendix (Table 9). The municipalities in the table are ranked based on their level of U5MR. In addition, the estimates of child mortalities are associated with geo-referenced data of the municipalities and mapped as shown on Figure 4. The map helps one to see the spatial patterns of child mortality in the country in that mortality is heavier in north-east, central and north-west part and lighter in south-east and northern parts of the country. Among all the municipalities, City of Cape Town (CCPT) has got the minimum U5M of 24.0 deaths per 1000 live births while uPhongolo of the KwaZulu-Natal province has recorded the maximum rate of 109.1 which is about 4.6 times higher than the mortality rate of CCPT. This implies that the

probability that a child who is born in uPhongolo is 4.6 times more likely to die before reaching its fifth birthday than a child who is born in CCPT.

For such ease of comparisons, the U5M rate estimates of all municipalities are divided by the minimum U5M rate (CCPT) in order to get a kind of standardised mortality index (SM). These indices and the corresponding U5M ranks for each of the municipalities are also given in Table 9. From this table one can appreciate the degree of differential of child mortality among municipalities in South Africa. In the time period where the mortality estimate applies, the U5M rate of 60 % of the municipalities is more than twice the mortality rate of the city of Cape Town. Furthermore, in 30 % of the municipalities, child mortality is three times higher while in 7 % of the municipalities the mortality is four times higher than the mortality in CCPT.

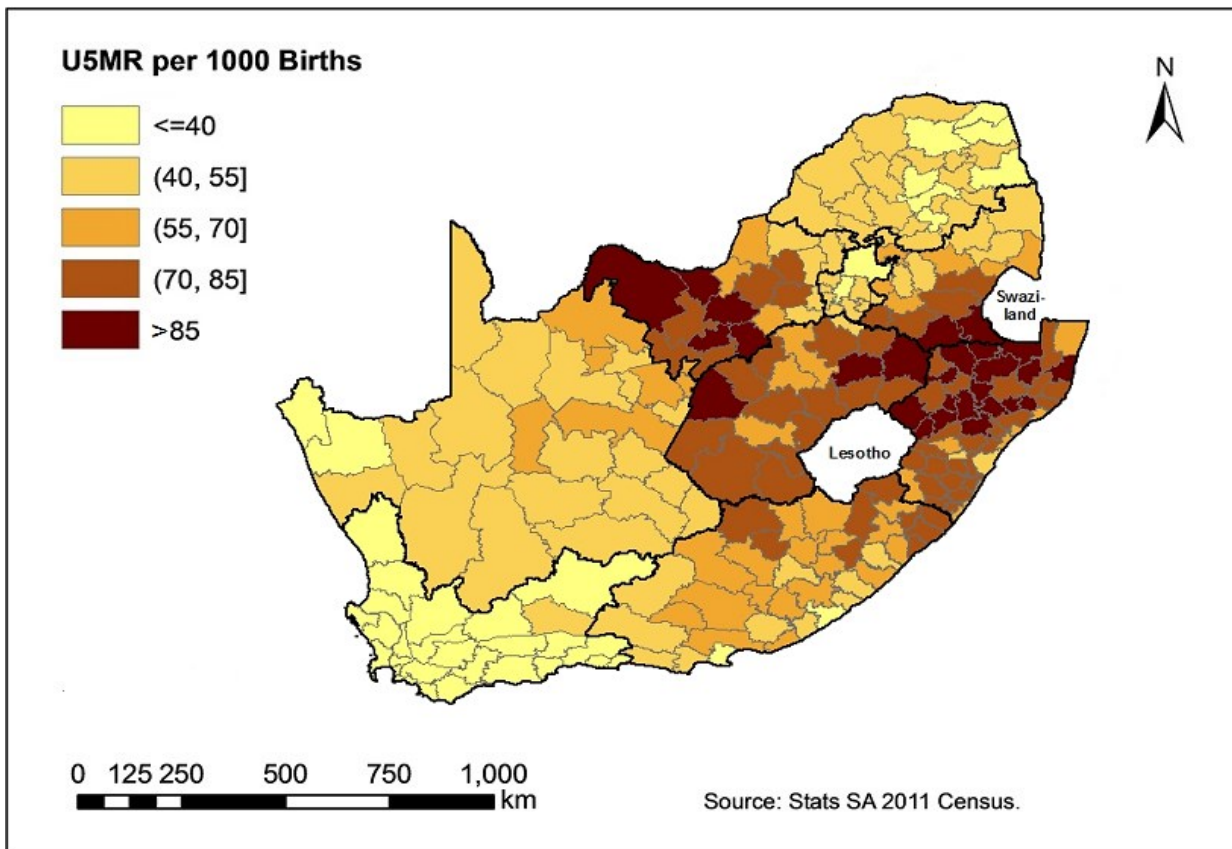


Figure 3 Spatially smoothed municipal-level estimates of U5MRs

There are clear and consistent evidences of elevated mortality levels in municipalities in KwaZulu-Natal and North West and lowest levels in municipalities of the Western Cape, Gauteng and Limpopo. Summary statistics of municipal-level U5M estimates in each province are given on Table 4. The information in the table together with the map helps to appreciate not only the magnitude of child mortality in the municipalities within provinces but also the degree of variation in mortality in each of the provinces. The greatest disparity in child mortality among

municipalities is observed in North-West and Mpumalanga provinces with a CV of 25 and 24 % respectively. The municipalities in Limpopo province, on the other hand, have the lowest variation in child mortality that they are the most alike relative to municipalities in other provinces. Nationwide, the 234 municipalities vary in child mortality by 33% while the mean and median values are 61 and 62 respectively. The box plots in Figure 5 present the combined information of extent and disparity of the mortalities in each province.

Table 2 Summary Statistics of U5MR Municipal-level estimates

Province	n	Mean	Median	Min	Max	SD	CV
Western Cape	39	32.28	32.18	23.97	40.41	4.72	14.61
Eastern Cape	20	60.99	59.31	32.28	82.18	11.26	18.46
Northern Cape	10	50.10	50.82	36.13	66.07	6.89	13.74
Free State	51	74.67	74.46	54.14	91.57	9.45	12.66
KwaZulu-Natal	25	81.09	81.54	50.80	109.08	13.60	16.77
North West	18	72.28	75.43	45.51	99.06	18.28	25.29
Gauteng	27	43.51	44.18	32.48	51.71	6.79	15.61
Mpumalanga	19	66.27	61.93	48.39	100.51	15.70	23.69
Limpopo	25	42.76	42.90	30.60	53.97	5.12	11.97
ZA	234	60.84	61.55	23.97	109.08	19.79	32.52

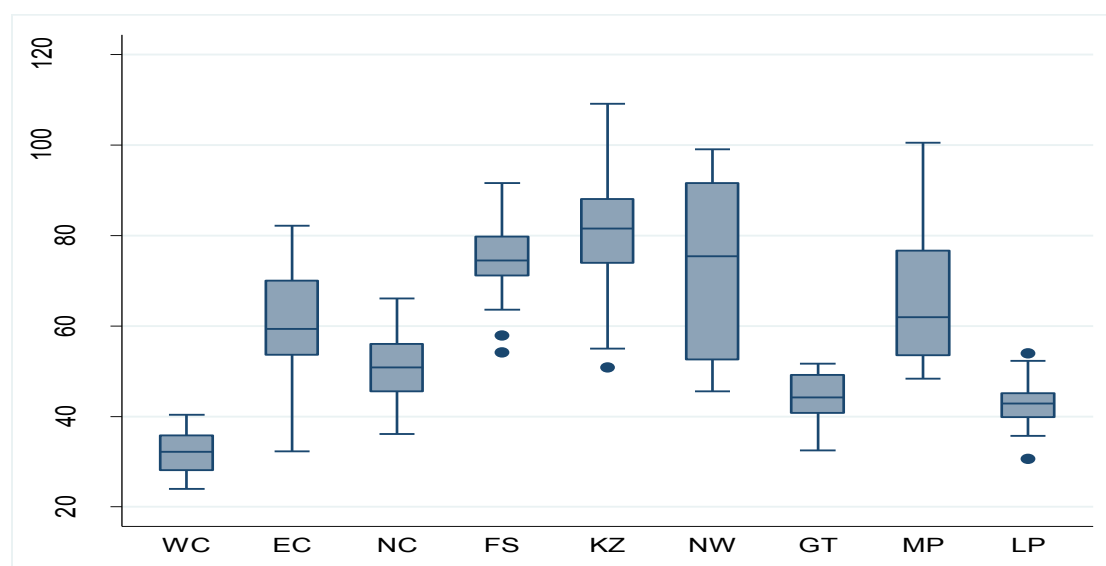


Figure 4 Distribution of municipal level estimates of U5MR among the provinces

Estimates child mortality in relation to poverty and inequality

The proportion of poor people at national level is estimated to be about 40 % both in terms of income and LS index while income inequality as measured by Gini index is 0.72. In order to understand the relationships at province level, Table 5 explicitly presents the information for each province. There are large differences in poverty among the provinces which range from 30 to 54 % in terms of income and from 18 to 69 % in terms of LS index while the variation in inequality is very low. These economic disparities can be compared with health differentials as measured by U5M rates (26-71 deaths per 1000 births). Western Cape (WC) has not only registered

the lowest child mortality rate but also had the smallest measures of poverty and inequality. It is only 18 % of the people living in the province that are classified as poor in terms of LS as compared to 30 % based on per capita monthly income. On the other hand, KwaZulu-Natal (KZN), stands but third and second from the last in terms of poverty and inequality respectively. Limpopo and Eastern Cape (EC) are the first and second poorest provinces based on both measures of poverty while EC seemed to be relatively the most unequal province, followed by KZN. It is apparent that Limpopo is the only province which had lower mortality rate unlike its higher level of poverty in both dimensions considered in this research.

Table 3 Estimates of U5MR, poverty and inequality at province level

Province	U5MR	PHCR (Income)	PHCR (LS Index)	Gini Index
Western Cape	26.06	30.22	18.06	0.6771
Eastern Cape	57.04	53.06	58.83	0.7243
Northern Cape	50.24	40.38	36.39	0.7054
Free State	68.17	42.92	30.33	0.7022
KwaZulu-Natal	70.61	48.66	52.06	0.7164
North West	62.03	43.87	50.03	0.6790
Gauteng	37.19	31.59	20.77	0.6824
Mpumalanga	59.85	45.73	48.65	0.7071
Limpopo	39.98	54.34	68.79	0.7174
ZA	49.95	40.73	40.22	0.7156

Note: U5MR is per thousand while PHCRs are expressed as percentages

The estimates of poverty and inequality for the 234 municipalities are also computed and are given together with the smoothed estimates of U5M rates and other related statistics in Table 9. It is evident that in most cases both measures of poverty are positively related with child mortality. It must be noted that the poverty measure computed based on the LS index has shown a stronger association with child mortality— correlation coefficient of 0.573, than the poverty measures computed based on per capita income alone – correlation coefficient of 0.475. In both measures, however, there are many exceptions in that lower poverty does not necessarily guarantee lighter mortality and vice versa. For instance, although Thulamela, a municipality in Limpopo province, is ranked as the 195th and 184th poor municipality in terms of income and living standard respectively, it has recorded the 13th lighter U5M rate. Similarly, Mutale, another municipality in Limpopo, has the 23rd smallest U5M while respectively scoring a rank of 206 and 208 in terms of income and living standard poverty. On the other hand, municipalities like Mpofana (in KZN province) with income poverty rank of 75th and Maquassi Hills (in NW province) with living standard poverty rank of 93 had registered among the highest mortality rates with ranks of 198th and 224th respectively.

The relationship between income inequality and child mortality, however is not as strong as the relationship between child mortality and poverty. In general, all municipalities experienced a very high

level of inequality, Gini index ranging from 0.576 in Ngqushwa (in EC province) to 0.784 in Jozini (in KZN province) and 79% of all the 234 municipalities scoring a Gini index greater than 0.65. Nonetheless, there is a weak positive correlation, , between income inequality and child mortality implying that on average there are more deaths in municipalities where the people are more unequal in terms of income than in municipalities with less unequal people. However, it is not surprising that there are inverse relationships between income inequality and child mortality in many municipalities including Nqutu and Dannhauser (both in KZN) with much lower inequality and higher mortality, and Knysna and Bitou (both in WC) with much higher inequality but lower mortality.

For a better understanding of the relationship among child mortality, poverty and inequality, municipalities are divided into poverty and inequality quintiles and the corresponding average U5M rates are then computed in each quintile. This information is provided below in Table 6. In each of the three cases, an increasing trend of child mortality is observed along the quintiles, confirming that on average an increase in poverty and inequality is associated with an increase in mortality of children. However, the magnitude of the changes in mortality along the quintiles of income inequality (Gini Index) are smaller, which supports the points raised above that child mortality has stronger association with income and living condition than income inequality.

Table 4 U5M rates under poverty and inequality quintiles

Quintiles	Mean U5MR in Quintiles of		
	PHCR (income)	PHCR (LS index)	Gini Index
Q1	42.77	44.00	54.99
Q2	53.41	57.43	58.40
Q3	65.51	63.32	59.25
Q4	67.87	66.10	61.08
Q5	74.97	73.64	70.72
Corr coefficient	0.4749	0.5727	0.2706

Table 7 presents the poverty and inequality measures for the top and last 15 municipalities according to the child mortality rankings and their corresponding ranks in in poverty and inequality. The top 15 best municipalities have recorded an average U5M rate of 28.8 per thousand as opposed to 100.6 by the bottom 15 municipalities. If one is interested to compare these results with the average measures of poverty and inequality, the mean income poverty head-count ratios are 31% and 61 % respective for

the first 15 and the last 15 municipalities while the mean living standard poverty head-count ratios are 23 and 76. The measure of income inequality has resulted in a mean value of 0.67 and 0.70 respectively for the top 15 and bottom 15 municipalities. This confirms that child mortality is heavier in municipalities where poverty and inequality are worse, and that the association is weaker with inequality.

Table 5 15 best and worst municipalities in terms of U5M and their rankings in poverty and inequality

Municipality	Province	U5MR	Ranks			Municipality	Province	U5MR	Ranks		
			PHCR	LS PHCR	GI				PHCR	LS PHCR	GI
City of Cape Town	WC	23.97	33	14	86	uPhongolo	KZN	109.08	171	170	214
Mossel Bay	WC	25.80	48	3	55	Msinga	KZN	107.91	228	231	76
Knysna	WC	26.62	52	60	170	eDumbe	KZN	105.77	197	169	88
Overstrand	WC	26.97	40	25	47	Emadlangeni	KZN	103.53	144	158	59
Bitou	WC	27.48	72	46	176	Abaqulusi	KZN	103.26	163	135	227
Stellenbosch	WC	27.69	44	24	104	Okhahlamba	KZN	102.08	220	199	201
George	WC	28.19	38	20	52	Nqutu	KZN	100.60	227	197	10
Drakenstein	WC	28.38	23	7	75	Mkhondo	MP	100.51	166	149	148
Breedee Valley	WC	30.40	27	43	50	Pixley Ka Seme	MP	99.89	157	116	234
Theewaterskloof	WC	30.48	21	28	42	Ratlou	NW	99.06	201	212	102
Thulamela	LP	30.60	195	184	123	Maquassi Hills	NW	98.44	161	93	230
Saldanha Bay	WC	31.18	19	1	26	Mthonjaneni	KZN	95.34	143	181	51
City of Tshwane	GT	31.29	24	31	68	Nongoma	KZN	95.24	223	209	128
City of Johannesburg	GT	32.18	34	15	146	Indaka	KZN	94.81	234	179	32
Nelson Mandela Bay	EC	32.28	104	11	144	Tokologo	FS	93.34	189	193	205

Discussions and conclusion

Discussion of results

Although child mortality in South Africa has improved substantially in the last decade, after some period of reversal mainly due to HIV, the level is much higher than the mortality in many other countries with similar economic development level. We believe that, in order to effectively address the problem and work towards further reductions of child mortality in the country it is essential that the efforts be focused more on lower administrative levels as opposed to concentrating only on the level of mortality at national level (Freedman et al., 2005). Hence, for these efforts to move forward, constructing reliable estimates of child mortality for small geographical areas should be considered as one of the first important steps. Consequently, the overall objective of this research was to produce estimates of child mortality rates for the provinces and municipalities of South Africa using the 2011 census data and assess the differentials in relation to the level of poverty and inequality. In addition, studying the factors associated with child mortality in South Africa considering the hierarchical structure of the data and with special emphasis on poverty and inequality was the second main objective. In this chapter an attempt will be made to discuss the extent at which these objectives have been met. This involves discussing the reasonableness of the estimates of child mortality produced at national, provincial and municipal level and the validity of the results obtained on factors affecting child survival in comparison with other studies.

Estimates of infant and U5M rates at national and province level are generated directly using household death data from the 2011 census. However, in attempting to estimate child mortality for smaller geographical areas it is often difficult to construct accurate estimates because population sizes also tend to be relatively small, resulting in unstable estimates. One common approach that would help us to overcome this issue is to use Bayesian smoothing method. Hierarchical Bayesian model has been used to construct spatially smoothed estimates of child mortality for the municipalities of South Africa. The first level of the model uses the household mortality data from the 2011 South African census while in the next level the probability of a child dying before reaching age one is modelled using a binomial model with a spatially structured random effect. The prior distribution for this random effect is constructed using a conditional autoregressive (CAR) model which incorporates spatial dependence among neighbouring municipalities and allows for its impact to be greater for municipalities with more unstable data. The estimates are further improved by incorporating average years of women's education of each municipality and the provincial HIV prevalence rates of adults aged 15-49. It is assumed that the ratio of U5M rate and infant mortality rate be the same at province level which helps us to get estimates of U5M rates for the municipalities from the infant mortality rates obtained from the Bayesian spatial smoothing model.

Having derived child mortality rates, the first important question has to be how the estimates are compared with those presented elsewhere. In this regard, the national level estimates can be compared with reports from Stats SA, Rapid Mortality Surveillance (RMS), ASSA model 2008, UN Inter-Agency Group for Mortality Estimation (IGME), world population prospectus (WPP) and the Institute for Health Metrics and Evaluation (IHME). Figure 6 presents the estimates of infant and U5M rates from these institutions as well as the estimates from this research and estimates from a recently published paper by Udjo (2014). Given the degree of controversy about estimates of child mortality in South Africa and the fact that each of the institutions might have used different approaches and data

sources to derive their corresponding values, it is fair to say that the estimates from this research are quite reasonable and consistent with most of these estimates. Relatively, both infant and U5M rates from RMS are lower than the others, for instance they are less by 29 and 25 % compared to our estimates, while those from Stats SA seem to be a bit inflated. Despite these, the estimates from Udjo (2014) are found to be highly exaggerated compared to the estimates from this research as well as the estimates from all other sources. It is very hard to have an infant and U5M rates of 60 and 80 per 1000 respectively for South Africa in 2011 unless there is some problem with the data used or the method of estimation applied.

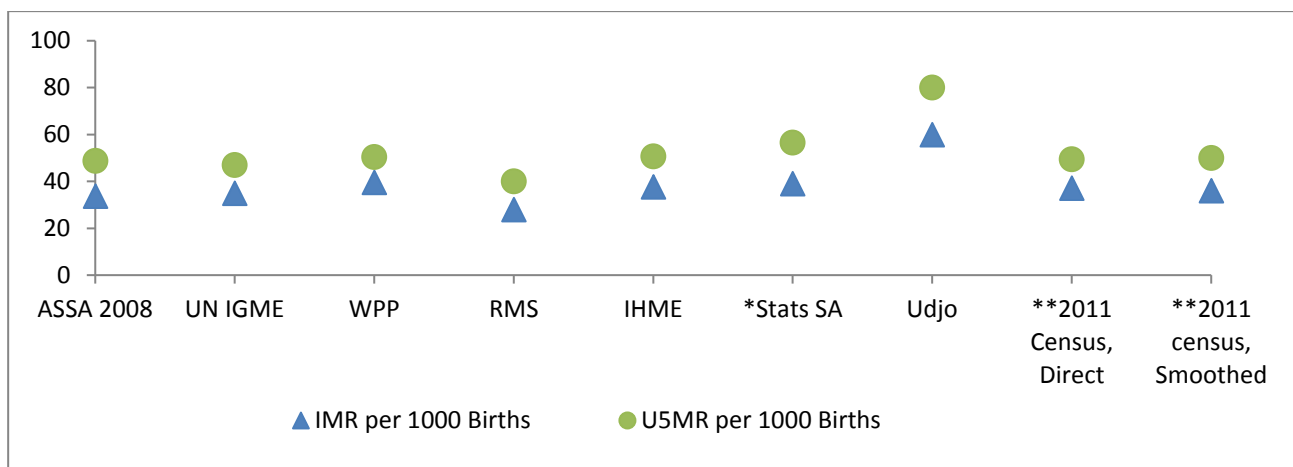


Figure 5 Comparisons of national level IM and U5M rates from various sources

Note: *Stats SA estimates refer to 2010 while others apply to 2011; **According to this research computation

Another way of evaluating the quality of municipal level estimates is to compare the robustness of the estimates with the crude estimates and smoothed but not improved by women education and HIV prevalence rate. Table 8 describes some summary statistics concerning these estimates. It is evident from the table that the Bayesian method has produced more stable and accurate results compared to the crude estimates as they have smaller variation. On the other hand, incorporating women education and HIV prevalence rate into the hierarchical Bayesian model has very little impact on the overall estimates. However, the real benefit of this adaptation can be felt in individual municipalities whose level of education and HIV prevalence differ from those of nearby

municipalities. In such cases, by incorporating these two variables into the construction of estimates of child mortality, these differences are recognised and more reliable estimates can be obtained. The correlations between the two covariates and child mortality rates are much stronger in the case of the Bayesian estimates than the crude rates. It is also very important to note that there are 11 municipalities with missing crude estimates of child mortality, but there are no municipalities with missing Bayesian estimates of child mortality. The general approach was also used by McKinnon (2010) to find U5M rates for the municipalities of Brazil and it can be observed that our results are similar in that the use of Bayesian smoothing together with women education has improved the estimates reasonably.

Table 6 Summary statistics estimates of U5M rates at municipal-level

Statistic	Crude estimates	Bayesian-Spatial only	Bayesian-with Education and HIV
No of municipalities	223	234	234

Mean	64.55	59.48	60.84
Median	57.41	57.44	58.18
SD	31.57	19.49	19.79
CV (%)	48.90	32.77	32.52
Minimum	8.72	24.64	23.97
Maximum	200.31	118.23	109.08
Correlation with Education	-0.34	-0.38	-0.51
Correlation with HIV	0.40	0.72	0.76
Missing municipalities	11	0	0

The child mortality differentials are believed to be highly associated with the level of poverty and inequality. Poverty in this research is measured both using income and LS. Income poor people are those who earn an average monthly household per capita income of less than R515 while LS based poor are those whose LS index lie either on the first or second quintile. The estimates of poverty are quite reasonable compared to Stats SA estimates (StatsSA, 2014b). For instance, Stats SA has estimated the percentage of people living under poverty line of R443 to be 32.3 % while our estimate is 41 percent at R515 poverty line.

The proportion of poor people in provinces and municipalities are positively correlated, as expected, with the level of mortality – 95 % significant correlation coefficients of 0.49 and 0.58 respectively for income and LS dimension of poverty. However, there are some exceptions in that higher poverty does not necessarily imply higher child mortality and vice-versa. Many municipalities in Limpopo province including Thulamela and Mutale, for example, have

scored lower mortality rates although the levels of poverty remain very high in both dimensions of poverty. This may suggest that socioeconomic differentials are not the sole determinants of child mortality but a combination of many other factors too.

Having used the Gini coefficient as a measure of the level of income distribution with in provinces and municipalities, it is also found that income distribution is associated positively with child mortality. However, the degree of association is weak relative to that of poverty resulting in only a 0.17 significant correlation coefficient at municipal-level – significant at 95 % level of confidence.

Conclusions

The study primarily aimed to derive up-to-date estimates of child mortality for the municipalities and provinces of South Africa using the 2011 census data. This is achieved through the use of direct synthetic cohort and Bayesian spatial smoothing

methods. It is revealed particularly that child mortality estimation at municipal level is possible which has never been attempted so far to the best of our knowledge. Clear and significant spatial differentials in child mortality are observed in the country – at province level, U5M rate ranges from 26 deaths per 1000 births in Western Cape to 71 deaths per 1000 births in KwaZulu-Natal province, while at municipality level, it ranges from 24 deaths per 1000 births in the City of Cape Town to as high as 109 deaths per 1000 births in uPhongolo. Furthermore, the estimates obtained are reasonable and, those at national and province level are in agreement with results from many other researches.

The study also aimed to find out how the spatial differentials in child mortality in the country are associated with the level of poverty and inequality. For this purpose, poverty in income and living standard dimensions and the Gini index are computed for each municipality as well as for the provinces and the country using data from the same census. The results show that in fact child mortality is higher in municipalities which are poorer, although there are some cases where inverse relationship is observed like several municipalities in Limpopo province that though the level of poverty is very high, child mortality is much lower in comparison with many other municipalities. It is also shown that the distribution of income similarly matters to some extent as greater child mortality is observed in areas which are more unequal although the degree of association is not as strong as with that of poverty.

Unlike its economic development status and despite policies put in place for reduction of child mortality in the country, South Africa's child mortality rate is still high as compared to other countries with similar economic development status. This research has claimed that one approach to bring better outcomes in the reduction is to address the issues at lower administrative level and has tried to provide the evidences gained from the latest available census data. The results obtained may help the government to implement policies more effectively and make more focused decisions

towards better reduction of child mortality in the country.

References

- ASSA 2010. Actuarial Society of South Africa 2008 AIDS and Demographic Models. Actuarial Society of South Africa.
- BANGHA, M. W. & SIMELANE, S. 2008. Spatial Differentials in Childhood Mortality in South Africa: Evidence from the 2001 Census. *African Population Studies*, 22.
- DORRINGTON, R., TIMAEUS, I. M., MOULTRIE, T. & NANNAN, N. 2004. Estimates of provincial fertility and mortality in South Africa, 1985-1996. *South Africa Journal of Demography*, 9, 25-57.
- FREEDMAN, L. P., WALDMAN, R. J., PINHO, H. D., WIRTH, M. E., CHOWDDHURY, A. M. R. & ROSENFELD, A. 2005. Who's got the power? Transforming health systems for women and children: Achieving the Millennium Development Goals. In: STERLING, V. (ed.) Earthscan.
- HAIR, J., BLACK, C., BABIN, J. & ANDERSON, E. 2010. *Multivariate Data Analysis*, Pearson Prentice Hall.
- HSRC 2014a. South African National HIV Prevalence, Incidence and Behaviour Survey. Human Science research Council.
- HSRC 2014b. State of Poverty and its Manifestations in the Nine Provinces of South Africa. Economic Performance and Development. Human Science Research Council.
- IGME 2013. Levels and trends in child mortality. In: DANZHEN YOU, P. B., JINGXIAN WU AND TESSA WARDLAW (ed.). UN Inter-agency Group for Child Mortality Estimation.
- STATSSA 2014a. 2011 South African census 10 percent Sample Metadata. Pretoria: Statistics South Africa.
- STATSSA 2014b. Poverty trends in South Africa: An examination of absolute poverty between 2006 and 2011.
- UDJO, E. O. 2014. Estimating demographic parameters from the 2011 South Africa population census. *African Population Studies*, 28, 564-578.
- KABIR, A., ISLAM, M. S., AHMED, M. S. & BARBHUIYA, K. M. A. 2001. Factors influencing infant and child mortality in Bangladesh: Research paper. *The Sciences*, 1, 292-295.
- LUNN, D., JACKSON, C., BEST, N., THOMAS, A. & SPIEGELHALTER, D. 2013. *The BUGS Book: A practical Introduction to Bayesian Analysis*, NW, CRC Press. Taylor & Francis Group.
- MCKINNON, S. A. 2010. Municipality-level estimates of child mortality for Brazil: A new approach using Bayesian Statistics PhD, University of Texas at Austin.
- MDBSA 2014. Shapefiles for South Africa Provinces and Municipalities. Municipal Demarcation Board of South Africa.
- NANNAN, N., DORRINGTON, R., LAUBSCHER, R., ZINYAKATIRA, N., PRINSLOO, M., DARIKWA, T., MATZOPOULOS, R. & BRADSHAW, D. 2012. UNDER-5 MORTALITY STATISTICS IN SOUTH AFRICA: Shedding some light on the trend and causes 1997-2007. South African Medical Research Council, Burden of Disease Research Unit.
- REIDPATH, D. D. & ALLOTEY, P. 2003. Infant mortality rate as an indicator of population health. *J Epidemiol Community Health*, 57, 344-346.
- RODGERS, G. B. 2002. Income and Inequality as determinants of mortality: an international cross-section analysis. *International Journal of Epidemiology*, 31, 533-538.
- SARTORIUS, B. K., SARTORIUS, K., CHIRWA, T. F. & FONN, S. 2011. Infant mortality in South Africa - distribution, associations and policy implications, 2007: an ecological spatial analysis. *International Journal Health Geographics*, 10.
- UNICEF 2013. South Africa 2012 Annual Report. UNICEF.
- WALDMANN, R. J. 1992. Income Distribution and Infant Mortality. *The Quarterly Journal of Economics*, 107, 1283-1302.
- WHITING, S. 2013. Overview of child mortality in South Africa. Research Unit, Parliament of the Republic of South Africa.
- WHO 1978. Declaration of Alma-Ata: International Conference on Primary Health Care. Alma-Ata, USSR: World Health Organization.

APPENDIX

Table 9 Municipal level estimates of infant and U5M rates with level of poverty and inequality*

Province	Municipality	IMR	U5MR	PHCR	GI	LS PHCR	SMR	Ranks			
								U5M	PV	II	LSP
WC	City of Cape Town	18.3	24.0	29.6	0.673	16.9	1.00	1	33	86	14
WC	Mossel Bay	19.7	25.8	34.4	0.655	14.3	1.08	2	48	55	3

Province	Municipality	IMR	U5MR	PHCR	GI	LS PHCR	SMR	Ranks			
								U5M	PV	II	LSP
WC	Knysna	20.4	26.6	34.9	0.704	27.2	1.11	3	52	170	60
WC	Overstrand	20.6	27.0	32.0	0.648	20.9	1.13	4	40	47	25
WC	Bitou	21.0	27.5	37.2	0.706	24.5	1.15	5	72	176	46
WC	Stellenbosch	21.2	27.7	33.7	0.681	20.6	1.16	6	44	104	24
WC	George	21.6	28.2	31.4	0.652	19.2	1.18	7	38	52	20
WC	Drakenstein	21.7	28.4	28.4	0.667	15.1	1.18	8	23	75	7
WC	Breede Valley	23.3	30.4	28.7	0.651	24.1	1.27	9	27	50	43
WC	Theewaterskloof	23.3	30.5	27.9	0.647	21.7	1.27	10	21	42	28
LP	Thulamela	22.2	30.6	60.1	0.688	77.3	1.28	11	195	123	184
WC	Saldanha Bay	23.9	31.2	27.8	0.636	13.3	1.30	12	19	26	1
GT	City of Tshwane	23.5	31.3	28.4	0.663	22.0	1.31	13	24	68	31
GT	City of Johannesburg	24.0	32.2	29.7	0.694	17.2	1.34	14	34	146	15
EC	Nelson Mandela Bay	24.2	32.3	40.7	0.694	15.9	1.35	15	104	144	11
WC	Cape Agulhas	24.8	32.5	21.0	0.623	14.8	1.35	16	1	13	4
WC	Oudtshoorn	23.9	32.5	36.1	0.688	23.5	1.36	17	66	122	38
WC	Swartland	24.6	33.2	25.5	0.660	16.2	1.39	18	12	63	13
WC	Langeberg	25.6	33.5	28.8	0.677	18.5	1.40	19	28	94	16
WC	Hessequa	25.7	33.6	23.0	0.613	13.5	1.40	20	5	9	2
WC	Bergrivier	26.0	34.0	21.6	0.592	19.2	1.42	21	2	4	19
WC	Swellendam	27.1	35.4	24.2	0.627	22.1	1.47	22	9	16	32
LP	Mutale	25.9	35.7	61.9	0.707	87.5	1.49	23	206	182	208
WC	Laingsburg	27.4	35.8	23.0	0.636	30.7	1.49	24	4	28	81
LP	Polokwane	26.2	36.0	40.4	0.711	49.7	1.50	25	103	191	129
NC	Richtersveld	27.8	36.1	22.9	0.614	15.5	1.51	26	3	10	8
LP	Makhado	26.3	36.3	55.3	0.697	76.2	1.51	27	173	152	178
WC	Beaufort West	28.1	36.7	37.8	0.691	15.9	1.53	28	78	131	10
NC	Nama Khoi	28.4	36.9	29.2	0.684	16.0	1.54	29	32	112	12
WC	Witzenberg	28.7	37.5	23.4	0.639	25.7	1.56	30	7	32	50
EC	Buffalo City	28.9	38.6	42.7	0.705	38.4	1.61	31	115	171	110
WC	Kannaland	29.6	38.7	36.5	0.719	27.0	1.61	32	69	203	57
WC	Matzikama	29.9	39.0	25.3	0.658	30.4	1.63	33	11	60	77
WC	Cederberg	30.1	39.4	24.7	0.636	28.5	1.64	34	10	24	68
LP	Lepele-Nkumpi	28.8	39.6	55.3	0.704	66.2	1.65	35	173	167	153
LP	Makhuduthamaga	28.9	39.7	64.7	0.718	81.0	1.66	36	218	202	189
LP	Ba-Phalaborwa	28.9	39.8	43.0	0.698	50.4	1.66	37	116	158	131
WC	Prince Albert	31.0	40.4	35.8	0.691	26.2	1.69	38	63	132	52
GT	Randfontein	29.5	40.8	28.1	0.628	22.7	1.70	39	22	17	35
NC	Sol Plaatjie	31.6	41.0	35.5	0.695	21.7	1.71	40	58	148	27
GT	Mogale City	29.7	41.1	31.1	0.667	25.3	1.71	41	36	75	48
LP	Fetakgomo	30.1	41.5	56.3	0.710	72.4	1.73	42	181	188	166
LP	Greater Tzaneen	30.2	41.5	52.2	0.719	76.9	1.73	43	152	204	182
LP	Aganang	30.3	41.6	56.2	0.639	75.1	1.74	44	180	33	172
LP	Greater Giyani	30.8	42.3	65.3	0.704	82.2	1.77	45	219	168	191
LP	Molemole	30.8	42.4	52.7	0.697	67.7	1.77	46	158	154	157
NC	Emthanjeni	33.0	42.8	35.7	0.660	21.5	1.79	47	59	64	26
LP	Musina	31.2	42.9	35.8	0.679	45.7	1.79	48	63	100	125
LP	Greater Tubatse	31.2	43.0	53.2	0.708	76.0	1.79	49	160	184	175
LP	Bela-Bela	31.5	43.4	33.7	0.666	29.5	1.81	50	45	73	71
GT	Ekurhuleni	31.6	43.7	33.6	0.664	23.5	1.82	51	43	70	40

Province	Municipality	IMR	U5MR	PHCR	GI	LS PHCR	SMR	Ranks			
								U5M	PV	II	LSP
EC	Kouga	32.9	43.9	36.8	0.697	28.0	1.83	52	70	154	65
LP	Greater Letaba	32.0	44.0	59.7	0.685	84.3	1.84	53	192	116	196
LP	Elias Motsoaledi	32.2	44.3	56.5	0.691	70.4	1.85	54	183	129	163
NC	Mier	34.3	44.5	36.8	0.693	36.0	1.86	55	71	137	97
GT	Emfuleni	32.3	44.6	40.0	0.679	15.0	1.86	56	98	102	6
LP	Maruleng	32.6	44.8	61.3	0.731	84.2	1.87	57	204	223	195
NC	Renosterberg	34.7	45.1	38.2	0.655	27.2	1.88	58	81	56	59
LP	Lephalale	32.8	45.1	35.0	0.688	52.6	1.88	59	53	120	134
NW	Rustenburg	33.3	45.5	28.9	0.597	40.1	1.90	60	31	6	114
NC	//Khara Hais	35.1	45.6	35.0	0.685	25.2	1.90	61	54	114	47
NC	Kamiesberg	35.5	46.1	39.5	0.703	30.0	1.92	62	91	165	73
LP	Mogalakwena	33.5	46.1	53.9	0.698	60.0	1.92	63	165	155	146
LP	Ephraim Mogale	33.6	46.2	55.2	0.705	78.1	1.93	64	170	173	187
NC	Khâi-Ma	35.7	46.4	26.4	0.582	36.0	1.93	65	15	2	95
GT	Midvaal	33.9	46.8	28.6	0.651	27.0	1.95	66	26	51	56
LP	Thabazimbi	34.0	46.8	25.6	0.597	39.9	1.95	67	13	5	113
NW	Moretele	34.3	46.8	51.4	0.607	66.7	1.95	68	149	8	154
NC	Umsobomvu	36.1	46.9	44.3	0.707	29.1	1.96	69	121	182	70
NC	Siyathemba	36.5	47.4	35.8	0.672	28.1	1.98	70	61	85	66
NW	Local Mun. of Madibeng	35.0	47.8	34.3	0.648	61.2	1.99	71	47	45	148
MP	Bushbuckridge	34.6	48.4	63.9	0.690	78.0	2.02	72	214	127	185
GT	Westonaria	35.6	49.2	39.8	0.601	46.2	2.05	73	95	7	126
LP	Mookgopong	35.8	49.2	32.2	0.630	35.3	2.05	74	41	19	91
EC	Kou-Kamma	37.0	49.3	31.5	0.666	27.9	2.06	75	39	71	64
NC	Hantam	38.3	49.6	28.5	0.720	26.9	2.07	76	25	206	55
MP	Emalahleni	35.7	49.8	27.8	0.638	33.6	2.08	77	20	31	89
EC	Makana	37.5	50.0	37.5	0.698	23.5	2.09	78	76	157	40
NC	Thembelihle	38.7	50.2	38.6	0.733	39.1	2.09	79	84	224	112
NW	Moses Kotane	37.0	50.4	43.9	0.632	55.5	2.10	80	118	21	142
KZ	eThekwini	37.1	50.8	37.4	0.681	30.4	2.12	81	74	105	76
NC	Karoo Hoogland	39.2	50.8	27.3	0.723	48.0	2.12	82	18	213	127
EC	Lukanji	38.1	50.8	47.2	0.696	36.0	2.12	83	129	150	94
NC	Ubuntu	39.3	50.9	38.4	0.760	35.6	2.12	84	83	232	92
NC	Kareeberg	39.3	50.9	37.2	0.678	37.3	2.13	85	73	98	103
NC	Kgatelopele	39.4	51.1	26.1	0.685	15.6	2.13	86	14	115	9
GT	Merafong City	37.3	51.5	31.3	0.583	31.8	2.15	87	37	3	85
EC	Baviaans	38.7	51.7	35.8	0.679	20.4	2.16	88	64	101	23
GT	Lesedi	37.5	51.7	34.9	0.671	20.2	2.16	89	51	81	22
EC	Mnquma	39.2	52.2	53.8	0.642	84.7	2.18	90	164	35	198
LP	Modimolle	38.1	52.3	36.2	0.661	31.5	2.18	91	67	66	84
MP	Mbombela	37.6	52.5	40.3	0.711	48.9	2.19	92	101	192	128
NW	Tlokwe City Council	38.6	52.6	35.7	0.672	22.3	2.19	93	60	83	33
EC	Camdeboo	39.5	52.7	39.4	0.699	19.5	2.20	94	90	159	21
NC	Ga-Segonyana	40.9	53.0	47.3	0.706	62.1	2.21	95	130	178	150
MP	Steve Tshwete	38.3	53.5	26.7	0.629	22.0	2.23	96	17	18	29
MP	Dr JS Moroka	38.4	53.6	54.2	0.637	61.0	2.24	97	167	29	147
EC	Great Kei	40.2	53.6	51.2	0.743	70.8	2.24	98	146	228	164
EC	Ngqushwa	40.2	53.6	53.2	0.576	86.0	2.24	99	159	1	202
MP	Thaba Chweu	38.5	53.8	28.9	0.636	43.6	2.25	100	30	26	120
LP	Blouberg	39.3	54.0	62.1	0.711	82.0	2.25	101	207	189	190

Province	Municipality	IMR	U5MR	PHCR	GI	LS PHCR	SMR	Ranks			
								U5M	PV	II	LSP
NC	Kai !Garib	41.7	54.0	26.4	0.641	43.6	2.25	102	16	34	119
FS	Metsimaholo	38.1	54.1	35.9	0.693	23.7	2.26	103	65	136	41
NC	Tsantsabane	42.1	54.6	33.3	0.717	36.0	2.28	104	42	201	96
EC	King Sabata Dalindyebo	41.2	54.9	56.1	0.729	72.0	2.29	105	179	220	165
KZ	The Msunduzi	40.1	55.0	39.7	0.702	38.1	2.29	106	94	163	109
EC	Nkonkobe	41.4	55.1	52.5	0.661	68.7	2.30	107	156	67	160
NC	Siyancuma	43.2	56.0	41.1	0.710	37.4	2.34	108	105	187	106
NC	IKheis	43.4	56.3	42.3	0.702	53.5	2.35	109	113	164	137
NC	Gamagara	43.5	56.3	23.3	0.652	26.5	2.35	110	6	53	53
MP	Thembisile	40.6	56.6	51.3	0.644	53.9	2.36	111	148	39	138
NC	Dikgatlong	44.1	57.2	49.8	0.644	37.2	2.39	112	139	38	102
EC	Amahlathi	43.2	57.5	52.5	0.675	76.3	2.40	113	155	91	180
EC	Nxuba	43.4	57.8	48.5	0.670	37.4	2.41	114	135	79	104
FS	Mangaung	40.8	57.8	34.8	0.694	26.8	2.41	115	50	143	54
NW	Mafikeng	42.6	58.1	43.6	0.712	51.2	2.42	116	117	193	132
NC	Phokwane	44.8	58.1	45.7	0.721	37.1	2.42	117	124	208	101
EC	Blue Crane Route	43.7	58.3	43.9	0.734	25.6	2.43	118	119	225	49
NC	Magareng	45.3	58.7	49.6	0.663	23.7	2.45	119	138	69	42
EC	Sundays River Valley	44.3	59.0	40.3	0.620	45.2	2.46	120	102	12	123
EC	Sakhisizwe	44.4	59.2	55.0	0.725	74.5	2.47	121	169	217	171
EC	Ikwezi	44.5	59.3	51.2	0.657	25.9	2.47	122	146	58	51
EC	Inxuba Yethemba	44.5	59.3	38.1	0.695	15.0	2.47	123	80	148	5
EC	Maletswai	45.4	60.5	39.7	0.693	29.7	2.52	124	94	140	72
MP	Govan Mbeki	43.6	60.8	35.1	0.689	23.0	2.54	125	56	125	37
EC	Intsika Yethu	45.8	61.0	57.4	0.678	93.9	2.54	126	187	97	224
EC	Mbhashe	46.2	61.5	62.5	0.683	94.9	2.57	127	208	109	230
KZ	uMngeni	45.0	61.5	28.8	0.690	28.3	2.57	128	29	127	67
MP	Umjindi	44.4	61.9	30.7	0.644	38.8	2.58	129	35	38	111
MP	Victor Khanye	44.4	61.9	39.6	0.678	30.9	2.58	130	92	95	82
KZ	Umdoni	45.3	61.9	38.7	0.693	54.3	2.58	131	85	138	139
EC	Ndlambe	46.7	62.2	41.7	0.708	33.9	2.60	132	108	183	90
KZ	Mandeni	45.7	62.5	46.1	0.643	69.8	2.61	133	125	36	161
FS	Moqhaka	44.9	63.6	37.7	0.675	18.6	2.65	134	77	90	17
KZ	KwaDukuza	46.5	63.6	33.9	0.683	54.6	2.65	135	46	109	140
KZ	uMhlatuze	46.6	63.7	37.9	0.684	36.6	2.66	136	79	112	99
NW	Ramotshere Moiloa	47.1	64.1	50.5	0.681	67.0	2.68	137	142	103	155
EC	Umzimvubu	48.3	64.2	61.1	0.703	91.6	2.68	138	200	166	217
EC	Tsolwana	48.4	64.5	51.8	0.649	68.7	2.69	139	151	48	159
MP	Emakhazeni	46.4	64.6	35.0	0.645	33.1	2.70	140	55	40	88
KZ	Greater Kokstad	47.3	64.7	38.7	0.693	37.4	2.70	141	86	135	105
KZ	Hibiscus Coast	47.5	65.0	38.2	0.693	55.7	2.71	142	82	140	143
NW	City of Matlosana	47.9	65.2	41.2	0.678	18.8	2.72	143	106	99	18
EC	Nyandeni	49.6	66.0	69.3	0.674	94.8	2.75	144	229	88	229
NC	Joe Morolong	51.0	66.1	61.6	0.748	86.8	2.76	145	205	229	204
EC	Mhlontlo	50.1	66.6	63.1	0.655	93.7	2.78	146	210	55	222
EC	Emalahleni	50.7	67.4	57.3	0.650	85.6	2.81	147	185	49	201
FS	Matjhabeng	47.9	67.8	42.0	0.667	22.0	2.83	148	109	77	30
KZ	Umhlabuyalingana	49.8	68.1	67.9	0.721	91.6	2.84	149	225	210	216
MP	Nkomazi	49.0	68.3	55.9	0.696	67.4	2.85	150	175	149	156

Province	Municipality	IMR	U5MR	PHCR	GI	LS PHCR	SMR	Ranks			
								U5M	PV	II	LSP
EC	Senqu	52.6	70.0	56.1	0.660	76.1	2.92	151	178	63	177
FS	Mafube	50.1	71.0	47.7	0.688	27.9	2.96	152	133	124	63
FS	Ngwathe	50.4	71.4	45.2	0.683	22.8	2.98	153	123	107	36
FS	Kopanong	50.8	71.9	38.9	0.716	24.4	3.00	154	88	198	45
FS	Mantsopa	50.8	72.0	42.2	0.714	32.4	3.00	155	111	197	87
EC	Gariiep	54.2	72.1	38.9	0.694	30.4	3.01	156	87	142	78
FS	Naledi	51.0	72.2	48.8	0.710	30.9	3.01	157	136	185	83
MP	Dipaleseng	51.9	72.3	39.9	0.635	32.0	3.02	158	96	23	86
KZ	Ubuhlebezwe	55.1	72.8	59.7	0.684	86.7	3.04	159	193	113	203
EC	Inkwanca	53.3	73.3	46.9	0.670	24.4	3.06	160	128	80	44
KZ	Ndwedwe	53.7	73.4	60.3	0.625	91.0	3.06	161	196	14	215
EC	Elundini	55.3	73.5	59.2	0.710	88.8	3.07	162	190	187	211
KZ	Endumeni	54.1	74.0	39.0	0.661	27.3	3.09	163	89	65	61
FS	Masilonyana	52.6	74.4	47.5	0.659	30.2	3.10	164	132	61	74
EC	Engcobo	56.0	74.5	63.4	0.713	94.2	3.11	165	211	195	227
FS	Dihlabeng	52.7	74.5	34.5	0.700	27.1	3.11	166	49	162	58
NW	Kgetlengrivier	54.9	74.7	42.2	0.705	45.6	3.11	167	112	173	124
KZ	Umzumbe	54.8	74.9	64.5	0.636	92.6	3.12	168	217	27	220
KZ	uMlalazi	54.9	74.9	54.7	0.696	79.3	3.13	169	168	151	188
EC	Ngquza Hill	56.6	75.3	69.5	0.734	94.5	3.14	170	230	226	228
NW	Ditsobotla	55.5	75.4	47.4	0.722	54.9	3.15	171	131	211	141
KZ	Mtubatuba	55.2	75.5	56.1	0.726	73.1	3.15	172	177	218	168
KZ	Impendle	55.5	75.8	59.3	0.647	87.0	3.16	173	191	41	206
NW	Ventersdorp	55.8	75.9	52.5	0.694	58.4	3.16	174	155	146	145
KZ	Richmond	55.8	76.2	46.7	0.690	78.1	3.18	175	127	128	187
EC	Matatiele	57.5	76.4	58.8	0.672	87.0	3.19	176	188	83	205
KZ	Ingwe	56.0	76.5	61.2	0.727	93.3	3.19	177	202	219	221
MP	Albert Luthuli	55.1	76.6	55.4	0.720	65.9	3.20	178	174	207	152
KZ	Umzimkhulu	56.1	76.7	64.4	0.673	91.6	3.20	179	216	87	218
FS	Mohokare	54.8	77.5	46.5	0.720	37.6	3.23	180	126	205	107
KZ	Mkhambathini	56.8	77.6	44.2	0.632	85.0	3.24	181	120	20	200
FS	Letsemeng	55.0	77.7	40.2	0.667	30.7	3.24	182	100	76	80
MP	Msukaligwa	56.1	78.1	36.3	0.686	37.7	3.26	183	68	118	108
EC	Ntabankulu	58.9	78.3	69.8	0.674	95.4	3.26	184	231	89	233
FS	Maluti a Phofung	55.4	78.4	56.1	0.683	53.5	3.27	185	177	106	137
KZ	Kwa Sani	57.6	78.7	23.5	0.657	52.0	3.28	186	8	59	133
KZ	Ezingoleni	57.6	78.7	60.0	0.648	90.8	3.28	187	194	44	214
KZ	Mfolozi	57.7	78.8	57.4	0.648	75.5	3.29	188	186	46	174
FS	Setsoto	56.1	79.4	50.2	0.704	40.5	3.31	189	140	169	115
MP	Lekwa	57.2	79.6	35.4	0.677	22.5	3.32	190	57	94	34
FS	Nala	56.7	80.2	51.3	0.684	30.2	3.35	191	147	110	75
EC	Port St Johns	60.5	80.3	72.0	0.730	96.5	3.35	192	233	222	234
NW	Naledi	59.2	80.4	39.9	0.693	37.0	3.35	193	97	140	100
NW	Greater Taung	59.2	80.4	60.9	0.687	82.5	3.36	194	199	119	192
NW	Lekwa-Teemane	59.6	81.0	40.2	0.706	28.6	3.38	195	99	180	69
KZ	Vulamehlo	59.7	81.5	63.1	0.620	94.0	3.40	196	209	11	225
KZ	Emnambithi/Ladysmith	59.7	81.5	48.4	0.700	43.8	3.40	197	134	161	121
KZ	Mpofana	59.8	81.6	37.4	0.668	45.2	3.40	198	75	78	122
KZ	Newcastle	60.0	81.9	51.7	0.724	30.5	3.42	199	150	215	79
KZ	uMuziwabantu	60.1	82.0	61.2	0.678	87.3	3.42	200	203	97	207

Province	Municipality	IMR	U5MR	PHCR	GI	LS PHCR	SMR	Ranks			
								U5M	PV	II	LSP
KZ	Maphumulo	60.1	82.0	66.2	0.688	94.2	3.42	201	221	121	226
EC	Mbizana	61.9	82.2	71.5	0.711	95.3	3.43	202	232	190	232
KZ	Hlabisa	60.3	82.3	63.8	0.724	87.9	3.43	203	213	214	210
KZ	uMshwathi	60.4	82.4	42.1	0.647	75.3	3.44	204	110	43	173
FS	Tswelopele	58.7	83.0	50.2	0.692	27.9	3.46	205	141	134	62
KZ	Ulundi	61.5	83.9	60.9	0.716	70.0	3.50	206	198	199	162
KZ	Jozini	61.8	84.3	66.5	0.784	84.0	3.52	207	222	234	194
FS	Nketoana	60.2	85.1	41.3	0.722	36.2	3.55	208	107	212	98
KZ	Dannhauser	63.0	85.9	64.2	0.625	77.0	3.58	209	215	15	183
KZ	Imbabazane	63.8	87.0	68.1	0.638	93.8	3.63	210	226	30	223
KZ	Nkandla	64.1	87.4	63.7	0.705	90.0	3.65	211	212	174	213
KZ	Umvoti	64.5	87.9	49.3	0.672	76.0	3.67	212	137	83	176
KZ	Umtshezi	64.6	88.1	52.4	0.751	49.8	3.68	213	153	230	130
KZ	Ntambanana	64.6	88.1	67.0	0.692	92.5	3.68	214	224	133	219
KZ	The Big 5 False Bay	65.1	88.7	56.5	0.775	72.5	3.70	215	184	233	167
FS	Phumelela	63.6	89.8	44.9	0.666	42.4	3.75	216	122	72	118
NW	Tswaing	67.5	91.6	56.3	0.706	65.1	3.82	217	182	178	151
NW	Kagisano/Molopo	68.8	91.6	59.2	0.739	82.9	3.82	218	189	227	193
NW	Mamusa	68.3	92.6	53.7	0.716	41.6	3.86	219	162	200	117
FS	Tokologo	64.9	93.3	42.6	0.713	56.9	3.89	220	114	196	144
KZ	Indaka	69.6	94.8	72.1	0.635	76.3	3.96	221	234	22	179
KZ	Nongoma	69.9	95.2	66.7	0.706	87.6	3.97	222	223	179	209
KZ	Mthonjaneni	70.0	95.3	51.0	0.676	76.6	3.98	223	143	92	181
NW	Maquassi Hills	72.7	98.4	53.7	0.725	35.8	4.11	224	161	216	93
NW	Ratlou	73.1	99.1	61.2	0.698	89.1	4.13	225	201	156	212
MP	Pixley Ka Seme	72.0	99.9	52.6	0.751	40.8	4.17	226	157	231	116
MP	Mkhondo	72.5	100.5	53.9	0.721	61.4	4.19	227	166	210	149
KZ	Nqutu	73.9	100.6	68.4	0.656	84.4	4.20	228	227	57	197
KZ	Okhahlamba	75.0	102.1	66.0	0.712	85.0	4.26	229	220	194	199
KZ	Abaqulusi	75.9	103.3	53.7	0.729	52.8	4.31	230	163	221	135
KZ	Emadlangeni	76.1	103.5	51.1	0.691	67.8	4.32	231	144	130	158
KZ	eDumbe	77.8	105.8	60.6	0.686	73.6	4.41	232	197	117	169
KZ	Msinga	79.4	107.9	68.7	0.699	95.1	4.50	233	228	160	231
KZ	uPhongolo	80.2	109.1	55.3	0.705	74.2	4.55	234	171	175	170

* Notations - IMR: Infant mortality rate per thousand; U5MR: U5M rate per thousand; PHCR: % income poverty head-count ratio; GI: Gini index; LSPHCR: living standard poverty head-count ratio; SMR: standardized mortality rate; U5M: U5M; IP: income poverty; II: income inequality; LSP: living standard poverty.