An Investigation of District Spatial Variations of Childhood Diarrhoea and Fever Morbidity in Malawi

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Abstract

Although diarrhoea and malaria are among the leading causes of child mortality and morbidity in Sub-Saharan Africa, few detailed studies have examined the patterns and determinants of these ailments in the most affected communities. In this paper, we investigate the spatial clustering of observed diarrhoea and fever morbidity in Malawi using the 2000 Malawi Demographic and Health survey. Clustering was achieved by mapping the residual district spatial effects using a Bayesian geo-additive logistic model that simultaneously control for spatial dependence in the data and potential nonlinear effects of covariates. For both ailments, we were able to identify a distinct district pattern of childhood morbidity. The spatial patterns emphasise the role of remoteness as well as climatic and geographic factors on morbidity. The fixed effects show the importance of exclusively breastfeeding for diarrhoea and maternal education for both ailments. Diarrhoea and fever were both observed to show an interesting association with a child's age.

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Introduction

The success of any policy or health care intervention depends on a broader and accurate understanding of the socioeconomic, environmental and cultural factors that determine the occurrence of disease and death. Until recently, available information on childhood morbidity was derived from clinics and hospital records. However, information obtained from hospitals represents only a small proportion of all cases, since many other cases do not seek medical attention (Black, 1984). Thus, the hospital records may not be appropriate for estimating the incidence of diarrhoea for program developments (Woldemicael, 2001).

Policy-makers and researchers often want to know the distribution of a disease incidence by geographical region, or association with environmental factors (Thomson et al., 1996; Diggle et al., 2002). In this regard, mapping risk variations in child morbidity is an invaluable tool. Further, the mapping of variation in risk of childhood morbidity can help improve the targeting of scarce resources for public health interventions. This paper is based on a study of the spatial distribution of childhood diarrhoea and fever in Malawi. The study applied Bayesian statistical and geo-statistical techniques to the 2000 DHS data of Malawi with location (district) attributes and other information to answer specific questions. The DHS in Malawi conducted in 2000 is a valuable resourse for population-based morbidity data, although we recognize its limitation, like other DHSs elsewhere, in that it relates only to reported child morbidity during the last two weeks before the survey.

To gain an understanding of the geographic variation or patterns based on the observed morbidity prevalence, a Bayesian hierarchical model was fitted, with the inclusion of spatial (district) and nonlinear metrical (mother's and child's age) covariates. Of particular interest in this study, was whether a significant geographic variation in childhood diarrhoea and fever existed; and if so, what potential risk factors could explain such variation?

Background of study area

Malawi is an African country in the south-east region of the continent with a population of about 10 million and a population growth rate of about 2.5 percent per year (WHO, 1998). With a gross national product (GNP) of US$ 170 per person per year, Malawi is among the 20 least economically developed countries in the world (WHO, 1998). Agriculture accounts for over a third of the GNP, about 90 percent of export earnings and approximately three-quarters of total employment (UNICEF and Government of Malawi, 1993). Despite economical difficulties Malawi has invested a lot in health. According to UNICEF statistics there is a reasonably good network of health facilities in Malawi (the median distance from home to the nearest facility is 5 km). For 90 percent of births, mothers have received antenatal care from a trained health worker, and 86 percent of children aged 12-23 months possess a health card indicating a high under-five clinic attendance and about 90 percent of children are reported to have been vaccinated against the most common illnesses. However, improvements in health indicators have been smaller than expected. Currently, the maternal mortality rate is estimated at 1120-1180 / 100 000 live births. Life expectancy at birth is only 44 years, largely because of high mortality amongst the children. For every 1000 live births, about 135 die before the age of 1 year and 200 before the age of 5 years (National Statistical Office [Malawi] and ORC Macro. (2001). Findings of the 2000 MDHS point to important changes in Malawi's health and demographic profile. Mortality of children under age 5 has declined since the early 1990s. During the period 1988-1992, the under-five mortality rate was 234 deaths per 1,000 live births, compared with 189 per 1,000 between 1996-2000 (National Statistical Office [Malawi] and ORC Macro. (2001). Although this represents important progress, the rate of the downward trend is modest and childhood mortality remains at a very high level.

The census results also indicate that, there is geographic variation in the rates of infant and under-five mortality with highest mortality rates in the Southern regions followed by the Central regions and the least in the northern regions. Household socio-economic status is associated with child survival because it determines the amount of resources (such as food, good sanitation, and health care) that are available to infants (Millard, 1994). Measures of socio-economic status that are thought to be associated with infant heath include: maternal and paternal education; household wealth; household size; parental occupation; and rural or urban residence. Kandala and Madise (2003), who used the 1992 DHS data from Malawi and Zambia, in their study of childhood morbidity, found that the level of maternal education was highly significant in the two countries. They also found that childhood morbidity was lower among educated women, and that although this effect attenuated with the inclusion of other socio-economic factors in the models, maternal education remained significant.

Lower morbidity was also reported in households with large number of adult members (Kandala 2002; Kandala and Madise 2003). The impact of the household's size should, however, not be over-interpreted, since to some extent it directly mirrors infant mortality. For instance, a household with high mortality risk will remain small. In contrast, a household's size might also reflect its wealth, as a rich household will attract occupants. Again, in a large household, a child might benefit from the help of several adults. Large households may benefit from scale economies in time for child care as well as in expenditures. Alternatively, they may have become better at raising children through accumulated experience (Christiansen and Alderman, 2001).

Child-level demographic factors such as birth order, the length of preceding birth interval, and the survival status of the preceding child have been shown to be strongly associated with infant mortality and health in Africa as well as Asia (Cleland and Sathar, 1984; Koenig et al., 1990 ; Madise and Diamond, 1995; Whitworth and Stephenson, 2002; Kandala, 2002; Kandala and Madise, 2003). First and higher order births, those born after birth intervals of less than two years, and those whose previous sibling have died appear to have high risks of morbidity and of dying in infancy. Some researchers have documented evidence of a U-shape pattern in the association between maternal age and infant mortality and morbidity, with teenage and older mothers having elevated risk of child loss (Geronimus and Kerenman, 1993; Bicego and Ahmad, 1996; Manda, 1998; Kandala, 2002; Kandala and Madise, 2003).

Sex differentials in infant health and mortality have been observed universally. In the majority of the world regions, girls have lower mortality, at least for the first few months of life (Sastry, 1997; Curtis and Steele, 1996; Kandala, 2002). Exceptions have been noted in some Asian countries. In India, girls are more than 30 per cent likely to die before their fifth birthday than boys and this is thought to be the result of son preference, which is manifest in lower spending on health for girls and higher prevalence of immunization among boys (Timaeus et al., 1998; Claeson et al., 2000).

Historically, variations in incidence and prevalence of diarrhoea and fever have been related to socio-economic factors and neglected temporal and geographical gradients and other variations in risk, in order to generate hypotheses towards the causation of disease. In this paper, we take advantage of advances in geographic information systems (GIS) and how the technology provides opportunities to study associations between environmental exposure and the spatial distribution of diseases. Jacquez (2000) discusses how GIS can be used to monitor disease outcomes, identify health risks, and design and implement intervention plans. The epidemiological approach has not yielded all the answers, but it holds great merit and much potential to further contribute to the knowledge of disease etiology. This study enhances our understanding of diarrhoea and fever prevalence in a dimension that could not have been possible prior to the availability of GIS. The results will help us making further decisions in planning for diarrhoea and fever research.

Data and Methods

Individual data record was constructed for 10185 children for diarrhoea and 10180 children for fever. Each record consisted of morbidity information and a list of covariates. Geo-additive logistic models were used (on the probability of a child having diarrhoea and fever during the reference period) to determine the socio-economic and demographic variables that are associated with the ailments while simultaneously controlling for spatial dependence in the data and possible nonlinear effects of covariates. The DHS data have been collected hierarchically at the family and community levels which are inter-related. Standard analysis of the fixed effects covariates for child morbidity neglects this correlation structure and dependence in the data. This neglect leads to underestimation of standard errors of the fixed effects that inflates the apparent significance of the estimates (Bolstad and Manda, 2001). Our analysis includes this correlation structure and account for the dependence of community in the model. The model also permitted borrowing strength from neighbouring areas to obtain estimates for areas that may, on their own, have inadequate sample sizes. This gives more reliable estimates of the fixed effect standard error.

Geo-additive regression

The modelling framework follows the approach by Kandala and others (2001). Consider regression situations, where observations (y_i; x_i; w_i); i = 1; : : : ; n, on a metrical response y, a vector x = (x_i; : : : ; x_p) of metrical covariates, times scales or spatial covariates and a vector w=(w_1;… w_r) of further covariates, in which categorical covariates, are often given. The generalized additive modelling framework (Hastie and Tibshirani, 1990) assumes that, given x_i and w_i, the distribution of the response y_i belongs to an exponential family, with mean $\mu_i = (y_i | x_i , w_i)$ linked to an additive semiparametric predictor $\mu_i = h(\eta_i)$, $\eta_i = f_1(x_{i1}) + ... + f_p(x_{ip}) + f_{spat}(s_i) + w'_i \gamma$ *(1)*; where h is a known response function, and $f_1,...,f_p$ are nonlinear smooth effects of the metrical covariates and f_{spat} is the effect of district $s_i \in \{1,...,S\}$ where mother *i* lives. Models with a predictor that contains a spatial effect are also called geo-additive models (see Kammann and Wand, 2003).

The response variable in this application is defined as $Y_i = 1$ if child i had diarrhoea or fever during the reference period t, and $Y_i = 0$ otherwise . We analyzed a probit model with dynamic and spatial effects $Pr(y_i=1 | x_{it}^*) = \Phi (\eta_{it})$ for the probability of having diarrhoea or fever at month t (i.e. we model the conditional probability of a child having diarrhoea or fever) given child's age in months, the district where the child lives, and X, with predictor (1). The Deviance Information Criteria (DIC) (Spiegelhalter et. al., 2002) was used for model fit and comparison. The non-linear effects in (1) of f_i, f_2, etc.. were modeled by cubic penalized splines (P-splines) with second order random walk penalty. For the structured spatial effect (fstr(s)) we experimented with different prior assumptions (two-dimensional P-splines or Gaussian random field (GRF) priors based on radial basis functions (Kammann and Wand, 2003)).

We estimated models where either a structured or an unstructured effect was included as well as a model where both effects were included. Based on these results, Markov random field (MRF) priors were used for fstr(s). The analysis was carried out using BayesX-version 0.9 (Brezger et al., 2003), a software for Bayesian inference based on Markov Chain Monte Carlo simulation techniques. We investigated the sensibility to the choice of different priors for the nonlinear effects (second random walk: RW2) and the choice of the hyper-parameter values a and b. We noticed that results for this application are not sensitive to the choice of the priors and hyper-parameter.

Spatially correlated effect of geographical location (districts)

We have previously reported evidence of spatial clustering of childhood mortality, under-nutrition and mordibity in Malawi and Zambia. Analysing the 1992 DHS data in the two countries (Kandala et al. 2001; Kandala, 2002; Kandala and Madise, 2003), we found a significant dependence of risks of cases residing in neighbouring districts. The analytical method used, originally proposed by Fahrmeir and Lang, lead directly to a visual representation of the clusters and make direct use of population-based data.

Fahrmeir and Lang have described a method for analysing spatial data (Fahrmeir and Lang, 2001) which is based on the idea that the effect of spatial covariates on a dependent variable can be modelled via Markov random field priors. The main purpose in this context is to provide the neighbourhood structure of the map and to compute weights associated with this neighbourhood structure via a prior specification. Such a prior is called a Gaussian intrinsic autoregression, see Besag, York and Mollie (1991) and Besag and Kooperberg (1995). Weights are based on the common boundary length of neighboring sites, or on the distance of the centroids of two sites. This is a common way in spatial statistics to introduce a spatially correlated effect by assuming that neighbouring sites are more alike than two arbitrary sites. For geographical data one usually assumes that two sites are neighbours if they share a common boundary. Thus the (conditional) mean of the spatial effect of a district is an unweighted average of function evaluations of neighbouring sites. Additional geographic information for the observations in the DHS data set is available. Here, the district where the mother of a child lives is given and may be used as an indicator for regional differences in the health status of children. A reasonable predictor for such data is given by models with a predictor that contains a spatial effect. The findings are robust with respect to the specification of the prior distribution.

Results

Preliminary results

Visual inspection of the maps of the observed diarrhoea and fever rates by regions and districts (Appendix A1 and A2) suggest that regional classification mask/conceal district variations. Table 1 shows that overall, the highest incidence of both diarrhoea and fever were observed in the Central region, followed by the South region. Although the Nothern region reported the lowest overall incidence of both fever and diarrhoea, it had the district with the highest fever incidence of 63 percent (Nkhata Bay), further confirming that regional classifications do mask important geographic variations.

(TABLE 1 ABOUT HERE)

The geographical variation was apparent for the district maps for the two morbidity conditions, but from the region maps it was not apparent. The hypothesis was investigated for both levels separately using Geo-additive logistic models. Incidence rates of disease for each household were related to the distance of the household from the nearest next district and region. The region variables were categorized into dummies. There was a clear spatial pattern as observed in the distribution of diarrhoea and fever rates at the distric level (Table1). For example, the aggregate regional levels of diarrhoea (Table 1 or Appendix A1) in the central and northern regions of Malawi mask large districts variabilty. The geographical information given in Table 1 (or Appendix A1) is highly aggregated and conceals local and district specific effects. On the other hand, diarrhoea rates stratified by districts in Table 1 (or Appendix A2) strongly depend on the sample size and may be rather unstable. We need some smoothing techniques to stabilize the observed rates in the sample as shown in the second figure of Apendix A1 and A2.

The bivariate distributions of fixed effects included in the analysis by the outcome variables is given in Appendix B, also showing significance based on Chi-square tests.

Multivariate results

Diarrhoea

The results for diarrhoea presented in Figure 1 suggest considerable spatial auto-correlation in the underlying posterior means. The left panel of Figure 1 reveals high risk clusters mainly in the central districts of Malawi.

(FIGURE 1 ABOUT HERE)

The result of the non-linear effect of child's age (Figure 2) suggests that there are continuous worsening of the diarrhoea morbidity up to about 12 months of age. Shown are the posterior means together with the 95% credible intervals. For comparison a regression line obtained by a linear fit is added to the plot. This deterioration set in right after birth and continues, more or less linearly, until 12 months and decreases thereafter.

(FIGURE 2 ABOUT HERE)

We find the influence of the mother's age (Figure 3) on diarrhoea to be non-linear. There is a general tendency for diarrhoea morbidity to decline with increasing maternal age, but the patterns are inconclusive. In particular, the interpretation of results at the end of the observation (wide credible interval) is less reliable due to few observations.

(FIGURE 3 ABOUT HERE)

With regard to the fixed parameters, Table 2 shows that the prevalence of diarrhoea in Malawi is lower among infants who are exclusively breastfed (but higher for those who are mixed fed), whose mothers are well educated, with a father having up to primary education (posterior mean either strictly negative or positive indicating respectively low risk and higher risk of diarrhoea). In general, lower parental education is associated with higher risk of diarrhoea.

(TABLE 2 ABOUT HERE)

We did not find a statistically significant association between diarrhoea and child's sex, preceeding birth interval, multiple birth (twin or singleton birth), the antenatal visits during pregnancy, birth order of the child, father's education, vaccination status, child's place of delivery (whether hospital or home), mother's marital status, child's place of residence, household size, the economic status of the household and child's size at birth.

Fever

The right panel of Figure 4 reveals a strong north-south gradient in the district spatial effects in Malawi with a fairly sharp dividing line that runs through the centre (the capital city Lilongwe) of the country. Over and above the impact of the fixed effects, there appear to be negative influences on fever in the north and central-west that are spread and affect most of the districts there. The right panel of Figure 4 reveals also lower risk of fever in the capital Lilogwe in spite of being surrounded by some of the high risk districts.

(FIGURE 4 ABOUT HERE)

The result of the non-linear effect of child's age (Figure 5) suggests that there are continuous worsening of the child morbidity up to about 8 months of age. Figure 6 shows the influence of the mother's age on fever to be non-lnear, but with a general tendency of declining with age. The results for the youngest and oldest maternal ages are less reliable as shown by the wide intervals.

(FIGURE 5 & FIGURE 6 ABOUT HERE)

The fixed parameters show that the prevalence of fever (Table 3) is higher among infants of small size at birth and low parental education (imcomplete primary education). Children living in urban areas are associated with lower risk of fever. The variables child's sex, family size, mother's marital status, the antenatal visit during pregnancy, the type of breastfeeding , preceeding birth interval, multiple birth (twin or singleton birth), birth order of the child, vaccination status, child's place of delivery (whether hospital or home), the economic status of the household and child's size at birth were not statistically significant.

(TABLE 3 ABOUT HERE)

Discussions and Conclusions

Spatial residuals of the geographical location (districts: Figures 1 and 4)

This study has shown significant district-specific geographical variation in childhood diarrhoea and fever in Malawi. The posterior mean estimates of the residual smooth spatial district effects (black coloured=high risk morbidity, shades of grey coloured=low risk morbidity) are shown in the left panel of maps of Figures 1 and 4. In addition, posteriori probability maps (right panel of Figure 1 and 4) indicate significance of the spatial effects (white/black colors = significantly negative/positive effect on diarrhoea, grey color = non significant). Note that the residual spatial effects are centered about zero, i.e. the average over all districts is zero, while the overall level is estimated through the intercept term in (1).

Over and above the impact of the fixed effects, there appear to be widespread negative influences on child morbidity in the central districts. The central districts are at a lower altitude than other parts of the country. It is likely that climatic factors and associated diseases are responsible for this pronounced district pattern. Food insecurity associated with drought and flooding in the shire valley, which is a result of hazardous effect of climate variation are among possible explanations for these negative effects. Furthermore, the central districts are among high density population areas and this environment tends to increase the child's exposure to disease.

For fever, it appears that children living in northern and central-west districts are the best off, with children living in the central-east and south being worst off. In general, children living in provincial capitals are significantly better-off than children in the rural areas.

The negative spatial effects on child morbidity in southern districts correspond to districts that are among densely populated areas in the province, therefore their share of disease spread may be one of the major factor of this negative impact on child morbidity.

From the analysis, it also appears that living in the capital cities such as Lilongwe is associated with significantly low prevalence of fever despite being surrounded by areas with negative district effects. Living in the capital is likely to provide access to health care that is superior in ways that have not been captured adequately in the fixed effects. The same is, however, not true for diarrhoea, where some urban agglomerations, such as Lilongwe, are associated with higher risk of diarrhoea. Possibly because of the high density of population associated with the phenomenon of slums in urban areas.

Nonlinear effects of mother's age and child's age

In Malawi, childhood diarrhoea and fever are associated with child's age and mother's age at birth of the child. Figures 2 and 5 shows the effect of child's age on diarrhoea and fever in Malawi and Figures 3 and 6 show the effect of mother's age on the two ailments. Shown are the posterior means together with 95 % credible intervals. For comparison a regression line obtained by a linear fit is added to the plot. While the effect of the variable"mother's age" is almost linear for both ailments, its effects on the variable"child's age" are clearly nonlinear. The linear model assumes a negative relationship between mother's age at child's birth and diarrhoea or fever and between the child's age and diarrhoea and fever. As we show in Figures 2, 3, 5 & 6, this glosses over important non-linearity in the effects. The data suggests deterioration in child diarrhoea that sets in right after birth and continues, more or less linearly, until 12 months of age. This immediate deterioration in child morbidity was not expected, as the literature commonly associates such deterioration with weaning at around 4-6 months. In a Kenyan study, children aged 1-2 years were the most vulnerable (Magadi, 1997). One reason for this unexpected finding could be that, according to the DHS surveys, most parents gave their children liquids other than breast-milk shortly after birth, a factor which might contribute to infections. This is due to the influence of poor quality nutrition that is replacing breast-milk as well as the onset of infectious diseases. These diseases are often related to unclean water and food which is replacing the breast milk, and the child no longer benefits from the mother's antibodies that are transmitted through the breast-milk (Stephenson, 1999). Initially, the worsening health status shows up as acute under-nutrition. But then childhood morbidity develops and worsens until about age 1. At that time, the body has developed its immune system to fight the impact of infectious diseases more effectively (WHO, 1995; Moradi and Klasen, 2000).

Mother’s age effect on child diarrhoea and fever show a general tendency for child morbidity to decline with increasing maternal age. Part of the explanation for the observed association of morbidity risk and younger mother’s age may be attributed to the tendency for young mothers to be socially and economically disadvantaged (World Bank, 1995), and the fact that younger mothers do not often use antenatal care services as much as older mothers (Magadi et.al., 2000). These results are indicative of general trends and may be of use to planners for targeting policy.

Fixed effects (Tables 2 and 3)

After controlling for the spatial dependence in the data, the fixed effects show the importance of parental education, breastfeeding, ethnicity, size of child, and rural-urban residence on child morbidity. The findings are generally as expected and consistent with the literature. Children of highly educated mothers or living in urban areas are at lower risk of fever than other children (Cleland and Sathar, 1984; Hobcraft et al., *1985;* Curtis and Steele, 1996*;* Kandala, 2002; Madise et .al., 2004*)*. The higher rural fever is possibly due to the fact that rural areas in Sub-Saharan African are under-developed and have less public service per capita compared with urban areas (Brockerhoff, 1993; Defo, 1996). As a result, living in rural areas provides no access to better bed net and health care and increases the risk of malaria or fever. After we control for child, households, and districts characteristics the residence location (rural versus urban) does not affect child diarrhoea. The urban- rural effect may be captured by the districts effects. Furthermore, the lack of corresponding urban advantage with respect to diarrhoea may be partly attributed to growing urban poverty in many parts of sub-Saharan Africa, which has been associated with poor sanitation in the densely populated slum settlements leading to increased incidence of diarrhoea among children of the urban poor (Magadi, 2003).

We have established in this analysis that diarrhoea and fever especially during the early months of life is sensitive to low levels of parental education. Similarly, in a study of the variation in African mortality, Blacker (1991), cites the much lower levels of female education in each country. Studies using WFS and DHS data have shown that about half of the education-mortality association is accounted for by the economic condition of the household (Cleland and Ginneken, 1988; Bicego and Boema, 1993).

We find that, for diarrhoea , maternal education rather than paternal education matters a lot in reducing diarrhoea risk, as where for fever both low maternal and parternal education do influence fever risk.

There are also some ethnic differences in terms of diarrhoea and fever risk where, for example children from the Sena ethnic group are more likely to have both diarrhoea and fever compared to other children. This suggests the need for in-depth studies in these communities to understand cultural child rearing practices that may put children at an increased risk of diarrhoea and fever.

It is important to point out that some of the factors observed to be significantly associated with incidence of both fever and diarrhoea in the bivariate analysis, such as antenatal care and delivery care, turned out not to be significnt in the multivariate analysis that simultaneously controlled for spatial effects as well as the effects of other covariates. It is possible that health care utilization is a reflection of accessibility of health care services and has been captured by the spatial effects in the multivariate analysis.

Policy implications

In conclusion, the study findings carry some important general pointers to policy directions. For instance, the age effect suggests the need to pay attention to child feeding practices, particularly during the first 6 months after birth. Second, the nonlinear influence of mother's age indicates that childcare promotion messages may be targeted particularly to younger parents. Of high significance are the district influences on child morbidity. In particular, they suggest that in Malawi, some urban agglomerations are associated with higher risk of diarrhoea . Also, more emphasis must be placed upon the role of remoteness as well as climatic and geographic factors on childhood morbidity. It would be of value to investigate left-out district-level factors such as environmental, socio-economic, cultural and human behavioural factors involved in the etiology of the disease. The North-Central divide in Malawi highlight the importance of such considerations.

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Table 1 Observed fever and diarrhoea rates by districts of Malawi (DHS, 2000).

Region/District	Fever rates(%)	No of children	Diarrhoea rates (%)	No of children
North	**36.4**	**1662**	**12.9**	**1666**
1 Chitipa	32.6	138	11.6	138
2 Karonga	37.2	732	12.8	734
3 Nkhata Bay	62.8	121	14.1	121
4 Rumphi	16.3	86	8.1	86
5 Mzimba	33.9	585	13.6	587
Central	**44.6**	**3767**	**19.3**	**3770**
10 Kasungu	45.0	611	22.2	613
11 Nkhota Kota	59.0	200	19.7	203
12 Ntchisi	48.7	154	18.8	154
13 Dowa	57.0	402	31.1	402
14 Salima	44.5	620	15.5	620
15 Lilongwe	36.1	718	15.7	718
16 Mchinji	38.8	271	17.3	271
17 Dedza	38	438	18.8	436
South	**41.7**	**4751**	**17.1**	**4749**
18 Ntcheu	50.4	353	17.3	353
20 Mangochi	42.2	512	19.8	511
21 Machinga	35.8	835	15.0	834
22 Zomba	37.4	645	17.2	645
23 Chiradzulu	40.7	162	16.1	162
24 Blantyre	41.0	591	17.8	591
25 Mwanza	43.7	103	12.6	103
26 Thyolo	35.2	590	13.6	589
27 Mulanje	47.0	845	16.9	846
28 Chikwawa	52.9	312	24.4	312
29 Nsanje	51.3	156	20.5	156
Total	41.7	10180	17.2	10185

Table 2 Posterior estimates of the fixed effect parameters for diarrhoea in Malawi

Variable	Mean	Std error	2.5% quantile	97.5% quantile
Constant	-1.37	0.16	-1.70	-1.04
Sex of child:				
Male	0.06	0.03	-0.01	0.12
Female[R]	0			
Preceding birth interval				
1st birth	-			
< 24 month [R]	0			
24+	0.06	0.05	-0.04	0.16
No breastfeeding [R]	0			
Exclusive breastfeeding	-0.46	0.12	-0.69	-0.22*
Mixed feeding	0.15	0.07	0.02	0.27*
Child a twin				
Singleton birth [R]	0			
Multiple birth	-0.19	0.14	-0.48	0.07
Child's size at birth				
Small size	-0.003	0.06	-0.11	0.11
Average size	-0.03	0.04	-0.11	0.05
Large size [R]	0			
Birth Order				
1rst birth	-0.003	0.06	-0.13	0.12
2nd & 3rd order [R]	0			
4th & 5th order	-0.04	0.06	-0.16	0.08
6+ order	0.02	0.08	-0.14	0.18
Mother's Education				
No educ. [R]	0			
Incompl. primary educ.	0.01	0.06	-0.10	0.12
Primary educ.	-0.04	0.08	-0.20	0.12
Secondary educ. and higher	-0.18	0.09	-0.35	-0.01*
Partner's Education				
No educ. [R]	0			
Incompl. primary educ.	-0.001	0.06	-0.11	0.10
Primary educ.	-0.0001	0.07	-0.14	0.13
Secondary educ. and higher	-0.06	0.08	-0.21	0.08
No partner	0.04	0.12	-0.18	0.27
Marital status				
Single mothers	0.06	0.09	-0.12	0.24
Married [R]	0			
Asset index				
1st quantile [R]	0			
2nd quantile	-0.01	0.05	-0.11	0.09
3rd quantile	0.02	0.05	-0.08	0.11
4th quantile	0.02	0.05	-0.08	0.12
Household size				
2 members [R]	0			
Between 3 & 5 members	0.01	0.04	-0.07	0.10
5+ members	-0.05	0.06	-0.16	0.06
Place of residence				
Urban	-0.09	0.06	-0.20	0.01
Rural [R]	0			

Table 2 (continued)

Variable	Mean	Std error	2.5% quantile	97.5% quantile
Antenatal visit				
No	0	0.10	-0.19	0.18
<3 visits	0.04	0.04	-0.03	0.11
3+ visits [R]	0			
Child's place of delivery				
Hospital	-0.05	0.04	-0.13	0.03
Home and others [R]	0			
Ethnicity in Malawi				
Chewa	0.15	0.13	-0.10	0.42
Tumbuka	-0.03	0.13	-0.27	0.23
Lomwe	0.22	0.14	-0.05	0.50
Tonga	0.12	0.18	-0.25	0.46
Yao	0.16	0.14	-0.12	0.44
Sena	0.34	0.17	0.03	0.68*
Nkonde	0.16	0.15	-0.13	0.45
Ngoni	0.14	0.14	-0.14	0.42
Amanganja/anyanja	0.30	0.15	0.02	0.62*
Other [R]	0			

[R] - reference category, * significant at 0.05 %

Table 3 Posterior estimates of the fixed effect parameters for fever in Malawi.

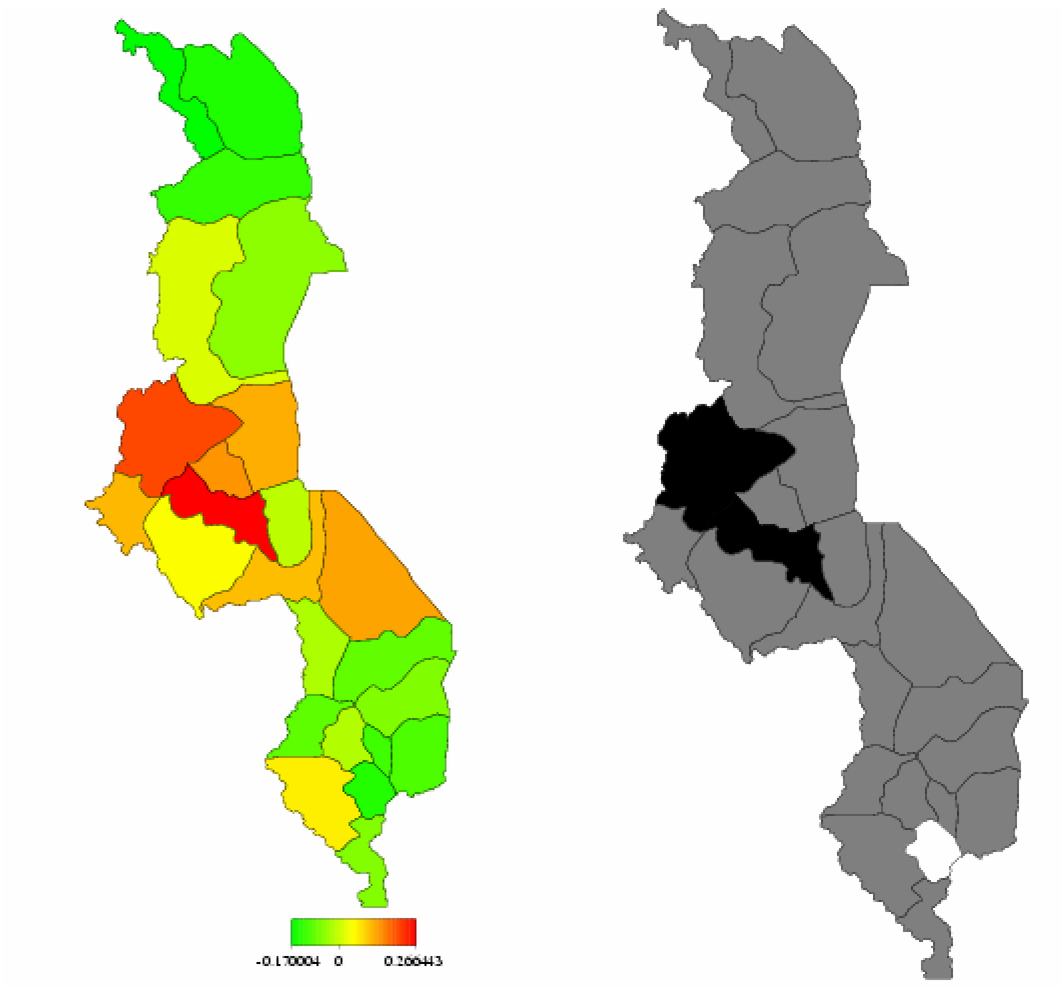
Variable	Mean	Std error	2.5% quantile	97.5% quantile
Constant	-0.43	0.14	-0.70	-0.16
Sex of child:				
Male	0.002	0.03	-0.06	0.06
Female [R]	0			
Preceding birth interval				
1st birth	-			
< 24 month [R]	0			
24+	-0.01	0.04	-0.10	0.07
No breastfeeding [R]	0			
Exclusive breastfeeding	-0.12	0.11	-0.33	0.08
Mixed feeding	0.09	0.06	-0.03	0.22
Child a twin				
Singleton birth				
Multiple birth				
Child's size at birth				
Small size	0.12	0.05	0.01	0.21*
Average size	-0.01	0.04	-0.08	0.06
Large size [R]	0			
Birth Order				
1rst birth	0.06	0.05	-0.04	0.16
2nd & 3rd order [R]	0			
4th & 5th order	0.06	0.05	-0.03	0.17
6+ order	0.12	0.07	-0.02	0.25
Mother's Education				
No educ. [R]	0			
Incompl. primary educ.	0.09	0.04	0.01	0.16*
Primary educ.	0.05	0.07	-0.08	0.18
Secondary educ. and higher	-0.12	0.07	-0.27	0.02
Partner's Education				
No educ. [R]	0			
Incompl. primary educ.	0.10	0.05	0.001	0.20*
Primary educ.	0.04	0.06	-0.08	0.16
Secondary educ. and higher	-0.03	0.07	-0.16	0.10
No partner	0.04	0.10	-0.16	0.23
Marital status				
Single mothers	0.06	0.08	-0.11	0.21
Married [R]	0			
Asset index				
1st quantile [R]	0			
2nd quantile	0.03	0.04	-0.05	0.12
3rd quantile	0.02	0.04	-0.07	0.10
4th quantile	0.04	0.04	-0.04	0.13
Household size				
2 members [R]	0			
Between 3 & 5 members	-0.04	0.04	-0.11	0.04
5+ members	0.04	0.05	-0.05	0.14
Place of residence				
Urban	-0.15	0.05	-0.24	-0.06*
Rural [R]	0			

Table 3 (continued).

Variable	Mean	Std error	2.5% quantile	97.5% quantile
Antenatal visit				
No	0.14	0.08	-0.03	0.31
<3 visits	-0.02	0.03	-0.08	0.05
3+ visits [R]	0	reference category		
Child's place of delivery				
Hospital	-0.05	0.03	-0.11	0.02
Home and others [R]	0	reference category		
Ethnicity in Malawi				
Chewa	0.22	0.12	-0.004	0.46
Tumbuka	0.08	0.12	-0.13	0.30
Lomwe	0.08	0.12	-0.16	0.31
Tonga	0.24	0.16	-0.07	0.56
Yao	-0.001	0.12	-0.24	0.26
Sena	0.40	0.15	0.10	0.67*
Nkonde	0.38	0.12	0.13	0.63*
Ngoni	0.07	0.12	-0.19	0.30
Amanganja/anyanja	0.11	0.13	-0.14	0.37
Other [R]	0	reference category		

[R] - reference category, * singificant at 0.05%

Figure 1 Residual spatial districts effects (left) and 95% posterior probability map (right) of diarrhoea in Malawi.



Black – significant positive effect

Grey – not significant

White – significant negative effect

Figure 2 Effects of child's age on diarrhoea in Malawi.

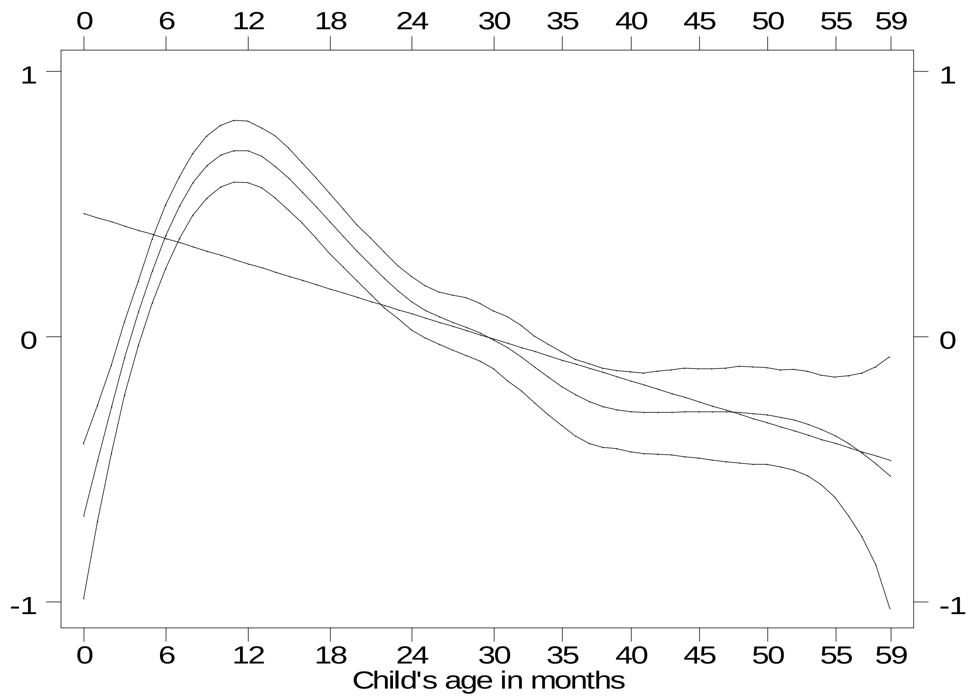


Figure 3 Effects of mother's age on diarrhoea in Malawi.

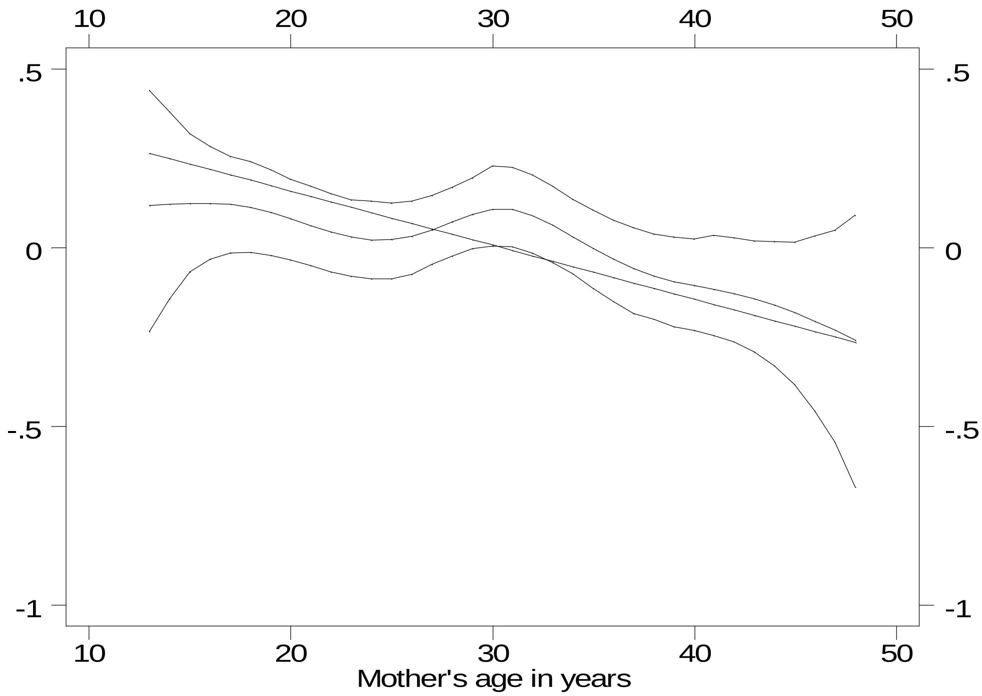
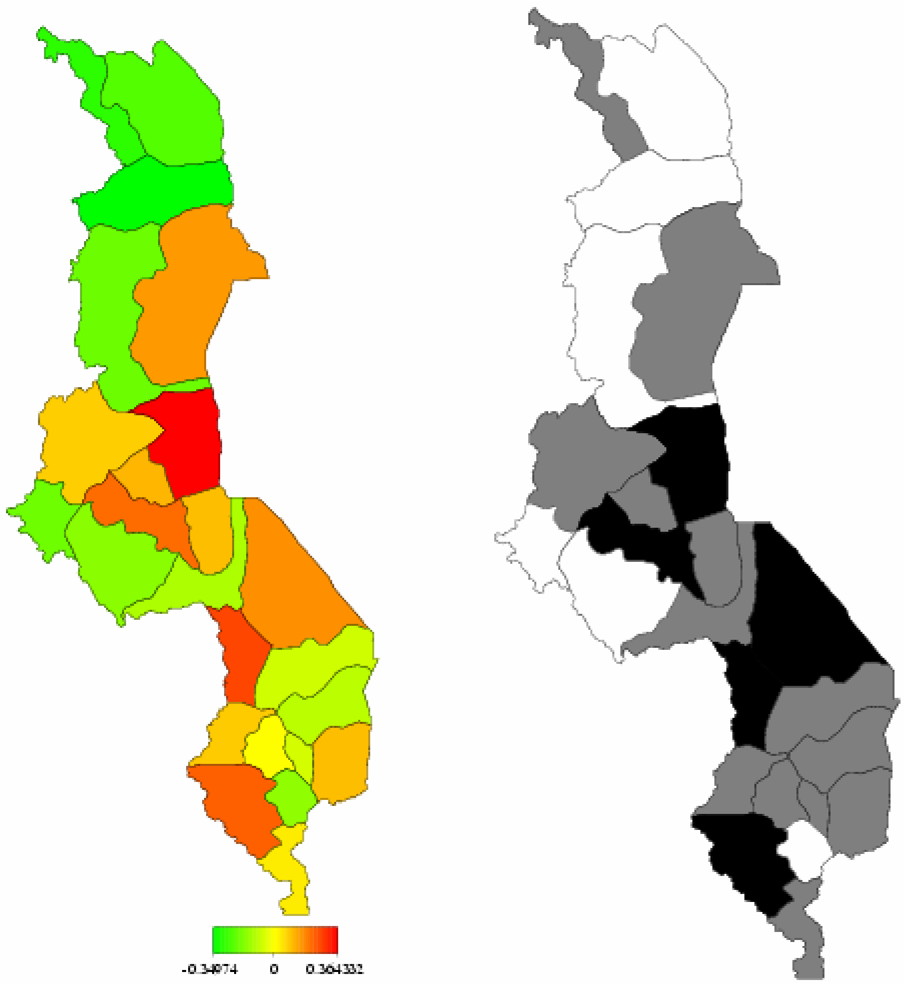


Figure 4 Residual spatial districts effects (left) and 95% posterior probability map (right) of fever in Malawi.



Black – significant positive effect

Grey – not significant

White – significant negative effect

Figure 5 Effects of child's age for fever in Malawi.

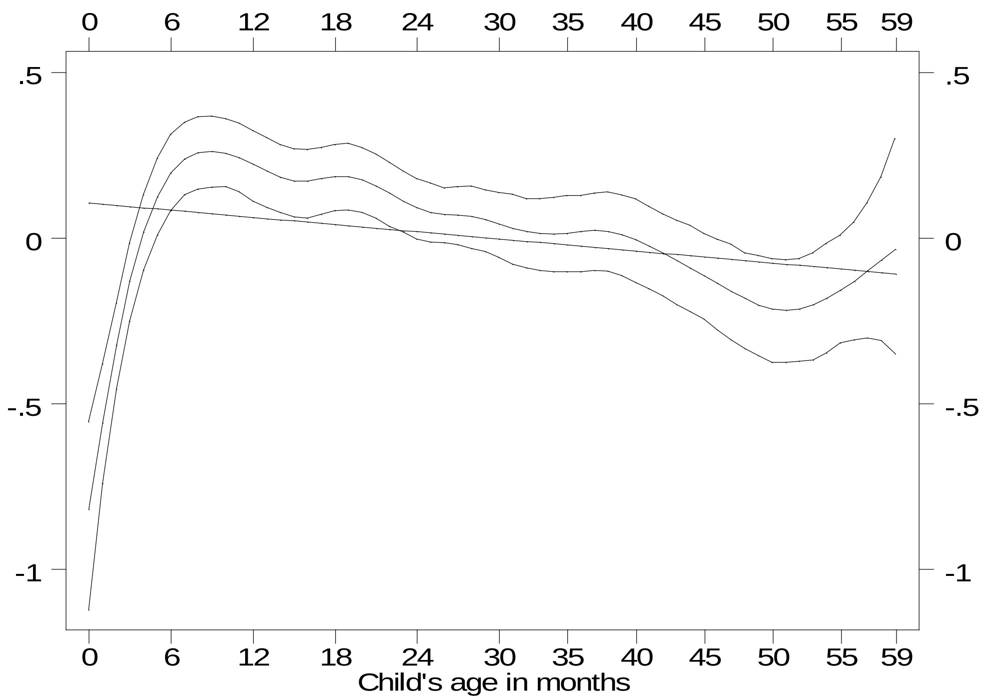
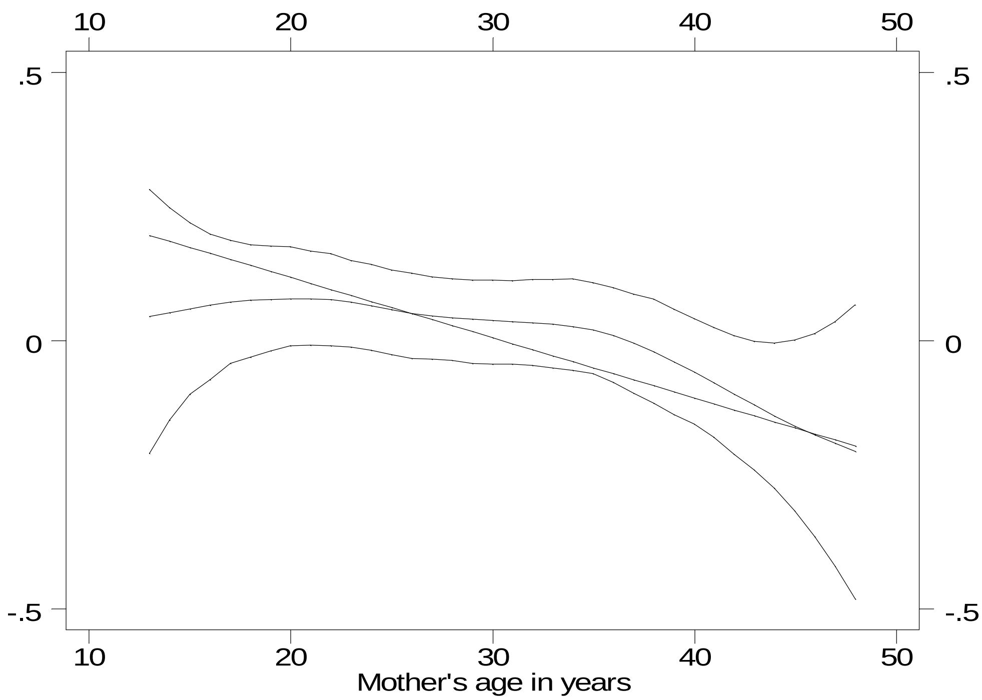
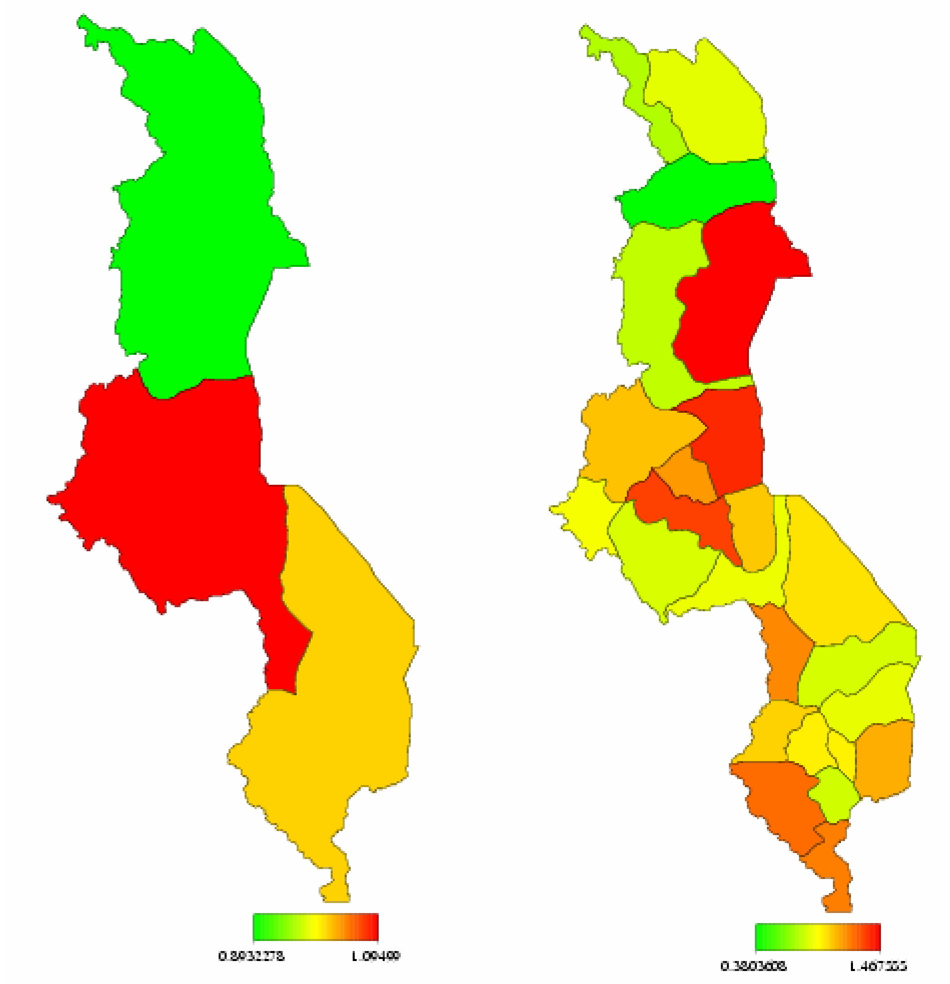


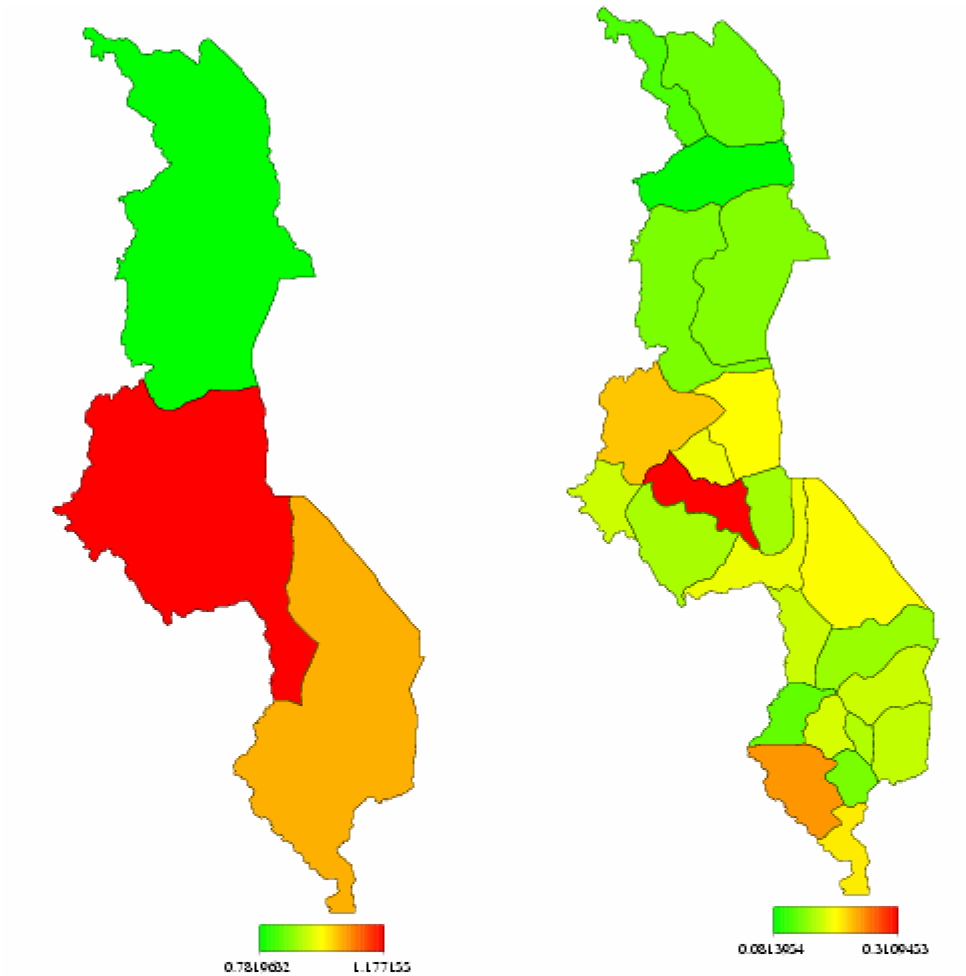
Figure 4 Effects of mother's age on fever in Malawi.



Appendix A1 Spatial distribution of observed diarrhoea by regions (left) and districts (rights) in Malawi .



Appendix A2 Spatial distribution of observed fever by regions (left) and districts (rights) in Malawi.



Appendix B Distribution of factors analyzed in child morbidity study in Malawi (DHS 20000)

Factor	Diarrhoea (% & N)		Fever (% & N)	
Individual characteristics				
Sex of child:				
Male	17.7	(5051)	42	(5050)
Female	16.7	(5134)	41.4	(5130)
Preceding birth interval				
1st birth	17.1	(2337)	40.3	(2335)
< 24 month	17.2	(1494)	41.9	(6353)
24+	17.3	(6354)	43.2	(1492)
Type of feeding	*		*	
No breastfeeding	10.5	(3001)	40.6	(2994)
Exclusive breastfeeding	6.1	(918)	26.3	(918)
Mixed feeding	22.1	(6266)	44.5	(6268)
Child a twin				
Singleton birth	17.3	(9850)	41.7	(9846)
Multiple birth	16.4	(335)	42.5	(334)
Child's size at birth			*	
Small size	17.4	(2598)	42.1	(2590)
Average size	18.5	(1543)	46.1	(1542)
Large size	16.9	(6001)	40.4	(6005)
Birth Order				
1rst birth	17.1	(2337)	40.3	(2335)
2nd & 3rd order	17.4	(3597)	40.7	(3596)
4th & 5th order	17.1	(2123)	42.1	(2121)
6+ order	17.3	(2128)	44.6	(2128)
Child's age in months	*		*	
<6	12.2	(1259)	28.8	(821)
6-11	34.2	(1203)	50.7	(657)
12-23	30.8	(2188)	56.4	(1212)
24-35	13.6	(1960)	52.6	(2139)
36+	7.0	(3575)	34.9	(5351)
Family characteristics				
Mother's age				
<20	18	(2107)	41.4	(2103)
20-24	16.5	(3294)	41	(3299)
25-29	17.1	(2185)	41.4	(2180)
30-34	19.2	(1340)	42.2	(1340)
35+	16.1	(1259)	44.2	(1258)
Mother's Education	*		*	
No educ.	17.8	(3043)	41.6	(3044)
Incompl. primary educ.	18.2	(5516)	44	(5513)
Primary educ.	14.0	(850)	36.6	(850)
Secondary educ. and higher	11.7	(776)	31.6	(773)
Partner's Education	*		*	
No educ.	18.1	(1422)	42.2	(1424)
Incompl. primary educ.	18.2	(4419)	44.4	(4416)
Primary educ.	17.1	(1696)	40.6	(1698)
Secondary educ. and higher	14.0	(1881)	35.3	(1878)
No partner	18.4	(767)	43.5	(764)
Marital status				
Single mothers	18.5	(1124)	41.4	(9059)
Married	17.1	(9061)	44.3	(1121)

Appendix B (continued)

Factor	Diarrhoea (% & N)		Fever (% & N)	
Asset index				
1st quantile	17.6	(2543)	412.1	(2544)
2nd quantile	17.0	(2537)	41.9	(2540)
3rd quantile	17.2	(2562)	41.3	(2554)
4th quantile	17.1	(2543)	41.5	(2542)
Under 5 children	*		*	
0 child	14.5	(152)	35.1	(148)
1 child	18.4	(3676)	45.6	(3671)
2 children	16.5	(4789)	40.2	(4792)
3+ children	17.1	(1568)	38.0	(1569)
Household size	*		*	
2 members	18.7	(3174)	42.5	(3172)
Between 3 & 5 members	16.8	(4892)	40.6	(4890)
5+ members	16.0	(2119)	43.2	(2118)
Community characteristics				
Place of residence	*		*	
Urban	14.1	(1855)	34.7	(1852)
Rural	17.9	(8330)	43.3	(8328)
Antenatal visit	*		*	
No	24.7	(255)	56.5	(255)
<3 visits	22	(2806)	47.5	(2804)
3+ visits	15.1	(7124)	38.9	(7121)
Child's place of delivery	*		*	
Hospital	15.8	(5803)	39.6	(5798)
Home and others	19.2	(4374)	44.6	(4374)
Ethnicity in Malawi	*		*	
Chewa	19.4	(2884)	46	(2881)
Tumbuka	13	(970)	35.2	(971)
Lomwe	16.6	(1834)	40.9	(1835)
Tonga	13.4	(1482)	45.6	(193)
Yao	17.3	(1482)	37.1	(1484)
Sena	22.8	(391)	53.7	(389)
Nkonde	14.9	(348)	42.8	(346)
Ngoni	16.8	(1107)	40.8	(1107)
Amanganja/anyanja	18.14	(601)	43.2	(602)
Other	12.5	(369)	31.9	(367)
Total	17.2	10185	41.7	10180

*** - Chi-square p<0.05**