Spatial Modelling of Initiation and Duration of Breastfeeding: Analysis of Breastfeeding Behaviour in Malawi – I

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Abstract

Background and aim: The benefits of breastfeeding for child health are well recognized. Appropriate health promotion strategies must recognize the interplay between neighbourhood factors and breastfeeding patterns that may lead to spatial clustering in the health outcome. We developed spatial models to study factors associated with breastfeeding behaviour in Malawi by introducing random effects that allowed for unobserved influences on breastfeeding behaviour.

Methods: Using the 2000 Malawi Demographic and Health Survey, we studied two breastfeeding behaviours: initiation of breastfeeding and duration of breastfeeding. We fitted an ordinal model to estimate the initiation of breastfeeding, and a discrete-time duration model to analyze the duration of breastfeeding. Each model incorporated two spatial random effects at the subdistrict level, one component to capture spatial similarities across neighbouring areas and the other to permit spatial heterogeneity.

Results: Findings indicate a breastfeeding initiation rate of 60% immediately after birth, and a further 37% within 1 hour of birth. Timing of breastfeeding initiation within 1 hour was associated with maternal education; ethnicity; wealth ranking; access to media such as newspapers, radio or TV; and health-

sector variables such as place of birth, prenatal care assistance and support at delivery. The mean duration time for breastfeeding was 17.6 months. Again, a range of socio-economic, demographic and health sector factors were identified as influential on breastfeeding duration. The mapped subdistrict-specific effects showed delayed initiation of breastfeeding in the north of the country, while early initiation was displayed in the south-eastern region. Shorter duration of breastfeeding was found in the southern region, whereas protracted breastfeeding was observed in the northern region.
Conclusion: This study offers important insight on the relative importance of both spatial effects and individual characteristics on breastfeeding behaviour in Malawi. This has potential implications for health policy planning and further research.

Introduction

The benefits of breastfeeding for child health are well recognized and undisputed (World Health Organisation 2000, 2001). For instance, breastfeeding offers infants a protective effect against infections such as gastro-intestinal and respiratory diseases (Howie et al. 1990; Oddy et al 2003), and in developing countries it is related to reduced infant mortality (Manda 1999). It is also associated with children's cognitive development and growth, and the benefits increase with duration of feeding (Anderson et al. 1999). Good breastfeeding behaviour is important to realize maximum gains for infants. The United Nations Children's Fund (UNICEF) and World Health Organisation (WHO) promote early initiation of breastfeeding, exclusive breastfeeding and sustained breastfeeding as some of the good practices necessary to achieve the full benefits of breastfeeding (WHO 2000, 2001). It is recommended that breastfeeding start immediately or within an hour of birth, that exclusive breastfeeding continue for 4–6 months and that breastfeeding be sustained for 2 or more years.

Breastfeeding is widely practised in Malawi (National Statistical Office 2000), yet many challenges compromise adherence to the recommended practice. Among them are morbidity, early introduction of complementary foods, insufficient milk, diseases such as HIV/AIDS, and socio-economic, traditional or cultural factors (Brennan et al. 2004). In 2006, UNICEF described Malawi's humanitarian crisis as a deadly combination of chronic poverty, bad weather conditions, bad harvest, a high prevalence of HIV/AIDS and an outbreak of cholera (UNICEF 2006). The humanitarian situation is particularly serious for the rural population. The factors that influence breastfeeding – the humanitarian situation, socio-economic inequalities, and unobserved community and family determinants – may cause geographically structured variations in breastfeeding behaviour. It is therefore worthwhile to quantify the influence of spatial factors on breastfeeding behaviour. Moreover, maternal sickness and lack of adequate food may lead to early weaning (WHO 2000, 2001). Indeed, patterns of breastfeeding initiation, total duration of breastfeeding and exclusive breastfeeding have not been investigated in detail, and at present, few studies have considered geographic variations and inequalities (Adebayo 2004).

In this study, we examined in detail the geographic variation in breastfeeding patterns in Malawi. We considered two indicators: (1) when was breastfeeding initiated (immediately, within 1 hour of birth or 24 hours of birth); and (2) duration of breastfeeding. Specifically, we applied spatial models that simultaneously estimated the effects of individual and location effects. Two other indicators, exclusive breastfeeding and intensity of breastfeeding, will be considered in accompanying papers (in preparation). Initiation and duration of breastfeeding have been studied together because in most countries these are highly correlated. Where duration is high, the incidence of initiation is high (Huffman 1984).

Applications of spatial models in human ecology or biology have increased in recent years. They have been enhanced by advances in statistical methodology that can deal with complex data structures often encountered in the field. For example, data often have a spatial and temporal dimension, and may include nonlinear variables that have to be jointly estimated. Such high dimensional data cause tremendous estimation problems. Furthermore, availability of geo-referenced bio-ecological data have generated interest in exploring the spatial aspects of these data. Recent developments in software that can handle geographic data, such as the geographical information system (GIS), accompanied by advances in statistical software that can implement such models, for example BayesX (Brezger et al. 2005), have seen an increase in literature detailing applications of spatial models.

Moreover, mapping of health indicators is an essential tool for policy decision making because "hotspot" areas can be highlighted, thereby could form the basis for distributing and targeting interventions across geographical zones (Carter et al. 2000; Benach et al. 2003). This is true in developing countries where resources are scarce, and implementing interventions requires selective strategies. Mapping can be achieving using GIS or spatial models. Here, we used spatial models. The advantage of spatial modelling is that, unlike GIS, spatial autocorrelation can be simultaneously adjusted for in the model, leading to more plausible estimates. We used the 2000 Malawi Demographic and Health Survey (MDHS) data, with subdistricts as location variables. We adopted the methodology developed by Fahrmeir and Lang (2001) to explore spatial patterns of breastfeeding. The two response variables (initiation of breastfeeding and duration of breastfeeding) were recast into a unified, generalized linear/additive model where both responses fall within an exponential family of response models (Fahrmeir and Lang 2001; Palmgren and Ripatti 2002).

Methods

Data

We used data collected as part of the 2000 MDHS (National Statistical Office 2000). The MDHS was designed to provide estimates of health and demographic indicators at the national and regional levels, and to allow for regional and urban–rural comparisons. A two-stage stratified sampling design was implemented to collect the data. A total of 560 enumeration areas (EAs) as defined in the Malawi Population and Housing Census of 1998 were selected, stratified by urban–rural status with sampling probability proportional to the population of the EA. Each EA was geo-referenced.

A fixed number of households were randomly selected in each EA. All women aged 15–49 years were eligible for interview. A total of 13,220 women were interviewed, with a response rate of 98%; however, due to missing responses in the data, this analysis is based on a complete set of 11,927 cases. The data were realized through an interviewer-administered questionnaire, which included questions on complete birth histories, child nutrition and feeding practices. The DHS breastfeeding data were restricted to women who had a child under 5 years of age to avoid recall problems. This analysis is based on the last child data.

Dependent Variables

We considered two dependent variables: (1) breastfeeding initiation and (2) breastfeeding duration. Breastfeeding initiation is measured as an ordinal categorical variable (0: immediately after birth; 1: within 1 hour; or 2: within 24 hours after birth), while duration of breastfeeding is reported in months.

Independent Variables

Three types of covariates were considered: socio-economic and demographic variables, and health-sector variables (Table 1). *Socio-economic and demographic variables* include place of residence; maternal age; maternal education; maternal occupation; husband's education; husband's occupation; wealth index; ethnicity; access to media such as TV, radio or newspapers; and birth order of the child. Place of residence, given as rural or urban, captures the effect of urbanization and modernization. Urbanization is usually associated with lower breastfeeding rates and shorter breastfeeding duration than in rural areas. In the rural environment, breastfeeding calls for little change in lifestyle (Abada et al. 2001). Maternal age affects the initiation and duration of breastfeeding, with older mothers likely to follow established norms. Moreover, older women have a strong attachment, thus prolonging breastfeeding. On the other hand, older women may also have a high parity, leading to early termination of breastfeeding (Akin et al. 1986). Adebayo (2004) showed that mother's age has a nonlinear effect on breastfeeding initiation and therefore provides a better model than dummy fixed effects. Level of education is another factor that should be related to breastfeeding practices because it affects

Table 1. Descriptive summaries of individual explanatory variables used in the model

Variable	Breastfeeding initiation Immediate[a]	1 hr	24 hrs	Duration Mean (Stdev)	Total (n)
Mother's age[b]	27.7 (7.0)				11,927
Residence					
Urban	58.2	39.2	2.6	17.8 (8.2)	2058
Rural	60.4	37.0	2.6	13.6 (5.0)	9631
Mother's education					
None	58.9	38.6	2.5	16.0 (9.0)	3476
Primary	61.0	36.5	2.5	15.6 (8.8)	7358
Secondary or higher	56.4	40.0	3.5	14.5 (7.5)	849
Husband's education					
None	57.5	39.5	2.9	14.2 (6.9)	1750
Primary	60.6	37.0	2.4	14.9 (6.7)	7472
Secondary or higher	60.3	37.0	2.7	16.1 (8.9)	2214
Mother's occupation					
Not working	58.0	39.5	2.5	17.5 (8.8)	4351
Household/domestic/agricultural	62.3	35.4	2.3	16.8 (8.9)	2262
Professional/admin/clerical	60.8	36.4	2.8	14.4 (6.0)	5070
Husband's occupation					
Household/domestic/agricultural	59.3	38.2	2.5	15.9 (7.9)	5115
Professional/admin/clerical	60.6	6.8	2.6	15.6 (7.5)	6331
Wealth index					
Poorest	57.1	39.6	3.2	15.4 (9.0)	2256
Poor	60.5	36.3	3.2	15.3 (8.9)	2394
Middle	60.4	38.2	1.5	15.8 (9.0)	2623
Richer	62.1	35.2	2.7	16.0 (8.8)	1804
Richest	60.3	37.1	2.6	15.9 (8.4)	2237
Ethnicity					
Chewa	56.8	39.8	3.5	15.5 (8.8)	3292
Tumbuka	65.5	31.2	3.4	15.2 (8.8)	1101
Lomwe	59.2	39.5	1.3	16.7 (7.7)	2157
Yao	54.5	42.9	2.6	15.4 (8.1)	1700
Ngoni	61.5	36.0	2.5	15.3 (8.3)	1258
Others	66.6	31.2	2.2	14.8 (7.9)	2181
Reading newspaper					
Not at all	60.1	37.2	2.8	16.7 (8.9)	8505
Less than once a week	58.6	39.4	2.0	15.3 (7.8)	2254
At least once a week	63.9	33.6	2.4	14.7 (6.9)	907
Listening to radio					
Not at all	63.2	33.6	3.2	17.5 (8.7)	2911
Less than once a week	57.1	40.4	2.5	15.6 (6.8)	2847
At least once a week	56.8	40.1	3.0	14.8 (5.0)	952
Almost daily	60.5	37.3	2.2	15.4 (6.9)	4969
Watching TV					
Not at all	60.6	36.9	2.5	16.4 (9.1)	10632
Less than once a week	53.7	42.1	4.2	14.8 (6.8)	756
At least once a week	56.4	42.6	1.1	14.4 (5.9)	282
Place of delivery					
Home	58.6	38.9	2.6	15.2 (5.8)	4941
Public hospital	62.8	34.7	2.5	15.9 (5.7)	4896
Private hospital	57.2	39.8	2.9	17.1 (8.6)	1745
Prenatal support					
No doctor	59.9	37.7	2.4	14.9 (6.1)	7166
Seen by doctor	52.9	42.8	4.3	16.1 (7.1)	652
No nurse	51.3	43.2	5.5	14.7 (5.2)	818
Seen by nurse	60.2	37.5	2.3	16.5 (8.1)	7000
No ward attendant (WA)	59.6	37.7	2.6	14.5 (5.1)	7155
Seen by WA	55.4	42.2	2.4	16.9 (7.8)	663
No traditional birth attendant (TBA)	59.4	38.1	2.5	15.3 (8.2)	7538
Seen by TBA	55.4	38.2	6.4	16.8 (8.4)	280
Support at delivery					
No doctor	60.9	36.7	2.4	15.9 (8.8)	10997
Doctor available	45.9	48.0	6.1	15.7 (5.9)	689
No nurse	57.0	40.2	2.7	15.2 (8.4)	5480

Nurse available	62.7	34.8	2.5	17.8 (8.8)	6206
No WA	60.3	37.0	2.7	15.1 (6.4)	10952
WA available	55.6	42.8	1.6	15.8 (5.8)	734
No TBA	60.2	37.2	2.6	15.1 (8.2)	9118
TBA support	59.4	38.0	2.6	15.0 (5.8)	2568
No relative	60.9	36.5	2.7	15.4 (6.6)	9086
Relative's support	57.2	40.4	2.4	17.6 (9.9)	2600
Sex of child					
Girl	60.0	37.4	2.6	15.8 (8.3)	5869
Boy	60.1	37.3	2.6	15.2 (8.5)	5820
Birth order					
1st born	60.1	36.9	3.0	15.6 (8.9)	2814
2nd–3rd born	61.2	36.5	2.4	14.5 (6.6)	4132
4th born or higher	59.0	38.4	2.6	15.7 (6.5)	4743

Note. (1) Sample for analysis was 11,927 with 1193 missing responses; (2) The "never-breastfed" category (0.5%) is not considered in the breastfeeding initiation as data is missing. [a]Row percentages. [b]Mean (standard deviation) for mother's age for whole sample.

knowledge and awareness of good breastfeeding practices and other nutrition needs.

Women in professional, administrative or clerical occupations are likely to spend less time breastfeeding because of work demands than those working at home or in the agricultural sector (Ryan et al. 2006). The husband's support of breastfeeding is an important predictor, with husbands having secondary or higher education and working as professionals, administrators or clerks being the most supportive (Houghton and Graybeal 1999). Ethnic differences in breastfeeding decisions are also well established. Patterns of breastfeeding vary considerably across different racial/ethnic groups because of socio-cultural differences (Kelly et al. 2006). Social determinants of breastfeeding initiation and duration also include wealth ranking or access to media (Akin et al. 1986; Adair et al. 1993; Abada et al. 2001), and these were equally examined in this study.

The *health sector variables* in the model are prenatal assistance through a doctor, nurse, ward attendant or traditional birth attendant; place of delivery, either at home, in a public facility or in a private/mission hospital; and support at delivery by a doctor, nurse, ward attendant, traditional birth attendant or with a relative's assistance. These variables measure advice given to mothers and may promote certain breastfeeding patterns (Akin et al. 1986). The presence of additional family members in the household, in particular mothers-in-law, provides positive support for breastfeeding practices, encouraging mothers to breastfeed for a longer period of time (Abada et al. 2001). All variables except mother's age are entered as fixed categorical effects.

Since the data were geo-referenced, each observation was linked to 364 subdistricts. This permitted inclusion of spatial correlation effects which captured residual or unobserved factors that may influence the pattern of the response.

Statistical Methods

The most basic approach to analyze observation data such as duration responses – "the number of month of breastfeeding," or ordinal responses – "when breastfeeding was initiated," is to use generalized linear models (GLMs) (McCullagh and Nelder 1989; Palmgren and Ripatti 2002). However, because of the random effects introduced due to the geographical nature of our data, a strictly linear approach may not have been appropriate. Instead, a flexible semi-parametric model that allows both parametric and nonparametric data structures was most appealing (Palmgren and Ripatti 2002; Fahrmeir and Lang 2001).

Given a set of observations (y_i, w_i, x_i, s_i), then y_i denotes the response connected to woman i and $w_i; x_i; s_i$ represen vectors of covariates. These covariates may exhibit spatial correlation s_i, or nonlinear effects x_i, in additional to the fixed effects w_i. Assuming that the conditional density of y_i given the explanatory variables is of the exponential family type, then the conditional expectation $\mu_i = h(\eta_i \mid w_i, x_i, s_i)$, for some known link function (h) and predictor (η_i), can be expressed as an additive semi-parametric regression model

$$\eta_i = w_i\beta + f_i(x_i) + f_{spat}(s_i) \quad (1)$$

where β is a vector of unknown regression parameters corresponding to the fixed effects w_i, f_j, $j + 1$, K, p are unknown smooth functions of the covariates such that $f_j(x_j)$ is the vector of possible nonlinear covariates, and $f_{spat}(s_i)$ is the spatial component of the model that captures effects of area, s_i, $s = 1$, K, S where person i lives. The component $f_{spat}(s_i)$ can be split further into two random variables (Fahrmeir and Lang 2001). The first random variable, $f_{unstr}(s_i)$, is assumed to be independent and identically distributed for all areas. This captures unstructured spatial heterogeneity of observations within a subdistrict. The second variable, the s*tructured component-* $f_{str}(s_i)$, represents spatial autocorrelation. This captures large-scale similarities in breastfeeding behaviour across subdistricts. A rationale behind this is that a spatial effect is a surrogate of many unobserved influential factors, some of which operate at small scale, while others operate at large scale, thereby inducing greater similarities in risk pattern for neighbouring areas than for those further apart. When these are estimated and mapped, they may be compared to known spatial patterns of possible explanatory factors, or they may provide leads for further epidemiological investigation. Incorporation of spatially correlated prior also permits smoothing for increased precision of effects, which is necessary when sparse counts are observed at a small area (Crook et al. 2003). In practice, the two spatial components are both included in the model and allow the data to quantify the most dominant spatial structure.

Breastfeeding initiation, being an ordinal categorical response variable, was modelled using a cumulative probit model (Tutz and Hennevogl 1996). For breastfeeding duration, we chose a grouped discrete-time survival model, which offers an attractive approach for demographic data (Crook et al. 2003; Steele et al. 1996). Estimation of model parameters followed a hierarchical Bayesian approach, using simulation techniques. The Appendix gives full details on the two models applied and the model fitting steps taken.

Results

Descriptive Summaries

Descriptive statistics of the sample are shown in Table 1. The mean age of the women was 27.7 years (standard deviation [*SD*] = 7.0). Most women (60%) initiated breastfeeding immediately after birth, 37.2% initiated within 1 hour, 2.3% within 24 hours, and the rest (0.5%) never breastfed. Timing of breastfeeding initiation varied from subdistrict to subdistrict, with the highest proportion who breastfed immediately after birth found in the northern district of Karonga and the lowest in the south-eastern districts of Mangochi and Machinga. The variation in initiation across levels of individual variables suggests small differences in both socio-economic and health-sector variables; for example, initiation varied by mother's education, access to media, prenatal assistance and support at delivery.

About 58.8% of the women reported having weaned (duration time was completely observed), while 41.2% were censored because they were still breastfeeding or had never breastfed (therefore complete duration of breastfeeding was unknown at the time the survey was conducted). Mean duration of breastfeeding for the whole sample was 15.65 months (*SD* = 8.83), for those who had weaned was 18.19 months (*SD* = 8.4) and for those censored was 12.03 months (*SD* = 8.12). Geographical variation was considerable, with mean duration of breastfeeding per subdistrict ranging from 7.78 to 21.17 months. However, there was little variation in mean duration of breastfeeding across different levels of individual covariates (Table 1).

Factors for Breastfeeding Initiation

Table 2 gives estimates of factors associated with timing of breastfeeding initiation. Included in the table are estimates of threshold parameters, θ_1 and θ_2 for categories "immediately" and "1 hour later," and the last category ("24 hours later") assigned as the reference. Threshold parameters are interpreted as follows: Higher values of the threshold, i.e., ($\theta > 0$), correspond to early initiation of breastfeeding, and lower values, i.e., ($\theta < 0$), correspond to delayed breastfeeding. For example, a lower (higher) values of θ signified a shift to the right (left) side on the latent scale, which implied a decreased (increased) probability for that category. From the table, θ_1 = 0:007, implied an increased chance of initiating breastfeeding immediately after birth relative to 24 hours later. For θ_2 = 1:799, it suggests that there was an increased likelihood of breastfeeding within 1 hour relative to 24 hours later.

Table 2. Posterior estimates of fixed covariates in the model – breastfeeding initiation

Variable	Posterior mean	Standard error	95% credible interval
Threshold points:			
θ_1	0.007	0.102	(-0.193, 0.203)
θ_2	1.799	0.104	(1.595, 2.004)
Fixed effects:			
Residence			
Urban	0		
Rural	-0.024	0.038	(-0.071, 0.026)
Mother's education			
None	0		
Primary	-0.156	0.056	(-0.231, -0.083)
Secondary or higher	0.329	0.115	(0.181, 0.483)
Husband's education			
None	0		
Primary	-0.041	0.034	(-0.084, 0.005)
Secondary or higher	0.068	0.074	(-0.030, 0.161)
Mother's occupation			
Not working	0		
Household/domestic/agricultural	-0.071	0.022	(-0.099, -0.044)
Professional/administrative/clerical	0.011	0.018	(-0.012, 0.035)
Husband's occupation			
Household/domestic/agricultural	0		
Professional/administrative/clerical	-0.010	0.014	(-0.028, 0.007)
Wealth index			
Poorest	0		
Poor	0.018	0.026	(-0.015, 0.051)
Middle	-0.032	0.025	(-0.065, 0.001)
Richer	-0.012	0.028	(-0.047, 0.024)
Richest	-0.061	0.031	(-0.100, -0.022)
Ethnicity			
Others	0		
Chewa	0.009	0.032	(-0.031, 0.050)
Tumbuka	-0.021	0.047	(-0.083, 0.040)
Lomwe	0.029	0.036	(-0.017, 0.074)
Yao	0.055	0.024	(0.010, 0.100)
Ngoni	-0.131	0.039	(-0.180, -0.082)
Access to newspaper			
Not at all	0		
Less than once a week	0.106	0.046	(0.035, 0.177)
At least once a week	-0.223	0.105	(-0.357, -0.096)
Access to radio			
Not at all	0		
Less than once a week	0.009	0.023	(-0.019, 0.039)
At least once a week	0.075	0.033	(0.032, 0.118)
Almost every day	-0.035	0.013	(-0.063, -0.005)

Table 2. Continued

Access to TV			
Not at all	0		
Less than once a week	0.094	0.094	(-0.028, 0.220)
At least once a week	-0.034	0.175	(-0.259, 0.194)
Prenatal assistance			
Doctor: No	0		
Doctor: Yes	-0.059	0.025	(-0.090, -0.027)
Nurse: No	0		
Nurse: Yes	-0.106	0.027	(-0.141, -0.070)
Ward attendant (WA): No	0		
WA: Yes	-0.039	0.014	(-0.069, -0.009)
Traditional birth attendant (TBA): No	0		
TBA: Yes	-0.015	0.032	(-0.055, 0.027)
Support at delivery			
No doctor	0		
Doctor available	0.123	0.030	(0.084, 0.162)
No nurse	0		
Nurse available	-0.123	0.032	(-0.164, -0.081)
No WA	0		
WA available	0.013	0.026	(-0.021, 0.045)
No TBA	0		
TBA available	-0.040	0.015	(-0.072, -0.008)
No relative	0		
Relative available	-0.028	0.024	(-0.060, 0.003)
Place of birth			
Home	0		
Public hospital	-0.021	0.028	(-0.058, 0.015)
Private/mission hospital	0.070	0.033	(0.029, 0.112)
Sex of child			
Boy	0		
Girl	0.008	0.005	(-0.002, 0.019)
Birth order			
1st born	0		
2nd–3rd born	-0.023	0.019	(-0.047, 0.001)
4th born or higher	0.030	0.027	(-0.006, 0.064)
Spatial variance components:			
Structured effects (τ^2_{str})	0.254	0.055	(0.155, 0.377)
Unstructured effects (τ^2_{unstr})	0.020	0.012	(0.002, 0.047)

Timing of breastfeeding initiation was associated with mother's education; mother's occupation; ethnicity; wealth index; access to media such as TV, newspapers or radio; health-sector variables such as prenatal assistance; availability of support at delivery and place of delivery. Compared to women with no formal education, mothers with primary education were less likely to start breastfeeding within 1 hour (coefficient [*coeff*] = -0.156, standard error [*SE*] = 0.056); however, mothers with secondary or higher education were most likely to start breastfeeding within 1 hour (*coeff* = 0.329, *SE* = 0.115). Mothers whose occupation involved domestic and agricultural activities were less likely to initiate breastfeeding within 24 hours than those who reported they did not work at all. No difference, however, was observed when comparing mothers in professional/clerical and administrative services with those who did not work. Mothers from the richest households delayed initiation of breastfeeding compared with the those from the poorest households = (*coeff* = -0.061, *SE* = 0.031). Mothers from the Yao ethnic group were positively associated with early initiation of breastfeeding, and those from the Ngoni ethnic group were negatively associated with early initiation. A positive effect was observed between those who had access to a newspaper less than once a week (*coeff* = 0.106, *SE* = 0.046) or those who listened to a radio at least once a week (*coeff* = 0.075, *SE* = 0.033) and initiated breastfeeding within 1 hour of birth relative to those who had no access to a radio or newspaper. On the other hand, seeing a newspaper at least once a week (*coeff* = - 0.223, *SE* = 0.105) or listening to a radio almost every day (*coeff* = -0.035, *SE* = 0.013) had a negative effect on early initiation.

Giving birth in a private health facility (compared to at home) had a positive effect on early initiation of breastfeeding. Having a doctor available during prenatal care or at the delivery had a positive association with initiating breastfeeding within 1 day of birth. When a nurse gave prenatal assistance, we also observed a positive effect, although a negative effect was seen if the nurse was available during delivery. Prenatal assistance from a ward attendant or support at delivery from a traditional birth attendant had a negative effect on early timing of breastfeeding.

Figure 1 shows the nonlinear effect of mother's age on breastfeeding initiation. The plot displays a departure from linearity, with an increasing effect for older women 38–45 years of age. The spatial effects described in Figure 2 are particularly interesting. The left panel map shows the total spatial effects varying smoothly from -0.99 to 0.56, while the right panel shows the probability map, which shows areas where these effects were significant. Black shows areas of significant positive effect, that is, areas where mothers were likely to begin breastfeeding earlier. White shows significant negative effect, areas where mothers were likely to delay breastfeeding. Significant positive effects are shown in the central region in Dedza and Lilongwe, in the northern region in Nkhatabay district and in the southern region in Mangochi, Machinga, Zomba and Balaka. Negative effects were observed in the northern districts of Chitipa, Karonga and parts of Mzimba. In the centre these are displayed in the areas of Mchinji and Nkhotakota, while in the south we observed negative effects in Machinga, Mulanje and Nsanje. The spatial variance components show that the structured effects were dominant compared to the unstructured effects (Table 2).

Factors for Breastfeeding Duration

Duration of breastfeeding was associated with place of residence; mother's occupation; ethnicity; access to media such as newspapers, TV or radio; prenatal assistance; support at delivery; place of birth; birth order and type of feeding (Table 3). No association was found between wealth index and duration of breastfeeding. Rural children were breastfed longer than urban children (*coeff* = 0.039, *SE* = 0.012). Mothers working in professional, clerical or administrative sectors had a higher probability of stopping breastfeeding early compared with those who did not work at all (*coeff* = -0.025, *SE* = 0.012). Our study also showed that women of the Lomwe ethnic group were most likely to breastfeed their children longer than women in other ethnic groups (*coeff* = 0.080, *SE* = 0.035). Women who had access to newspapers or magazines less than once a week were more likely to wean their young early than women who lacked this access (*coeff* = - 0.079, *SE* = 0.040), while those who had access at least once a week breastfed longer than their counterparts who did not have weekly access (*coeff* = 0.208, *SE* = 0.101). In this analysis, listening to a radio less than once a week had a positive effect on the duration of breastfeeding relative to those who did not listen, but listening to a radio at least once a week had a negative effect. In contrast, women who watched TV less than once a week were most likely to stop breastfeeding earlier than those who did not watch at all (*coeff* = -0.194, *SE* = 0.091), while those who watched at least once a week were more likely to prolong breastfeeding than those who did not watch at all (*coeff* = 0.314, *SE* = 0.117).

Prenatal care advice received from doctors, nurses, ward attendants or traditional birth attendants was associated with prolonged duration of breastfeeding. Availability of support at delivery from nurses or relatives had a positive effect on the duration of breastfeeding. Mothers who gave birth at private health centres were likely to stop breastfeeding earlier than those who gave birth at home (*coeff* = -0.056, *SE* = 0.023). On birth order, we observed a negative association with duration of breastfeeding for the second or third child compared with the fourth or higher (*coeff* = -0.047, *SE* = 0.020).

Figure 1. Nonlinear effect of mother's age on the breastfeeding initiation (centre line) with the corresponding 80% and 95% confidence lines

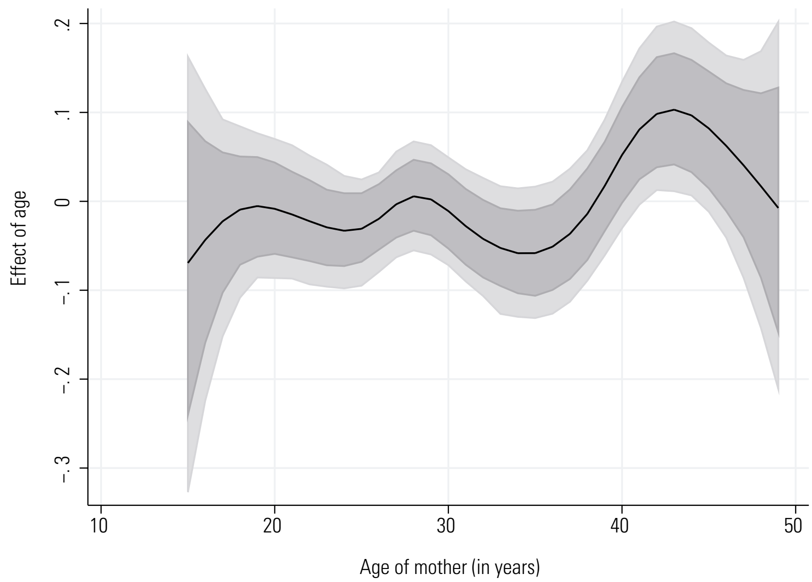


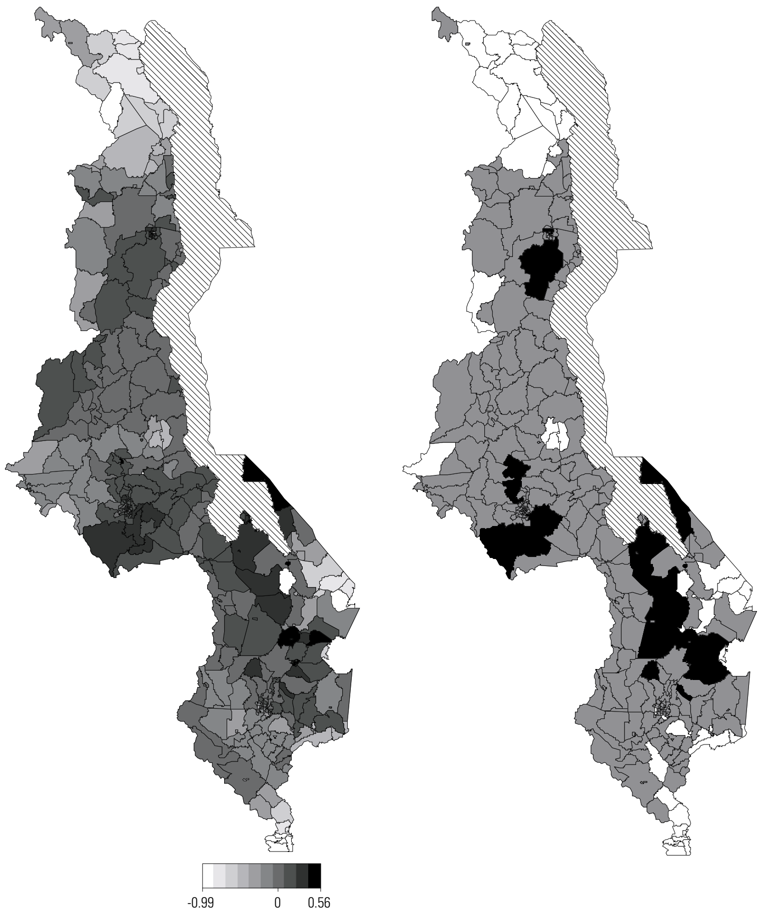
Figure 3 shows a nonlinear effect of mother's age on the duration of breastfeeding. Overall, there was a decreasing trend between mother's age and duration of breastfeeding, and the relationship clearly displayed nonlinear effects. The residual spatial effects were relatively small (Figure 4), ranging from -0.32 to 0.45 and indicating that much of the variation in the response was explained by individual variables. The probability map shows areas with significant effects at 80%. Few subdistricts showed a significant positive effect (black area) or negative effect (white area) of timing of breastfeeding initiation. While the structured spatial component was more dominant than the unstructured components as indicated by the variance component (Table 3), the structured components on average were weak, as illustrated on Figure 4.

Discussion

Breastfeeding patterns have received considerable attention, as seen in the vast literature that covers the topic. The preceding analysis adds to this body of knowledge by applying spatial models to analyze initiation and total duration time of breastfeeding in Malawi. Our approach simultaneously modelled the effects of individual factors and geographical location of breastfeeding. Although individual-level variables are often investigated, few examples account for the effect of location on breastfeeding practices or for individual-level variables and location in a single model (Adebayo 2004).

Our findings demonstrate that location is important in explaining variation in breastfeeding practices. The effect of location was more pronounced in breastfeeding initiation. Spatial effects can be interpreted as surrogates of unobserved factors. These factors are a matter of conjecture. They may be mostly defined by unmeasured ethnic or cultural differences that go beyond the major groupings used in our analysis. Childhood eating practices, traditional norms in childcare and/or inequalities in socio-economic levels are many of the attributes that explain the observed spatial

Figure 2. Residual spatial effects for breastfeeding initiation at sub-district level. Shown in the map are the posterior means (left panel) and posterior probability map at nominal level of 80% (right panel). Black areas indicate significant positive effects; white areas indicate significant negative effects and grey areas indicate no significant effects



differences in breastfeeding (Kelly et al. 2006; Brennan et al. 2004; Adebayo 2004). Socio-economic inequalities between rural and urban areas, for example in the central region, justify some of the notable geographical differences in timing of breastfeeding initiation (Akin et al. 1986; Abada et al. 2001). The influence of ethnicity may clarify the spatial differences estimated in the south-eastern region (Figure 2), where children were most likely to be breastfed within 1 hour in one section of the region, and yet further east of the region, children were less likely to be breastfed within 1 hour. Such positive and negative effects are not surprising because of ethnic differences in those two areas. Further studies are needed to find out about local breastfeeding knowledge and practices in these communities and their socio-cultural contexts. For example, the practice of not giving colostrum to newborns because of the belief that it is bad and may delay breastfeeding has been observed in many African cultures (Kelly et al. 2006; Lauer et al. 2004; Perez-Escamilla 1994). Investigating this practice in Malawian society could be worthwhile.

The nearly similar spatial patterns of breastfeeding duration (Figure 4) mean that residual variation was not spatial. We may explain this observation by the fact that traditionally, alternative methods of child feeding are not the norm for women in Malawi, as indicated in studies elsewhere (Adair et al. 1993). Therefore, under these circumstances, there is little to distinguish regional patterns. The findings also indicate that most of the variation in outcome had already been explained by individual-

Table 3. Posterior estimates of fixed covariates in the model – total number of months of breastfeeding

Variable	Posterior mean	Standard error	95% credible interval
Fixed effects			
Residence			
Urban	0		
Rural	0.039	0.012	(0.007, 0.071)
Mother's education			
None	0		
Primary	0.039	0.061	(-0.039, 0.117)
Secondary or higher	-0.069	0.127	(-0.232, 0.093)
Husband's education			
None	0		
Primary	-0.008	0.036	(-0.054, 0.039)
Secondary or higher	0.005	0.078	(-0.095, 0.106)
Mother's occupation			
Not working	0		
Household/domestic/agricultural	-0.018	0.022	(-0.046, 0.010)
Professional/administrative/clerical	-0.025	0.012	(-0.049, -0.001)
Husband's occupation			
Household/domestic/agricultural	0		
Professional/administrative/clerical	0.007	0.014	(-0.011, 0.024)
Wealth index			
Poorest	0		
Poor	-0.011	0.027	(-0.046, 0.023)
Middle	-0.008	0.026	(-0.041, 0.025)
Richer	-0.015	0.029	(-0.052, 0.022)
Richest	-0.002	0.032	(-0.042, 0.039)
Ethnicity			
Others	0		
Chewa	0.018	0.032	(-0.024, 0.059)
Tumbuka	-0.054	0.044	(-0.111, 0.003)
Lomwe	0.080	0.035	(0.035, 0.124)
Yao	-0.007	0.036	(-0.053, 0.040)
Ngoni	0.003	0.038	(-0.045, 0.051)
Access to newspaper			
Not at all	0		
Less than once a week	-0.079	0.040	(-0.148, -0.010)
At least once a week	0.208	0.101	(0.079, 0.337)
Access to radio			
Not at all	0		
Less than once a week	0.036	0.012	(0.006, 0.066)
At least once a week	-0.050	0.035	(-0.095, -0.005)
Almost everyday	-0.010	0.022	(-0.039, 0.018)
Access to TV			
Not at all	0		
Less than once a week	-0.194	0.091	(-0.311, -0.077)
At least once a week	0.314	0.117	(0.099, 0.529)
Prenatal assistance			
Doctor: No	0		
Doctor: Yes	0.357	0.026	(0.323, 0.391)
Nurse: No	0		
Nurse: Yes	0.052	0.023	(0.009, 0.095)
Ward attendant (WA): No	0		
WA: Yes	0.272	0.025	(0.240, 0.304)

Table 3. Continued

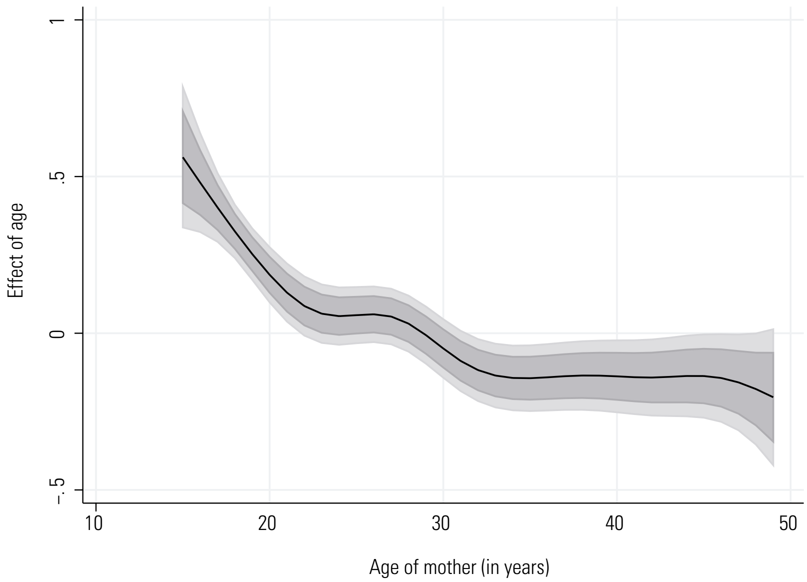
Traditional birth attendant (TBA): No	0		
TBA: Yes	0.595	0.035	(0.551, 0.639)
Support at delivery			
No doctor	0		
Doctor available	-0.035	0.030	(-0.074, 0.004)
No nurse	0		
Nurse available	0.077	0.034	(0.033, 0.121)
No ward attendant	0		
Ward attendant available	0.004	0.028	(-0.031, 0.040)
No TBA	0		
TBA available	-0.002	0.027	(-0.036, 0.033)
No relative	0		
Relative available	0.051	0.026	(0.018, 0.085)
Place of birth			
Home	0		
Public hospital	-0.036	0.030	(-0.074, 0.003)
Private/mission hospital	-0.056	0.023	(-0.099, -0.013)
Sex of child			
Boy	0		
Girl	0.004	0.007	(-0.009, 0.016)
Birth order			
1st born	0		
2nd–3rd born	-0.047	0.020	(-0.072, -0.022)
4th born or higher	0.001	0.029	(-0.037, 0.038)
Spatial variance components:			
Structured effects (τ^2_{str})	0.275	0.062	(0.116, 0.371)
Unstructured effects (τ^2_{unstr})	0.017	0.011	(0.002, 0.034)

level characteristics. Besides estimating for unobserved factors, by including random effects in the models, we aimed to produce reliable estimates for the parameters because of the hierarchical structure of the survey data used in our analysis. Failure to do so often leads to standard errors of the parameters being underestimated giving highly significant model estimates (Bolstad and Manda 2001).

A range of socio-economic, demographic and health-sector factors have been identified as influential on breastfeeding patterns (Tables 2 and 3). The effect of maternal age is interesting, as it is estimated to vary with increasing age. Results confirm that continuous variables such as mother's age exhibit a nonlinear relationship with breastfeeding behaviour. It suggests that categorization of continuous variables at ad hoc intervals may not be appropriate and cannot adequately model the behaviour exhibited by such factors. In fact the results may be misleading, and the model may not be the best (Lang and Brezger 2004; Adebayo 2004; Fahrmeir and Lang 2001).

The influence of old age is highly positive. The advantages of breastfeeding are well known to older women, and they initiate breastfeeding without delay. Longer and shorter duration in rural and urban areas, respectively, reflect lifestyle differences in the two settings. In urban areas, modernization factors such as demands of employment could lead to early weaning to allow mothers to resume work. While this may be the case, other studies have shown than in African countries urbanization has little impact on breastfeeding behaviour compared to the impact in Latin American countries (Perez-Escamilla 1994). Although we found no evidence of effect on initiation of the child's sex, wealth ranking, husband's education or occupation, all these factor are known to affect the decision to breastfeed (Akin et al. 1986; Hegney et al. 2003; Ford and Labbok 1990).

Figure 3. Nonlinear effect of mother's age on the breastfeeding duration (centre line) with corresponding 80% and 95% confidence lines



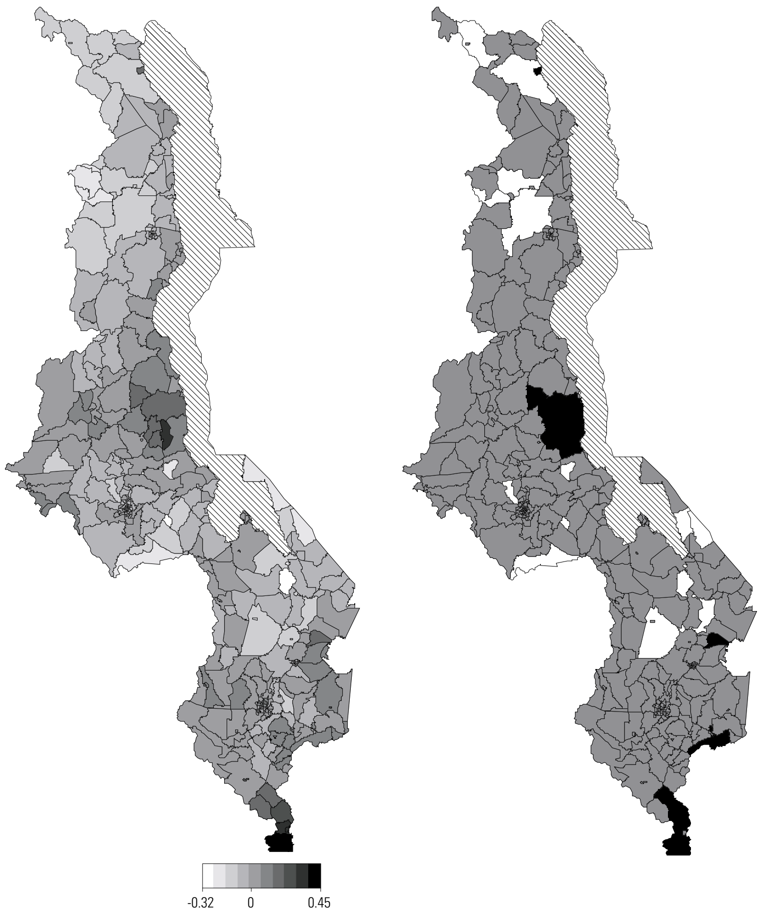
The importance of access to media on breastfeeding initiation and duration emphasizes the need for mass media breastfeeding campaigns. Occasional messages through radio can reach a much larger audience than through TV or newspapers. Support from health personnel during and after birth also has an impact on the initiation and duration of breastfeeding. A number of studies provide evidence that increased knowledge of the importance of breastfeeding increases the likelihood of exclusive breastfeeding and longer duration of breastfeeding (Adair et al. 1993; Ford and Labbok 1990; Vella et al. 1992). Health education programs designed to promote initiation and continuation of breastfeeding should target women across all ethnic and socio-economic status (SES) strata and those with lower levels of SES and social support (Ford and Labbok 1990).

The relationship between duration of breastfeeding and mother's education is also well documented. The more educated the mother, the shorter the duration of breastfeeding. This relationship is indirectly associated with the woman's working status; it is expected that highly educated women are employed, hence employed women wean earlier than their non-employed counterparts (Hegney et al. 2003; Ford and Labbok 1990). However, as employment is included as a covariate in the model, education may be influenced by other factors such as availability of breast milk substitutes. These are matters of conjecture and can be unveiled in detail through focus group discussions.

Our results indicated sex made no difference in breastfeeding duration. Studies on nutritional feeding practices that included sex have reported behaviour where girls were more nourished than boys (Madise and Mpoma 1997). However, studies in South Asia indicated the contrary (Akin et al. 1986), while in others there was no association (Vella et al. 1992). From these results, it is difficult to establish evidence of sex discrimination.

Parity is another determinant of breastfeeding duration. The negative relationship of birth order is as expected in demographic findings conducted in developing countries. First-born children are breastfed for less time, mostly because mothers quickly progress to subsequent pregnancies that prompt them to stop breastfeeding the earlier infant. Similarly for the succeeding orders, children are weaned because of short birth intervals. Children spaced at adequate intervals are likely to be better nourished and survive longer (Brennan et al. 2004; Manda 1999; Bolstad and Manda 2001).

Figure 4. Residual spatial effects for the duration of breastfeeding at subdistrict level. Shown in the map are the posterior means (left panel) and posterior probability map at nominal level of 80% (right panel). Black areas indicate significant positive effects, white areas indicate significant negative effects and grey areas indicate no significant effects



Conclusion

This study is by no means exclusive. Breastfeeding has a behavioural aspect, and many factors affect breastfeeding practices, including biological, socio-demographic, the health sector and the food industry (Adair et al. 1993). However, our study offers important insight into the relative importance of both spatial location and individual characteristics on breastfeeding behaviour in Malawi. This has potential implications for further research and health policy planning purposes. First, the maps generated in our study may offer leads for in-depth epidemiologic or geographic studies that may shed light on factors contributing to such inequalities. Second, results can form the basis for distributing and targeting interventions across geographical zones (Carter et al. 2000; Benach et al. 2003).

Appendix

This section gives details on the two models used to analyze breastfeeding initiation and duration.

Modelling Breastfeeding Initiation

Breastfeeding initiation falls naturally into ordered categorical response, y_i, of delay. Cumulative threshold models are assumed for such ordered categories (Tutz and Hennevogl 1996). The response y_i is assumed to be a categorized version of the latent variable $U_i = \eta_i + \varepsilon_i$, obtained through the threshold mechanism, where ε_i is an error term. The common choice for ε_i is the logistic or standard normal leading to cumulative logit or probit models. This naturally brings the response in the exponential family of response model that is given by the predictor (1). For identifiability, the last category threshold is set to zero and no intercept is included in the model.

Modelling Duration of Breastfeeding

The duration of breastfeeding, given in months, can be modelled using a Cox regression. However, we chose a grouped discrete-time survival model, which offers an attractive approach for demographic data (Crook et al. 2003; Steele et al. 1996). Under such models, the time scale t is segmented into m intervals: $\{ I_t = [a_{t-1}, a_t): 0 < a_0 < \ldots < a_{t-1} < a_t < \ldots a_m < \infty \}$, and censoring is assumed to happen at the end of the interval. The hazard function is cast as a binary regression model such that

$$P(y_{it} \mid \eta_{it}) = h(t \mid \eta_{it}) = h_0(t)\exp(\eta_{it}) \qquad (2)$$

where y_{it} is a binary that records an event in the interval I_t, $h_0(t)$ is the baseline hazard, and η_{it} is the predictor linked to the covariates. Because of possible nonlinear and random effects in the data, we assume an additive predictor, which is expanded as follows:

$$\eta_{it} = f_0 + w_i\beta + f_j(x_i) + f_{spat}(s_i) \qquad (3)$$

where $f_0(t) = \log(h_0(t))$ is the log-baseline effect, and the rest is as defined above (equation 1). We assumed that the time interval is partitioned into 6-month intervals: [0-6), [6-12), [12-18), [18-24), [24-30), and [30+), corresponding closely to the intervals used to describe child-feeding practices (see, MDHS: National Statistical Office [2000]). This means that a breastfeeding duration time of say, t = 16 months that resulted in weaning the child i can be represented as $y'_{it} = (0; 0; 1)$; $a' = (6; 6; 4)$, while another child who was not weaned at 12 months can be partitioned as $y'_{it} = (0; 0)$; $a' = (6; 6)$, where is fitted as a baseline effect. The first 6 months allow for the period of exclusive breastfeeding, 6-12 months captures the period when complementary foods are introduced to the child, and beyond this, weaning starts. The baseline hazard is estimated non-parametrically as explained below. The augmentation of the data now allows the logistic regression model to be used for the response (Crook et al. 2003).

Analysis

Modelling the two models follows a similar hierarchical Bayesian approach. Initially prior assumptions are specified for each parameter in equation (1). For the fixed effects, diffuse priors are a suitable choice. For the spatially correlated effects, we used a conditional autoregressive (CAR) process (Besag et al. 1991). The CAR assumes that contiguous areas have similar effect patterns. The CAR has the form

$$f_{str}(s) \mid \{ f_{str}(r), r \neq s \} \sim N(\bar{f}_{str}(r), \tau^2_{str} / N_s) \qquad (4)$$

where s and r are adjacent areas, N_s is the number of adjacent areas, and str is the variance component controlling spatial smoothing. The unstructured spatial effects were assigned an exchangeable normal prior with the following properties:

$$f_{unstr} \sim N(0, \tau^2_{str}) \qquad (5)$$

For the smooth functions f_j, for example the baseline hazard and mother's age, we assumed the penalized splines with second order random walk to achieve a good fit to the nonlinear function (Lang and Brezger 2004), that is, $f_j(x) = \sum_{t=1}^{m} \beta_t B_t(x)$, where $B_t(x)$ are cubic B-splines with 20 equidistant knots, and B_t is assumed to follow a second order random walk prior, i.e., $\beta_t = 2\beta_{t-1} - \beta_{t-2} + u_t$, such that $u_t \sim N(0,\tau^2_t)$. The initial values β_1 and β_2 are assumed diffuse priors. To complete the Bayesian hierarchy, the hyper-parameters for the variance components (τ^2_{str}, τ^2_{unstr}, τ^2_t) were assigned the inverse Gamma prior, $IG(a; b)$ where a = 0:001 and b = 0:001. Sensitivity analysis of the model was carried out to assess the stability of model results on starting values.

Model estimates were derived from the posterior distribution. The posterior distribution is a product of the prior distribution and the data (the likelihood). Because of the higher dimensionality of the data, modelling relies on Markov Chain Monte Carlo (MCMC) techniques. We considered an initial burn-in of 12,000 iterations, carried out another 40,000 iterations and thinned every 20th iteration to obtain 2000 samples for parameter estimation. The two models were implemented in BayesX Version 1.4 (Brezger et al. 2005). Convergence was assisted by carrying out simulations that were block-sampled at between 50 and 80 depending on the dataset being analyzed. Convergence was visually assessed by plotting cumulative path plots for each parameter.

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