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Pathways of the Determinants of Unfavourable Birth Outcomes in Kenya

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Abstract

This paper explores the pathways of the determinants of unfavourable birth outcomes, such as premature birth, the size of the baby at birth, and Caesarean section deliveries in Kenya, using graphical loglinear chain models. The results show that a number of factors which do not have direct associations with unfavourable birth outcomes contribute to these outcomes indirectly through intermediate factors. Marital status, the desirability of a pregnancy, the use of family planning, and access to health facilities have no direct associations with poor birth outcomes, such as premature births and the small size of the baby at birth, but are linked to these outcomes through antenatal care. Antenatal care is identified as a central link between various socio- demographic or reproductive factors and birth outcomes.

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1 Introduction

Kenya is characterized by huge internal differences, and many women endure a lifetime of poor health and nutritional status as a direct consequence of societal, cultural, political and economic factors. The risks that women throughout the world face during pregnancy and childbirth are seriously exacerbated by these factors in Kenya, making Kenyan women particularly vulnerable to adverse outcomes, both for themselves as well as their infants (Graham and Murray, 1997). Poor accessibility of services has been identified as an impediment to receiving adequate maternal health care in the country, including antenatal care (see Magadi, Madise and Rodrigues 2000), leading to poor birth outcomes for both the mother and the baby. This paper explores the direct and indirect pathways of the determinants of unfavourable birth outcomes in Kenya. The birth outcomes examined are premature births, small size of the baby at birth and Caesarean section deliveries. Prematurity and the size of the baby at birth are both important determinants of the survival of a newborn baby. On the other hand, delivery by Caesarean section represents difficult delivery that might have resulted in the death of the mother and/or the newborn baby had appropriate medical care not been received.

The number of possible factors which are associated with pregnancy outcomes is vast. These include background socio-economic, demographic and cultural factors, and a wide range of health care factors and nutritional status. Socio-economic and demographic factors, such as income, low maternal education level, very young or old maternal age, and first births, have been linked to higher risks of poor pregnancy outcomes (Herz and Measham 1987; Anandalakshmy *et al*. 1993; Gonzalez-Perez and Vega-Lopez 1996; Cramer 1995).

Lack of appropriate maternal health care contributes significantly to poor pregnancy outcomes. Previous

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studies have demonstrated the importance of antenatal care in reducing adverse pregnancy outcomes such as perinatal mortality, low birth weight and premature delivery (Hollander 1997; NSO and MI 1993; Coria-Soto, Bobadilla and Notzon1996; Magadi, Diamond and Madise 2001). Apart from maternal health care, general health care behaviour in matters relating to reproduction is also likely to influence birth outcomes. For example, use of family planning can reduce the number of high risk pregnancies and, consequently, reduce the incidence of adverse pregnancy outcomes.

A woman's general health condition, including her nutritional status, has a direct impact on her quality of life and productivity, and the life of her newborn. Poor nutrition is closely associated with intrauterine growth retardation and premature birth in both the developing and the developed countries. Studies in different parts of the world have identified short maternal stature as a risk factor of poor birth outcomes such as perinatal death, premature birth, low birth weight and Caesarean section deliveries (Achadi *et al*. 1995; NSO and MI 1993; Mavalankar *et al*. 1994). Other maternal anthropometric indicators such as pre-pregnancy weight, weight gain in pregnancy, body mass index (BMI) and mid-upper arm circumference have also been identified to be associated with perinatal outcomes (Achadi *et al*. 1995; Pelletier *et al*. 1995; Mavalankar *et al*. 1994; Sharma et al. 1994).

Previous studies have shown a fairly consistent relationship between some of the demographic factors, such as maternal age and parity, and adverse pregnancy outcomes. However, the effect of some of the background socio-economic factors, such as maternal educational attainment, has not shown a consistent pattern. While it is believed that high maternal educational attainment improves birth outcomes by improving women’s status and access to information and services, some studies have linked higher maternal educational attainment with increased incidence of unfavourable birth outcomes, such as premature delivery (see, for example, Prazuck *et al*. 1993). Such unexpected patterns need to be scrutinized carefully to eliminate possible confounding associations. For example, educated women may be more likely to report such events. It is also possible that some of the background factors, such as maternal education, might influence birth outcomes indirectly through the intermediate factors.

Conceptual frameworks on the determinants of maternal health outcomes (McCathy and Maine 1992; Magadi 1999) illustrate that background socio-economic and cultural factors influence adverse pregnancy outcomes through a wide range of intervening factors, including maternal health care and maternal health status. Other frameworks for health outcomes, such as the Mosley and Chen framework for child survival, also acknowledge that background factors operate through proximate determinants to influence health outcomes (Mosley and Chen, 1984). However, most empirical studies have focussed on the direct associations between the various factors and health outcomes, without paying much attention to the pathways of the determinants. The few empirical studies that have taken into account the proximity of the determinants of birth outcomes have mainly used multi-stage regression models, involving inclusion of background and proximate (intervening) variables in the model at different stages (see for example Cramer 1995). While this is no doubt an important step towards recognizing the pathways of the determinants, such methods fall short of enabling an examination of the complex interrelationships between the covariates, and hence, a comprehensive understanding of the pathways of the determinants.

This paper recognizes that an adverse pregnancy outcome is the result of complex interactions between socio-economic and cultural factors, reproductive behaviour, health care utilization, maternal health and other biological factors. Thus, to understand these interrelationships and the pathways of the determinants, it is necessary that an appropriate statistical approach be employed. It has been noted that one of the major problems hindering investigations of the effects of socio-demographic variables on a wide range of pregnancy outcomes is the scarcity of well structured multivariate techniques to determine the relative importance of various socio-demographic factors that have an impact on pregnancy outcomes (Hajo and Wildschut 1995). This paper uses graphical chain models to explore the association structure of the factors that may contribute to unfavourable birth outcomes in Kenya. This approach enables us to establish both the direct and indirect paths between the determinants and the outcomes.

2 Data and Methods

2.1 The Data

This study used data from the individual women's and the household questionnaires of the 1993 Kenya Demographic and Health Survey (KDHS). A description of the KDHS sampling procedure is reported elsewhere (National Council for Population and Development, Central Bureau of Statistics and Macro International 1994). The household questionnaire provided information for assessing household socio-economic status, based on household possessions and amenities, while the women's questionnaire provided information on individual women's characteristics as well as information relating to specific pregnancies or births which occurred during the five years preceding the survey. A total of 6115 births to 3929 women were eligible.

The 1993 KDHS sample was a nationally representative household based sample. The response rates for the sampled households and eligible women of reproductive age were reasonably high at 97.1 and 94.8 percent, respectively. Furthermore, there was little variation in response rates by key background variables such as age, ranging from a low of 92.3 percent for the 15-19 year olds to a high of 96.0 percent for the 20-24 year old women (NCPD, CBS and MI, 1994). Although the overall KDHS sample reflects a fair representation of the population of Kenyan women of reproductive age, it is important to note that this study is based on recent births, hence women who are unlikely to have had a recent birth will no doubt be underrepresented in the cases analysed. Nevertheless, such under-representation is unlikely to influence the association patterns of interest, unless there is selective omission of specific subgroups of women who are more prone to particular birth outcomes.

One consideration in the analysis relates to use of specific births as opposed to individual women as the unit of analysis. Previous analyses based on the 1993 KDHS data set have found evidence of a significant correlation between births to the same mother for the variables of interest, such as maternal health care and birth outcomes (see Magadi, 1999). Hence, we cannot assume complete independence of the observations. One way of eliminating this correlation is to include only one birth per woman, for example the most recent birth. However, such an approach reduces the sample size, and consequently the statistical power to detect significant associations. On the other hand, when multiple births per woman are used without controlling for the woman effect, some non-existing associations may appear important as p-values will be reduced.

We note the fact that the first option of using only one birth per woman would be appropriate if all births to a woman were perfectly correlated, while the latter option would be ideal if births to the same mother were uncorrelated. Neither of these situations is applicable in our case. Since excluding some cases from the analysis is likely to further increase the anticipated problem of sparseness of cells, we choose to include all the births. A significance level of 0.01 rather than 0.05 is used during model selection to account for the expected reduction in p-values. In order to assess the degree of potential bias in the result, comparisons are made with equivalent multilevel models that take into account the potential correlation of births to the same woman, for selected key variables.

2.2 Analytical Methods

2.2.1 Loglinear Models

Loglinear models are useful in describing association patterns among categorical variables. The loglinear models make no distinction between response and explanatory variables and may be based on different sampling schemes: multinomial sampling scheme, in which the total number of observations is considered fixed; row-multinomial, in which the row totals are fixed; and the independent Poisson sampling scheme, which imposes no restrictions on the cell counts. Nevertheless, much of the theory carries through, regardless of which sampling scheme is adopted (Edwards 1995). Under Poisson sampling, the general loglinear model for a three-way table is given by:

$$log\ m_{ijk} = \mu + ?_i^X + ?_j^Y + ?_k^Z + ?_{ij}^{XY} + ?_{ik}^{XZ} + ?_{jk}^{YZ} + ?_{ijk}^{XYZ} \qquad [1]$$

where m_{ijk} are the expected cell frequencies; singly-subscripted ? are the main effects; doubly-subscripted terms pertain to two-factor interactions; and the triply-subscripted term pertain to the three-factor interaction.

Equation [1] represents the saturated model which perfectly fits the data, and setting certain parameters in the equation equal to zero yields models of marginal, conditional or mutual independence. In this paper, selection of terms in the model is based on the likelihood ratio test statistic, particularly edge exclusion deviances. The modelling is restricted to hierarchical loglinear models, whereby the inclusion of higher-order effects implies that the corresponding lower-order effects are also included in the model. Details on loglinear model estimation and selection is available in standard textbooks on categorical data analysis (see for example, Agresti 1996).

2.2.2 Graphical Models

Graphical modelling is a powerful method of formulating and interpreting complex multivariate models, where graphs are used to represent models. The models enable concise representations of associational and causal relations between variables under study (Edwards 1995). Graphical association models include graphical loglinear models for contingency tables and covariance selection models for correlation matrices. In this paper, we only focus on graphical loglinear models for categorical data analysis.

Each model is represented by a graph where variables (vertices) are represented by dots. Connections (edges) between variables are either lines, representing symmetric associations between variables, or arrows, representing potentially causal associations. Each missing connection corresponds to conditional independence. Two variables are said to be conditionally independent, given the remaining variables, if and only if in the loglinear model all interaction terms involving the two variables are zero. In graphical modelling, our interest is in the inclusion or exclusion of a connection (association/ interaction between variables) and not individual variables.

A class of graphs of special interest is the class of chain graphs, which tie in with the early proposal for path analysis, where the use of graphs with arrows and lines were suggested to formulate a statistical model (Wermuth and Lauritzen 1990). A description of the chain graphs is given in Appendix i.

Graphical loglinear chain models are used, in this paper, primarily to formulate hypotheses about indirect relations in an association structure. The procedure involves partitioning the variables into sub-sets (blocks), ordered to form a chain, based on possible causal direction that is determined a priori. The analysis entails the study of inter-block associations and associations between variables in different blocks to provide direct and indirect pathways from each of the determinants to the outcome variables. Any association between two variables from the same block is assumed to be non-causal, while association between two variables from different blocks is considered as potentially causal. Linking the blocks into a chain gives the direct and indirect paths between any variables and their potential determinants. This method has been applied successfully in the analysis of determinants of infant mortality in Malaysia (see Mohamed, Diamond and Smith 1998).

The factors included in this analysis are partitioned into four distinct blocks, ordered to form a chain. At the end of the chain is the block consisting of indicators of unfavourable birth outcomes, namely, premature delivery, small baby at birth and Caesarean section delivery. The birth outcomes are assumed to be directly influenced by maternal health care and nutritional status grouped in the third block. Alongside these factors are the biological factors, such as multiple births and sex of child, which may also have a direct influence on the birth outcomes. The second block consists of factors relating to reproductive behaviour and accessibility of health services. These factors may contribute to unfavourable birth outcomes either directly or indirectly through the factors in the third block. In the first block, we have the socio-economic and demographic factors, which may influence birth outcomes through the intermediate factors, but may at the same time have a direct influence on the birth outcomes. These potential interrelations are summarized in the conceptual framework presented in Figure 1.

(Figure 1 about here)

The number of cases included in the analysis ranges from 6107 for the model containing only Block 1 variables to 5336 for the complete model containing variables in all the blocks. The analysis is based on cases which had complete information on all the variables in the respective models. The per cent distribution of variables in the complete model is given in Table 1.

(Table 1 about here)

The final models are selected by stepwise backward elimination procedure. Starting with the model with all connections present, the non-significant connections (based on edge exclusion deviances) are excluded one at a time, removing the least significant connection first, until only the significant connections ($p<0.01$) are left in the model.

3 Results

3.1 Associations Between the Background Socio-economic and Demographic Factors

The socio-economic and demographic factors that are included in the analysis are urban/rural residence, ethnicity, the level of maternal education, household socio-economic status, maternal age group and marital status. Some of the important factors, such as region and partner's education, were not included due to their strong correlation with variables already in the model. For instance, region is strongly correlated with ethnicity and the partner's level of education has a strong correlation with both household socio-economic status and the level of maternal education. The decision of which factor to retain was made on the basis of theoretical as well as statistical considerations. For example, ethnicity was chosen over region since it is a good indicator of the different cultural practices that play an important role in maternal health and birth outcomes. Within the Kenyan context, and Africa as a whole, ethnicity defines an individual's identity with a particular group, having a distinctive language, values and culture. It is a powerful factor from which individuals derive their fundamental identities and values. Indeed, preliminary analysis confirmed that ethnicity explains a larger proportion of the variations observed than region of residence. The edge exclusion deviances based on the two-way interactions model are presented in Table 2.

(Table 2 about here)

The total deviance to explain in Block 1, which is the deviance against complete independence of the six background socio-demographic factors, is 4169 on 957 degrees of freedom. The residual deviance of the two-way model presented in Table 2 is 991 on 880 degrees of freedom, implying that a substantial proportion of the deviance is accounted for by the two-way interactions.

The results show that all the background socio-demographic factors in Block 1, except maternal age and household socio-economic status are dependent on each other given the rest of the factors. The particularly high edge exclusion deviances for the interactions between age and marital status, and between household socio-economic status and both rural/urban residence and education are due to the fact that single mothers are more likely to be young and women of high socio-economic status are more likely to be highly educated and reside in urban areas. The independence graph for the associations between Block 1 variables is presented in Figure 2. Any two variables connected with an edge have a significant association given the rest of the factors in this block, while the absence of an edge implies conditional independence between the factors.

(Figure 2 about here)

The independence graph shows that maternal age is independent of household socio economic status given the rest of the variables. The relationship between maternal age and ethnicity is a reflection of regional/cultural differentials in fertility behaviour. For instance, a relatively high proportion of births will occur among younger women in communities where women marry and start child bearing early as opposed to those where marriage usually occurs at a later age. It is important to note that the associations observed between the various factors and ethnicity may reflect the association between these factors and region, since region and ethnicity are highly correlated.

3.2 Reproductive Behaviour and Accessibility of Maternal Health Care Services

Three factors relating to reproductive behaviour and one factor used as an indicator of the accessibility of a facility offering maternal health care were included in Block 2. The reproductive factors were the birth order, the desirability of the pregnancy, and ever use of family planning while time to the nearest delivery care facility was used as a measure of accessibility of maternal health care. The loglinear models at this stage included the variables in the first two blocks. The analysis of the association structures involved the study of the associations between factors in Block 1 and Block 2 (inter-block associations), as well as associations of variables within Block 2 (intra-block associations), conditioned on factors in both Block 1 and Block 2. The edge exclusion deviances for the two-way interactions with the Block 2 variables are presented in Table 3.

(Table 3 about here)

A very strong association was observed between maternal age and the birth order. This is expected since higher order births are more likely to occur among the older than younger women. The other fairly strong associations are: between the birth order and the desirability of a pregnancy, the level of maternal education and marital status; between desirability of a pregnancy and marital status; between family planning use and ethnicity; and between health facility accessibility and urban/rural residence. The conditional probabilities (not shown) reveal that women with high education or those who are single are less likely to have higher order births compared to their counterparts with lower education or those who are married. The strong association between ethnicity and ever use of modern family planning methods is a reflection of the regional and/or cultural disparities in the use of family planning in Kenya. As would be expected, urban residents have better access to maternal health care services than rural residents.

The independence graph for the intra-block associations of reproductive behaviour and service accessibility, as well as the associations with the background socio-demographic characteristics, is given in Figure 3.

(Figure 3 about here)

The independence graph in Figure 3 shows that birth order, the desirability of a pregnancy and ever use of family planning are mutually dependent given the background socio-demographic characteristics and accessibility of a maternal health facility. However, each of these three factors is independent of maternal health facility accessibility once urban/rural residence, ethnicity and household socio-economic status are controlled for.

The graph further shows that birth order and ever use of modern family planning methods are associated with all the background socio-demographic factors included in the analysis. The desirability of a pregnancy is also associated with all except household socio-economic status. Maternal health facility accessibility is dependent on urban/rural residence, household socio-economic status and ethnicity. The association between the accessibility of maternal health services and ethnicity is a reflection of the regional disparities in the distribution of health facilities in the country.

As mentioned earlier, this analysis uses multiple births per woman which might create spurious associations, since births to the same mother are likely to exhibit some similar characteristics. For instance, some women may be more likely to have unintended (unwanted or mistimed) pregnancies than others. One way of assessing the degree of potential bias resulting from use of multiple births per woman is through a comparison of the results obtained in the loglinear analysis with results based on multilevel logit models that control for correlation between births to the same mother. When all explanatory variables are categorical, logit models have equivalent loglinear models (see, for example, Agresti 1996:163). A comparison of the loglinear results for factors associated with the desirability of a pregnancy with the corresponding multilevel logit model, that controls for potential correlation of births to the same woman, gives fairly consistent results between the loglinear and the multilevel logit model, despite the observed fairly strong woman effect on the desirability of a pregnancy. All the variables which showed a significant association with the desirability of a pregnancy in the loglinear analysis are significant in the multilevel logistic regression analysis. The loglinear analysis shows that desirability of a pregnancy is independent of household socio-economic status and maternal health facility accessibility. These results are confirmed by the multilevel logistic analysis, which shows that these variables are not significantly associated with the odds of an unintended pregnancy.

3.3 Prenatal Care and Maternal Nutritional Status

Prenatal care and maternal nutritional status are likely to have a direct influence on undesirable birth outcomes, such as premature delivery, size of baby at birth and Caesarean section deliveries. Appropriate antenatal care is measured in terms of the timing of the first visit and the frequency of visits during pregnancy. These two variables were combined into one in order to retain those who never received any antenatal care in the analysis while at the same time ensuring we do not have structural zero cells which might create problems in the modelling process. Maternal nutritional status is based on maternal height and weight-for-height. These three variables make up the third set of factors, Block 3. The edge exclusion deviances for the two-way associations between these variables with Block 1 and Block 2 variables are presented in Table 4.

(Table 4 about here)

The associations between antenatal care and ethnicity, the level of maternal education and household socio-economic status are fairly strong. An examination of the conditional probabilities reveal that the Luo have the highest probability of having no antenatal care. On the other hand, the Kikuyu have the highest probability of having received some antenatal care, but at the same time more likely to start antenatal care late in pregnancy. Those with at least secondary level education or in households of high socio-economic status have significantly higher probabilities of starting antenatal care early (in the first trimester) and of receiving at least four antenatal care visits during pregnancy.

The indices of nutritional status, namely height and weight-for-height, are strongly associated with each other. The conditional probabilities show that short women are likely to have high weight-for-height. Like antenatal care, weight-for-height has significant associations with almost all the factors in the first and second blocks. The relationships with household socio-economic status and ever use of family planning are particularly strong. The conditional probabilities indicate that high household socio-economic status and ever use of modern family planning methods are associated with high weight-for-height score.

On the other hand, height has significant associations only with ethnicity and education level, in addition to weight-for-height. Even though height is a measure of nutritional status, the strong association between height and ethnicity can be partly attributed to genetic differences between the various ethnic groups. Members of specific ethnic groups tend to be shorter or taller than others even when they are exposed to the same environment. However, the fact that conditional probabilities of height given education show that those with low education are more likely to be shorter than those with higher educational attainment is probably an indication of higher nutritional status for the later. Figure 4 summarises the direct associations with Block 3 factors based on intra-block associations and inter-block associations with factors in Blocks 1 and 2.

(Figure 4 about here)

3.4 Associations with Unfavourable Birth Outcomes

The unfavourable birth outcomes included in this analysis, namely, premature delivery, small size of the baby at birth and Caesarean section deliveries may be associated directly or indirectly with the factors in the three blocks discussed in the previous sections. In addition to these factors, birth outcomes may also be directly associated with some biological factors, such as multiple births or the sex of child. A test for an association between multiple births and the sex of child showed no significant relationship. The direct associations between the unfavourable birth outcomes and the potential determinants are shown by the edge exclusion deviances given in Table 5.

(Table 5 about here)

There is a strong association between the size of the baby at birth and premature deliveries, which is not surprising since premature babies are usually smaller than average. Other strong associations are between Caesarean section deliveries and ethnicity, household socio-economic status and maternal height. The highest proportion of Caesarean section deliveries are among the Kikuyu women, those in households of high socio-economic status and among short mothers. While short maternal stature may be associated with difficult deliveries, making it necessary to have a Caesarean section, higher rates of Caesarean section deliveries among the Kikuyu or women of high socio-economic status may be attributed to better access and utilization of essential maternal health care services by these sub-groups of women. With respect to the baby's size at birth, the most important factors include the sex of child, multiple births and birth order. The intra-block and inter-block associations of the undesirable birth outcomes are presented in Figure 5.

(Figure 5 about here)

Figure 5 shows that the size of baby at birth and Caesarean section delivery are independent, given the timing of birth (premature or full term) and the rest of the factors. However, both the size of the baby at birth and Caesarean section delivery are associated with the timing of birth. Premature babies are more likely to be small at birth, and also more likely to be by Caesarean section delivery compared to full term babies.

The factors which are directly associated with premature delivery include: maternal age, ethnicity, birth order, antenatal care and multiple births. The size of the baby at birth is associated with the same set of factors except ethnicity. In addition to the above factors, the sex of the child is also associated with the baby's size. A number of factors have a direct association with Caesarean section deliveries. These include: socio-economic and cultural factors, such as maternal education level, urban/rural residence, household socio-economic status, and ethnicity; demographic factors, namely, maternal age and birth order; health care factors, such as service accessibility, and ever use of modern family planning methods; and maternal nutritional status, measured in terms of maternal height and weight-for-height.

Some of the variables do not have a direct association with the poor birth outcomes, but may be linked to these outcomes indirectly through other factors. For instance, the desirability of a pregnancy and marital status have no direct association with poor birth outcomes. However, both of these factors appear to be associated with a premature birth and the baby's size at birth through antenatal care. There are many possible paths in the system, and it is difficult to present these clearly in a single graph. Hence, the variables are re-arranged such that variables which are dependent on each other, and have common associations, are put in sub-blocks. The set of edges connecting each of the variables in a sub-block to a particular variable may then be replaced with a single edge connecting the variable to the sub-block. However, if the associations are only with some of the variables in a sub-block, then edges are drawn to these particular variables (see, for example, Mohamed *et al*. 1998). The intra-block and inter-block associations for the whole framework are presented in Figure 6. This figure shows both the direct and indirect associations.

(Figure 6 about here)

Figure 6 demonstrates that all the factors in Block 1 have a direct or an indirect association with a premature birth, the baby's size at birth and Caesarean section deliveries. Marital status has no direct link with these birth outcomes, but is linked to them through its association with intermediate factors, such as birth order, family planning practise, and antenatal care. Maternal age on the other hand, has both direct and indirect associations with all these birth outcomes. The socio-economic indicators, namely, the level of maternal education, urban/rural residence and household socio-economic status all have direct associations with Caesarean section delivery and are linked to premature deliveries and the size of the baby at birth through the factors in the second and third blocks. Ethnicity has a direct association with premature births and Caesarean section deliveries, and is linked to the baby's size through birth order and antenatal care.

Among the variables in Block 2, birth order has a direct link with all the birth outcomes. Ever use of modern family planning methods and accessibility of maternal health care have a direct association with Caesarean section deliveries and also have an indirect link with both premature delivery and the baby's size at birth through antenatal care. The desirability of a pregnancy has no direct association with the unfavourable birth outcomes, but is linked to premature delivery and the size of the baby at birth through antenatal care. An important variable in this analysis worth singling out is antenatal care, which constitutes a central link between many of the socio-economic or reproductive factors and birth outcomes. All the socio-economic and demographic factors in Block 1 and the factors relating to reproductive behaviour (except birth order) and facility access in Block 2 are associated with the size of the baby at birth and premature births through antenatal care, even though some of these factors do not have direct associations with the poor birth outcomes.

4 Discussions and Conclusions

This study has examined the associations between various sets of factors that can contribute to unfavourable birth outcomes either directly or indirectly through other factors. The results show a wide range of significant associations both within and between the various sets of factors. The intra-block associations show that all the socio-demographic factors are associated with each other, with the exception of maternal age and household socio-economic status which are independent given the other factors in the block. Clearly, there is an enormous number of potential pathways of the determinants of the unfavourable birth outcomes, considering the observed direct and indirect associations between factors in all the four blocks. These pathways cannot all be discussed in detail, but some deserve particular mention.

When considering only the direct associations with birth outcomes, we would conclude that reproductive factors, such as marital status and the desirability of a pregnancy, have no association with unfavourable birth outcomes, such as prematurity or small baby's size at birth. However, an examination of possible pathways of the determinants of these birth outcomes shows that both marital status and desirability of a pregnancy have an indirect link to the birth outcomes through antenatal care. For example, conditional probabilities show that unintended births or births to single mothers are both associated with poor antenatal care (late start of antenatal care and inadequate number of visits), which is in turn associated with higher probabilities of poor birth outcomes such as premature delivery. Although previous studies had observed similar association patterns between antenatal care and the desirability of a pregnancy or marital status (Weller, Eberstein and Bailey 1987; Joyce and Grossman 1990; Magadi, Madise and Rodrigues 2000) and between antenatal care and birth outcomes (Ahmed and Das 1992; Coria-Soto *et al* 1996; Magadi, Madise and Diamond 2001), the linking role of antenatal care between the different sets of factors only becomes evident in the kind of analysis employed in this paper.

Similarly, results from a single multivariate model on the determinants of premature births can lead to the conclusion that socio-economic factors, such as maternal education, urban/rural residence and household socio-economic status, have no significant association with prematurity (Bener, Abdulrazzaq and Dawodu 1996; Magadi *et al*. 2001; Xu *et al*. 1995). However, this analysis illustrates that even though these factors have no direct association with premature births, they do have an indirect association through some of the intermediate factors, particularly antenatal care, and sometimes through access to maternal health care service. More or less similar pathways exist for the determinants of the baby's size at birth.

In terms of policy implications, an important finding relates to the central role of antenatal care. Antenatal care constitutes the link between many of the socio-economic factors as well as reproductive factors with poor birth outcomes, such as prematurity and small baby's size at birth. Emphasis on appropriate antenatal care, with respect to both timing and frequency of the visits should, thus, be given priority by safe motherhood programmes in Kenya. Such programmes should have special focus on the subgroups which have been identified as having higher risks of not receiving adequate antenatal care, such as women with unplanned pregnancies, single mothers, women of low socio-economic status, and women living in rural areas. The results suggest that poor access of maternal health care services is associated with inadequate antenatal care. A preliminary examination of the distribution of the sample indicated that the majority of women (71%) travel for at least an hour to get to an antenatal care facility, and the results confirm a significant association between the time it takes to get to an antenatal care facility and adequate antenatal care. Thus, making antenatal care services more accessible is likely to make a significant contribution to improving antenatal care in the country.

While the findings of this study highlight the importance of adequate antenatal care in promoting favourable birth outcomes, it is important to recognize that a number of recent studies have queried the effectiveness of some components of antenatal care in reducing the risk of poor pregnancy outcomes. In particular, questions have been raised on the effectiveness of maternal weight and blood pressure measurements, and the frequency of visits (McDonagh 1996; Munjanja, Lindmark and Nystrom 1996; Villar and Bergsjo 1997). Despite these reservations, there is wide support for the argument that antenatal care encourages women to seek trained delivery assistance (Bloom, Lippeveld and Wypij 1999). It is, therefore, necessary that the limited resources available target those components of antenatal care proven to be the most cost effective (see, for example, Villar and Bergsjo 1997).

Apart from providing a comprehensive picture of the determinants of unfavourable birth outcomes, the analysis in this paper sheds some light on possible explanations to some of the inconsistencies on the determinants of poor birth outcomes with respect to specific variables observed in previous studies. For example, the effect of maternal education on premature births is unclear from previous studies. It is likely that studies based on models which include factors, such as antenatal care, through which education is likely to influence premature births, would conclude that education has no effect on prematurity. On the other hand, if the intermediate factors, through which education influences prematurity are not included in the model, education would then appear to be associated with prematurity. This shows that careful selection of variables to be included in the models would help minimise spurious direct association and hence lead to a more accurate identification of the important factors.

A potential limitation of this analysis, mentioned earlier, is the use of multiple births per woman without controlling for the woman random effect, even though we recognize that births to the same mother are likely to be correlated. One way of assessing the extent of the potential bias in the associations due to these correlations is through comparisons with equivalent multilevel logit models that take into account the woman level homogeneity. One such comparison with unintended births as the outcome variable identified exactly the same set of important factors, suggesting that it is unlikely that correlations between births to the same woman could have affected our results significantly.

Further comparisons of the direct associations with unfavourable birth outcomes, with the multilevel logit models of the same outcomes in a separate analysis (see Magadi 1999) also suggest high consistency in the identification of important factors, with a few exceptions. One noticeable difference is with respect to maternal age which is observed to have a significant association with both premature birth and baby's size at birth in the loglinear analysis, but not in the equivalent multilevel logistic analysis. It is likely that the unobservable woman characteristics, which are taken into account by the multilevel models, are correlated with maternal age. As such, the models which do not control for the woman random effect would tend to identify age as an important factor.

With respect to Caesarean section deliveries, again there is reasonable consistency in terms of the important factors, such as maternal height, birth order, ever use of modern family planning methods, maternal age, and household socio-economic status. However, other factors, namely ethnicity, rural/urban residence, maternal education, health facility accessibility and weight-for-age score are significant in the loglinear analysis, but not in the multilevel logistic regression analysis. These factors are likely to be correlated with unobservable factors at the district or woman level which are taken into account in the multilevel analysis.

An important issue worth mentioning is that of self-selection, where for example, mothers from economically advantaged backgrounds, who may have lower risks of adverse birth outcomes, choose to use antenatal services frequently, resulting in a strong positive association between the use of antenatal services and favourable birth outcomes. If the economic characteristics of the women are not adequately captured in the modelling process, the association between antenatal care and birth outcomes may be estimated with positive bias. Alternatively, high-risk mothers may self-select and use antenatal services so that an observed negative association between the use of antenatal care and favourable birth outcomes could be a result of this self-selection (see, for example, Kotelchuck *et al*. 1984; Manski 1989; Pitt 1996). Statistical software to attenuate selectivity bias or endogeneity have recently become available (see, for example, Lillard and Panis 1998) but to the authors' knowledge, such software cannot handle the graphical loglinear chain models used in this study. This is an area for further research.

Overall, this study has made an important contribution on the understanding of the pathways of the determinants of birth outcomes. In particular, the study reveals the importance of factors that may have an indirect association with birth outcome, a phenomenon that other approaches might conceal. The analysis also sheds some light on possible explanations to some inconsistent results from previous studies on the determinants of poor birth outcomes. An important finding for policy relates to the importance of antenatal care, identified as a central link between a number of factors and birth outcomes.

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Table 1 The per cent distribution of variables in the complete loglinear model

Variable Category	Percent	Number of cases[1]
Residence		
urban	10.6	564
rural	89.4	4772
Ethnicity		
Kalenjin	15.8	843
Kamba	9.7	515
Kikuyu	15.3	819
Luhya	18.9	1006
Luo	14.5	775
other	25.8	1378
Maternal Education Level		
None or primary incomplete	58.6	3127
primary complete	20.9	1115
secondary and above	20.5	1094
Household Socio-Economic Status[2]		
low	34.7	1853
medium	53.7	2867
high	11.5	616
Maternal Age		
below 20 years	18.4	984
20-34 years	70.0	3736
35 years and above	11.5	616
Marital Status		
single	7.7	409
married	85.3	4552
previously married	7.0	375
Birth Order		
1st	20.2	1077
2-4	43.2	2303
5+	36.7	1956
Desirability of the Pregnancy		
wanted then	47.9	2554
wanted later or no more	52.1	2782
Ever use of Family Planning		
never used modern methods	60.3	3216
ever used modern methods	39.7	2120
Time to Nearest Maternal Health Facility		
less than 1 hour	28.7	1533
1 hour or more	71.3	3803

[1] – Cases missing information on any of the variables in the complete model are excluded.
[2] - Household socio-economic status index, derived from reported household possessions and amenities.

Table 1 (Continued)

Variable Category	Percent	Number of cases
Timing of 1st Antenatal Care Visit, and Frequency of Visits		
no antenatal care	3.8	203
3rd trimester, less than 4 visits	11.5	615
2nd trimester, less than 4 visits	17.5	933
1st trimester, less than 4 visits	0.6	33
3rd trimester, 4 or more visits	4.4	234
2nd trimester, 4 or more visits	48.9	2607
1st trimester, 4 or more visits	13.3	711
Weight-for-Height[3]		
low (less than 100)	18.0	959
average (100-120)	51.9	2769
high (greater than 120)	30.1	1608
Height (cm)		
less than 150	5.4	290
150-160	49.6	2648
more than 160	44.9	2398
Sex of Child		
male	49.9	2664
female	50.1	2672
Multiple Births		
single birth	97.0	5176
multiple births	3.0	160
Baby's Size at Birth		
normal /big	84.7	4518
small /very small	15.3	818
Premature Delivery		
full term	96.2	5134
premature	3.8	202
Delivery by Caesarean		
no	95.0	5069
yes	5.0	267
All	**100**	**5336**

[3] - Weight-for-height per cent of WHO reference median, categorized as: Low (less than 100), Average (100-120), and High (greater than 120).

Table 2 The edge exclusion deviances for the associations between the socio-demographic factors (The degrees of freedom are given in brackets)

Variable	Age	Education	Residence	Socio-economic Status	Ethnicity
Education	290.4 (4)**				
Residence	11.0 (2)*	40.9 (2)**			
Socio-economic status	1.1 (4)	370.8 (4)**	652.1 (2)**		
Ethnicity	48.2 (10)**	158.2 (10)**	153.8 (5)**	193.4 (10)**	
Marital status	417.4 (4)**	76.7 (4)**	15.1 (2)**	20.4 (4)**	104.3 (10)**

Note: ** - Significant at 0.1% level (p<0.001)
* - Significant at 1% level (p<0.01)

Table 3 Edge exclusion deviances for the factors relating to reproductive behaviour and service accessibility factors (The degrees of freedom are given in brackets)

Variable	Birth order	Pregnancy wantedness	Use of family planning	Facility accessibility
Pregnancy wantedness	191.4 (2)**			
Use of family planning	30.75 (2)**	38.73 (1)**		
Facility accessibility	3.93 (2)	0.07 (1)	5.19 (1)	
Maternal age	2584 (4)**	22.26 (2)**	9.51 (2)*	1.45 (2)
Education	268.3 (4)**	16.05 (2)**	131.5 (2)**	9.61 (2)*
Residence	24.61 (2)**	13.47 (1)**	39.99 (1)**	330.1 (1)**
Socio-economic status	19.25 (4)**	3.20 (2)	90.18 (2)**	10.16 (2)*
Ethnicity	59.6 (10)**	67.73 (5)**	170.2 (5)**	28.59 (5)**
Marital status	291.1 (4)**	213.9 (2)**	12.79 (2)*	1.63 (2)

Note: ** - Significant at 0.1% level ($p<0.001$)
* - Significant at 1% level ($p<0.01$)

Table 4 Edge exclusion deviances for the factors relating to antenatal care and maternal nutritional status (The degrees of freedom are given in brackets)

Variable	Timing and frequency of antenatal care	Height	Weight-for-height
Height	25.55 (12)		
weight-for-height	42.79 (12)**	268.7 (4)**	
Birth order	24.35 (12)	9.13 (4)	7.87 (4)
Pregnancy wantedness	42.12 (6)**	1.20 (2)	6.74 (2)
Use of family planning	91.70 (6)**	2.57 (2)	128.4 (2)**
Facility accessibility	22.85 (6)**	0.31 (2)	24.91 (2)**
Maternal age	40.51 (12)**	5.66 (4)	23.35 (4)**
Education	149.9 (12)**	61.1 (4)**	29.38 (4)**
Residence	36.40 (6)**	8.54 (2)	63.40 (2)**
Socio-economic status	144.6 (12)**	12.76 (4)	120.6 (4)**
Ethnicity	210.1 (30)**	368.9 (10)**	113.3 (10)**
Marital status	38.18 (12)**	7.70 (4)	10.09 (4)

Note: ** - Significant at 0.1% level ($p<0.001$)
* - Significant at 1% level ($p<0.01$)

Table 5 Edge exclusion deviances for the associations with poor birth outcomes and assistance during delivery (The degrees of freedom are given in brackets)

Variable	Premature birth	Small baby	Caesarean section
Small baby	219.0 (1)**		
Caesarean section	10.65 (1)*	2.97 (1)	
Antenatal care	40.28 (6)**	25.95 (6)**	10.80 (6)
Height	4.82 (2)	3.49 (2)	31.39 (2)**
weight-for-height	2.96 (2)	5.14 (2)	29.54 (2)**
Birth order	15.45 (2)**	22.63 (2)**	29.47 (2)**
Pregnancy wantedness	0.15 (1)	0.04 (1)	0.12 (1)
Use of family planning	2.92 (1)	1.02 (1)	17.44 (1)**
Facility accessibility	1.97 (1)	0.57 (1)	10.80 (1)*
Maternal age	11.27 (2)*	18.69 (2)**	10.54 (2)*
Education	8.01 (2)	1.18 (2)	20.95 (2)**
Residence	6.49 (1)	0.46 (1)	29.77 (1)**
Socio-economic status	7.52 (2)	0.33 (2)	40.69 (2)**
Ethnicity	18.95 (5)*	8.34 (5)	65.45 (5)**
Marital status	4.81 (2)	8.86 (2)	6.69 (2)
Sex of child	0.27 (1)	38.45 (1)**	2.16 (1)
Multiple births	25.01 (1)**	20.87 (1)**	0.52 (1)

Note: ** - Significant at 0.1% level ($p<0.001$)
* - Significant at 1% level ($p<0.01$)

Figure 1 Framework for pathways of determinants of unfavourable birth outcomes

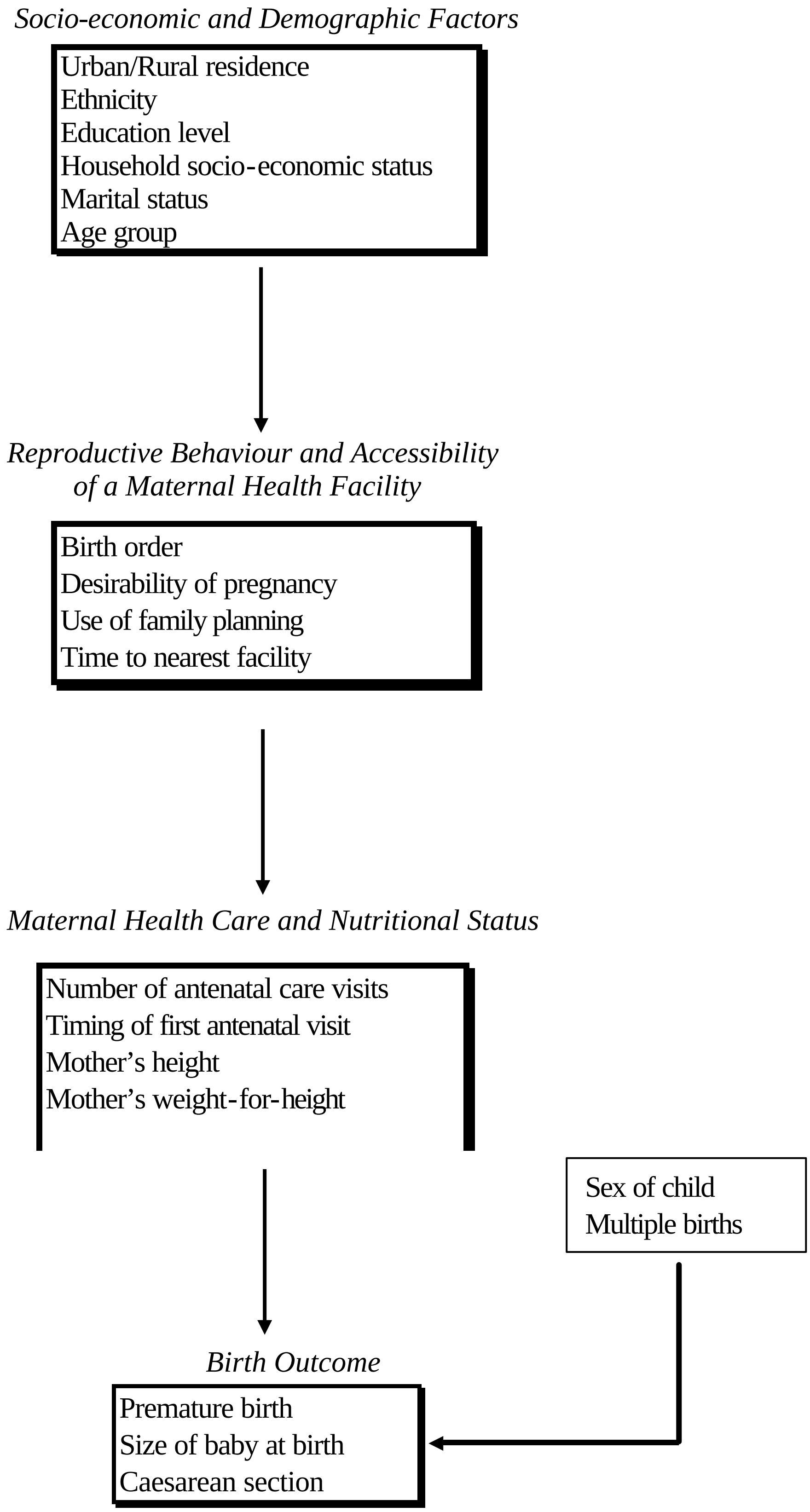


Figure 2 Independence graph for background socio-demographic factors

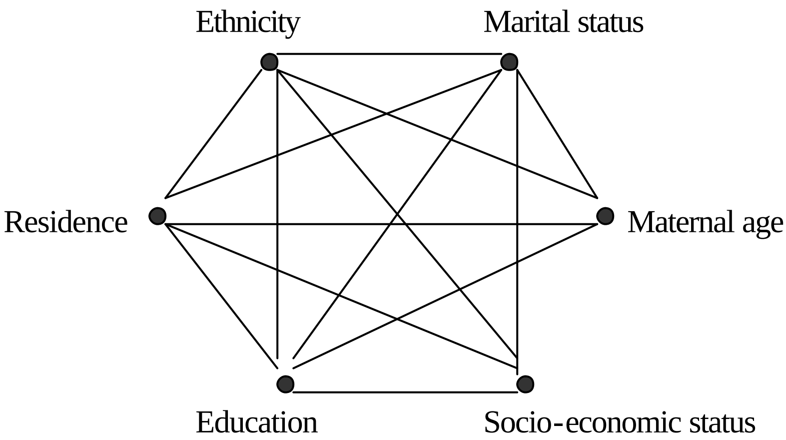


Figure 3 Reproductive behaviour and service accessibility factors (intra-block and inter-block associations)

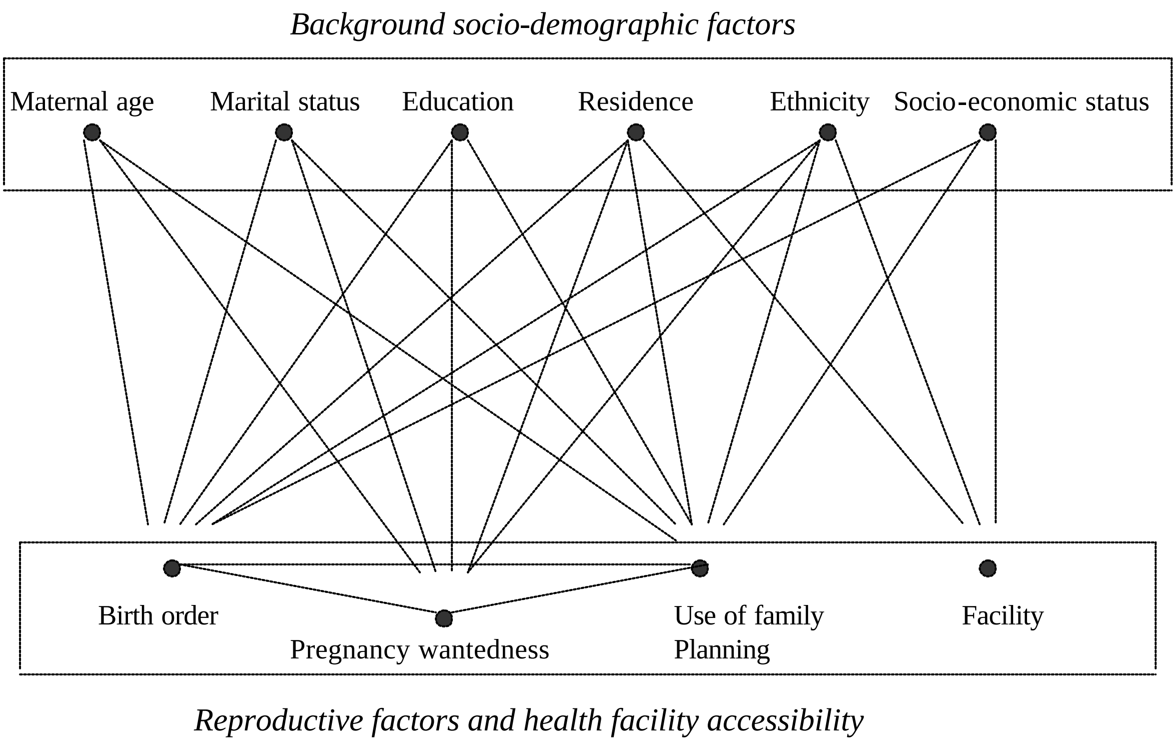


Figure 4. Intra-block and inter-block associations with antenatal care and maternal nutritional status

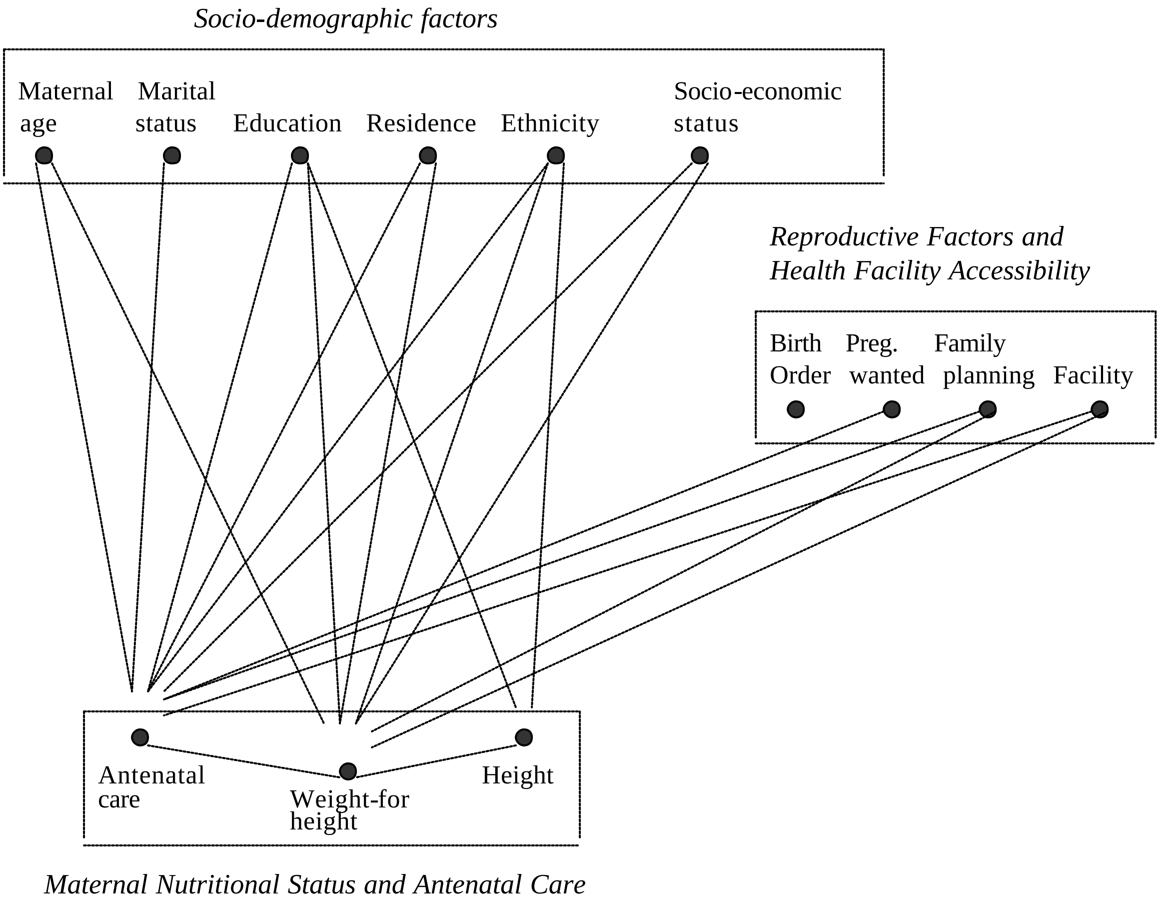


Figure 5 The direct associations with unfavourable birth outcomes

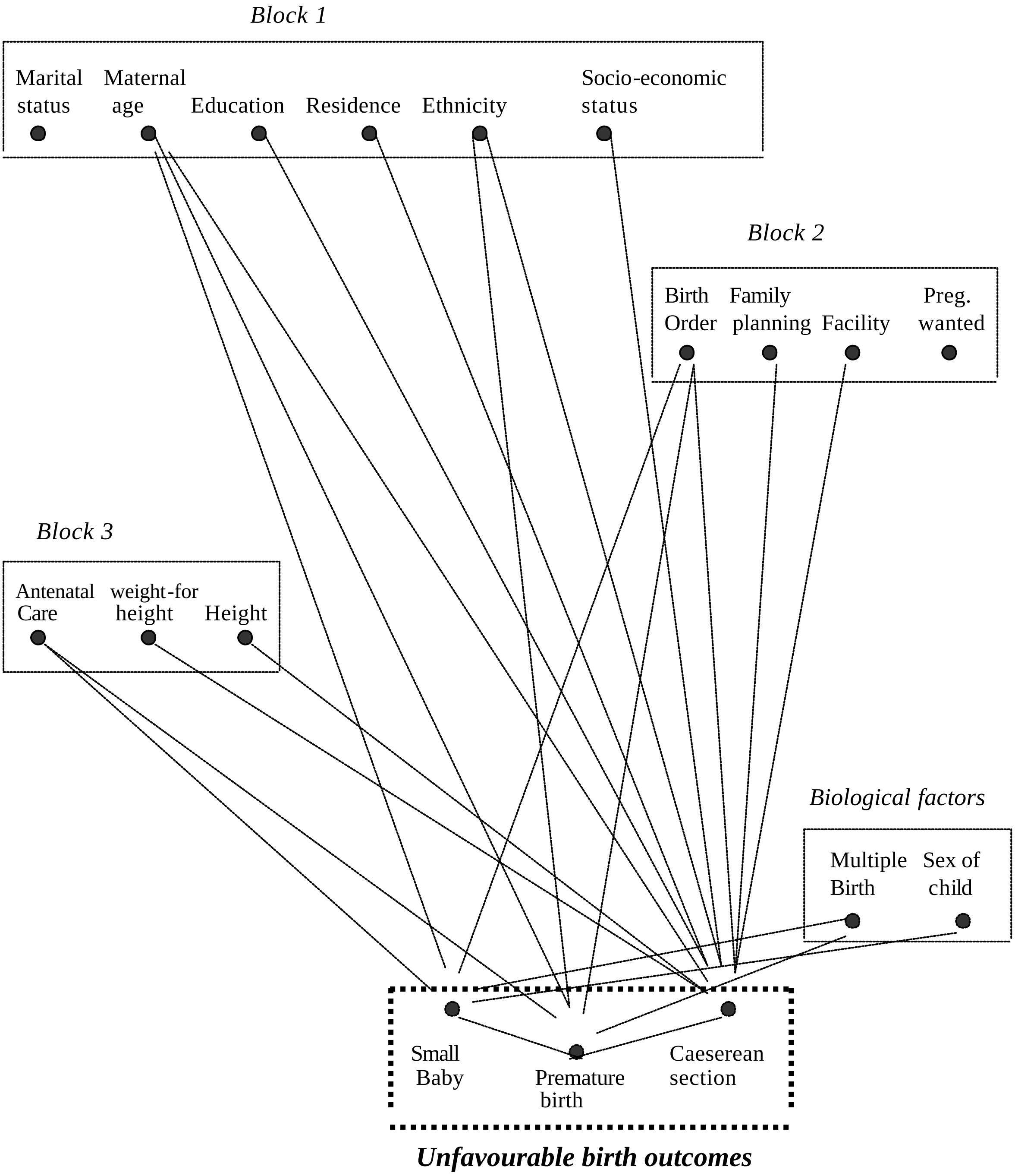
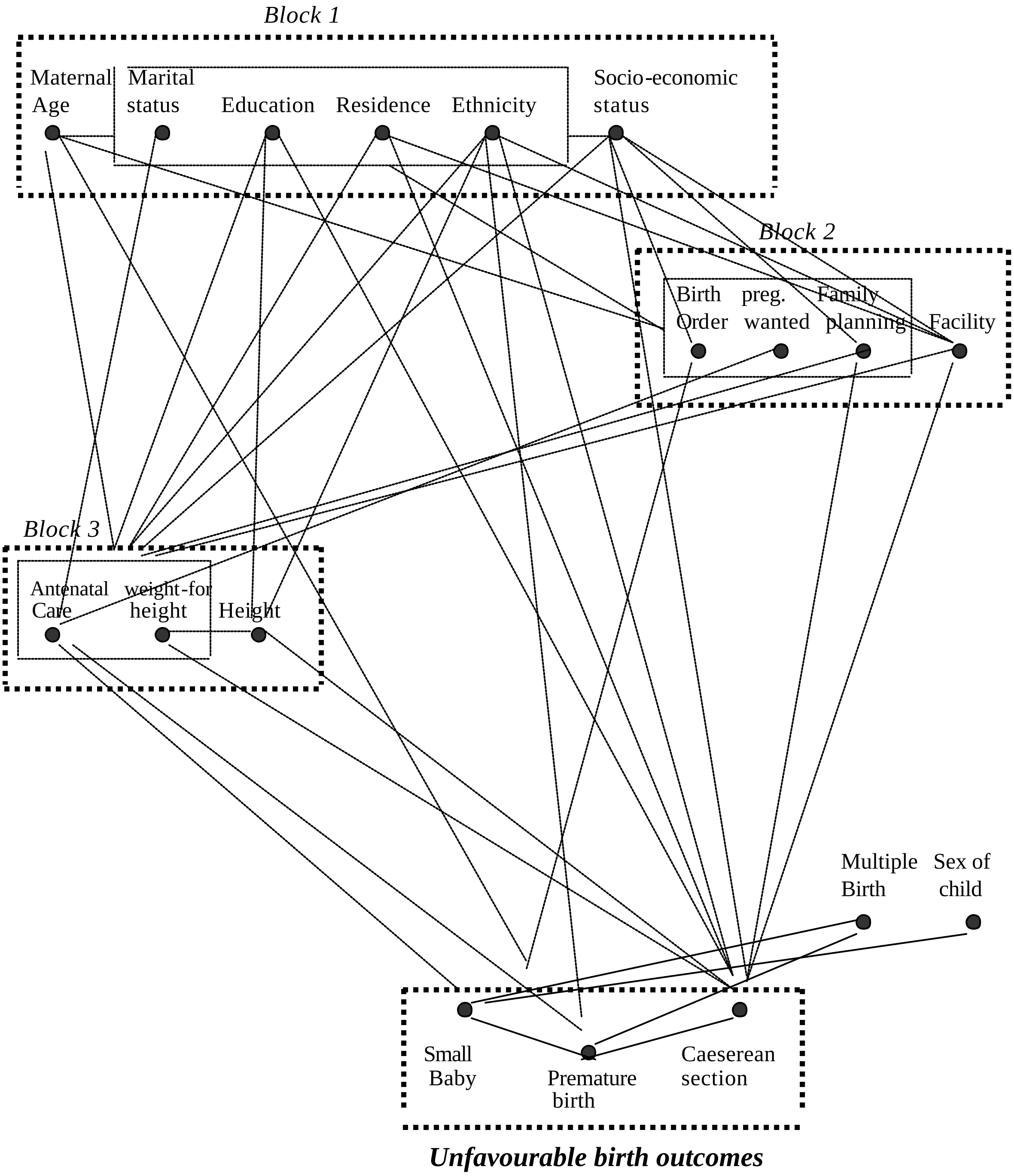


Figure 6 The direct and indirect pathways of determinants of unfavourable birth outcomes



Appendix i: A Description of Chain Graphs.

The chain graphs are based on a partition of the variable (vertex) set $V = \{ v_1,...,v_n\}$ into disjoint subsets, $V = S_1 \cup S_2 ... \cup S_k$ and a corresponding factorization of the joint density $f(v_1,...,v_n)$ as:

$$f(S_1)f(S_2 \mid S_1)...f(S_k \mid S_{k-1}, S_{k-2}, ..., S_1)$$ (see Edwards 1995).

The subsets S_i are called chain components or blocks. Variables in the same block are concurrent, thus, their association structure is assumed symmetric, without causal ordering. The components are ordered such that S_i is prior to S_{i+1} for $i = 1,...,k-1$. All edges between vertices in the same block are undirected, and all edges between different blocks are directed, pointing from the block with the lower number to the higher. If a line is missing between two vertices v,w in the same block S_i , or an arrow is missing from $v \in S_j$ for $j<i$, to $w \in S_i$ then this means that:

$$v \perp w \mid S_1 \cup S_2 \cup ... \cup S_i \setminus \{v,w\},$$

read as, v is independent of w, given the rest of the factors in the current and previous blocks. The chain components are perhaps best interpreted as delineating a data analysis strategy: first, an undirected model for the variables in S_1 will be chosen, then the conditional distribution of S_2 given S_1 will be modelled, then the conditional distribution of S_3 given S_1 and S_2 will be modelled, and so on.