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Birth Weight Data in 15 Demographic and Health Surveys

by

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Abstract

Birth weight is an important indicator of the health and survival prospects of a newborn and is related to disease in later life. Population representative data on birth weight in many developing countries is lacking, especially where many births occur at home. Retrospective surveys, such as Demographic and Health Surveys (DHS), are widely used although restrictions on data availability still occur as many infants are never weighed at birth. Due to this, major bias is observed when birth weight is used in statistical modelling of health outcomes, as many infants are excluded from analyses. To reduce this bias a mother's perception of the size of her baby at birth is used by researchers as a proxy variable for birth weight. Little research exists on the systematic evaluation of these data from the DHS, particularly comparing birth weights with mothers' perception of size. There has also been a lack of investigation into alternative methodological approaches which could potentially be used to account for the missing birth weight information in order to derive unbiased parameter estimates from cross-sectional survey data.

This thesis assesses the quality of birth weight information from 15 selected DHS and derives estimates for the proportion of infants with low birth weight (LBW) using a variety of methods. Mother's perception of size is studied in detail to ascertain its validity. The determinants of mother's perception are investigated and the factors contributing to an infant having a correct size assessment established. The assessment of different statistical methods to reduce bias when using birth weight in models of mortality was conducted. These methods included the utilisation of mother's perception of size as a proxy for birth weight and the application of multilevel multiple imputation and inverse probability weighting to the incomplete datasets.

In many countries a large proportion of infants do not have a recorded birth weight, and the weights which are recorded in surveys are highly heaped. Birth weight distributions differ by the method by which birth weight is recorded, either reported from a health card or recalled from a mother's memory. The proportion of infants with LBW varies widely across countries, although the level depends on how infants with weights heaped on 2500g, the boundary for LBW, are treated. By using mother's perception of size for infants without a recorded birth weight, the validity of LBW estimates are improved. Mother's perception of size is skewed towards larger sizes, although birth weight is the strongest predictor of size perception. The reduction of bias in parameter estimates of mortality was greatest when using the technique of multilevel multiple imputation. Using mother's perception of size as a proxy was also seen to be successful in reducing bias in parameter estimates of model covariates.

The quality of birth weight data in DHS surveys is highly variable. Increasing the proportion of infants weighed at birth must be the long-term aim. Before this is achieved various techniques are available to allow the use of current birth weight information in analyses.

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Chapter 1

Introduction

Birth weight is acknowledged to be one of the most important indicators of health in both childhood and in later life (McCormick, 1985; Barker, 1992). New research on different aspects of birth weight is published daily. The importance of birth weight information is implicitly known by the general public, as indicated by the birth weight being reported to friends and relatives after the birth of a child. Mothers can remember their infant's birth weight for many years after the event (O'Sullivan *et al.*, 2000; Catov *et al.*, 2006), although there is less accuracy seen if an individual attempts to remember their own birth weight (Lucia *et al.*, 2006). However, in many developing countries many infants are not weighed at birth, the mother may not be informed of the weight, or she is illiterate and does not understand the usefulness of the birth weight. This thesis examines birth weight in 15 developing countries and investigates methodological issues surrounding the collection and analysis of these weights.

This importance placed on birth weight does have a medical reason, as birth weight is considered to be one of the most important determinants of child survival and health (McCormick, 1985; Kramer, 1987; Abrams and Newman, 1991; Abell, 1992), and is seen as a good indicator of general health at birth (McCormick, 1985; Millman and Cooksey, 1987). On an individual level, a baby who is of light weight at birth is at greater risk of dying early in life than a heavier infant, and thus birth weight can be used as an individual indicator of lifetime risk. Estimates of mean birth weight and the proportion of children who are classified as having low birth weight (LBW; to be defined later) are considered to be good measures of the health of children on a regional and national basis. Furthermore, as birth weight is highly reliant on the nutritional and health status of the mother the average birth weight of infants in an area is sometimes used as a proxy for the health of the local community (World Health Organization, 1984). Reducing the proportion of children with LBW is an important goal of 'A World Fit for Children', a plan of action proposed by the United Nations, which aims to reduce LBW by at least one-third before 2010 (United Nations, 2002), with the ultimate aim of improving rates of child survival. The Millennium Development Goals, although not explicitly having the reduction of LBW as a goal, implicitly includes this as an important facet in the reduction of child mortality by two-thirds between 1990 and 2015 (United Nations, 2000).

As birth weight is such an important indicator, it is essential to be accurate when measuring and recording an individual baby's birth weight. Babies who are at risk due to having a light weight can be immediately placed under medical observation, as happens in many countries in the developed world. A known birth weight is also important for researchers in many fields, as the relationships between covariates and birth weight are often investigated, and as birth weight is an indicator of how healthy the individual child is at birth. The group of infants who are weighed are not a random selection of all children, but are seen to be of a higher socio-economic status (Miller *et al.*, 1993; Eggleston *et al.*, 2000). Analyses conducted on the group of infants with a recorded birth weight will therefore not be valid for the whole population. Thus it is of interest to investigate whether there are any methods that could be used to reduce the bias observed in population estimates when only using those with a reported birth weight. The production of representative estimates of the proportion of LBW infants, the mean birth weight and the relationship between birth weight and mortality within the first year of life can be enhanced if complete birth weight information is known. It is therefore important to study the methodology of birth weight data collection and measurement in order to improve birth weight statistics in developing countries. The understanding of the effect of birth weight on mortality and health outcomes in developing countries is poorer than desired due to the lack of good population representative data.

The official recording of all birth weights for every newborn is desirable and should be the long-term goal of countries. Yet before this goal is attained researchers still have to use the data that is currently available. One source of data in developing countries are Demographic and Health Surveys (DHS). These surveys are nationally representative and study various aspects of population, health and nutrition (ORC Macro, 2005b). These surveys record the birth weight of the infant, if known, and also a great deal of other information. It is possible that this extra information collected may be used if birth weight is missing for an individual to alleviate the issues encountered when there is missing data. One question, asked on a number of DHS questionnaires, is especially interesting: the mother is asked for her assessment of the size of her baby at birth. This variable has been used in some studies as a proxy for birth weight (Da Vanzo *et al.*, 1984; Rodrigues and da Costa Leite, 1999; Magadi *et al.*, 2001; Ghosh, 2006; Magadi *et al.*, 2007), although the exact relationship between birth weight and mother's perception of size is not yet known.

The aim of this thesis is to explore the data on birth weights in 15 DHS and to analyse the association between birth weight and a mother's perception of her baby's size. This is to assess whether birth weight collected in retrospective surveys such as the DHS is valid and reliable in developing countries, and to consider if a mother's perception of her baby's size can be used as a proxy for birth weight. Additionally, the thesis will investigate the use of birth weight in models studying mortality in the first year of life. Statistical methods which can be used when there is missing birth weight data to obtain unbiased estimates of the relationship between birth weight and mortality will be assessed. The research questions of the thesis are presented in the next section.

1.1. Research Questions

There are seven research questions addressed in this thesis:

1. How accurate and representative are mothers at reporting their infant's birth weights?

2. Are there any differences in the distributions of birth weight by reporting method, either from a health card or from a mother's memory?

3. To what extent can mothers' reports of their babies' sizes improve the estimation of mean birth weight and the percentage of infants with LBW in a population?

4. Does the method by which birth weight is recorded in a survey influence the proportion of infants with LBW?

5. What are the maternal characteristics which are associated with an accurate assessment of the size of a baby at birth?

6. What are the determinants of a mother's perception of the size of her baby at birth?

7. Are there any statistical missing data methods that can be applied to datasets which will reduce bias in the parameter estimates of the relationship between birth weight and early neonatal, neonatal and post-neonatal mortality?

1.2. Organisation of the Thesis

The thesis is organised into nine chapters. Chapter 1 provides a brief overview of the background and the rationale of the study, and lists the research questions that this study aims to answer. Chapter 2 provides an overview of the existing literature pertaining to this topic. It is divided into three main sections studying the collection of birth weight information in surveys, the causes of birth weight differentials and the health consequences of various birth weights. There is also an introduction to the terminology that is used when studying birth weight. The data and methods used in the thesis are explained in Chapter 3. The data used in the study will be introduced, and the survey methods used to obtain these data explained. In addition there is a discussion of the explanatory variables used in the analysis, and the quality and limitations of the data. Finally, the main statistical methods used in the thesis will be explained.

Chapter 4 takes a close look at birth weight in the selected surveys to assess the quality and the reliability of these reports. The amount of missing information and the digit preference shown by the recorded birth weights will be calculated. Differences between infants with and without a reported birth weight will be investigated. Also studied will be the differences in the characteristics of infants by the method of reporting birth weight, either from a health card or from a mother's memory, and the effect of the method of reporting on the proportion of infants with LBW will be estimated. The determinants of LBW will also be modelled.

Chapter 5 investigates mother's perception of her baby's size and assesses whether it could be used as a proxy for low birth weight in the countries in the analysis. The reported perception will be studied to gauge if this variable is good at predicting low birth weight at an individual level. To obtain population based estimates of low birth weight, the mother's perception will then be combined with the recorded birth weights. The effect of reporting method on birth weight estimates will also be examined.

The use of mother's perception of size in the accurate estimation of LBW depends on the size assessment by the mother actually being correct. Chapter 6 investigates the proportion of mothers who choose a suitable category of size for their baby, and models the determinants of a correct assessment. The concept of an incorrect appraisal of size is further investigated for three countries, Cambodia, Kazakhstan and Malawi, by studying which mothers overestimated and underestimated the sizes of their infants

Chapter 7 studies the determinants of a mother's perception of size. This is done for infants with a reported birth weight and for all respondents in Cambodia, Kazakhstan and Malawi. The variation in the determinants of size between regions and areas will be examined using a multilevel ordinal response framework.

The determinants of early neonatal, neonatal and post-neonatal mortality are studied in Chapter 8, focusing on statistical missing data methods to mitigate the problem of the missing birth weight information. Four different methods will be studied: complete case analysis, inverse probability weighting, multilevel multiple imputation and using size at birth as a proxy for birth weight. Modelling of mortality will be conducted, applying each of these methods, and the results of the models compared to assess if the estimates of the relationship between birth weight, a number of covariates and mortality are improved.

The final chapter, Chapter 9, draws the main conclusions of the study in relation to the research questions stated in Section 1.1. Limitations of the thesis will be discussed, and possible future avenues of work elucidated.

Chapter 2

Birth Weight: Collecting, Causes and Consequences

This chapter reviews the relevant literature pertaining to the collection of birth weight in surveys, with an emphasis on collection in developing countries. Also reviewed will be literature relating to the causes of birth weight differentials. The weight of a child at birth has important health and social implications, both in the short and long term, and these will be explored. This chapter will firstly explain why the accurate measurement of birth weight is important, before studying previous work which assesses the precision and validity of retrospective surveys in obtaining birth weight information. Previous attempts to compensate for missing birth weight information in surveys from developing countries will also be reviewed. Further sections will then investigate the causes and consequences of birth weight and low birth weight.

2.1. Introduction

It has long been known that a small newborn baby is at great risk of dying at a young age (McCormick, 1985). But what is a small baby in terms of birth weight? In order to answer this, to facilitate easy comparison between different populations and to increase the simplicity of making targeted policy decisions, birth weight is normally classified into categories. The usual system of classification is to categorise low birth weight into three levels: low birth weight (LBW), very low birth weight (VLBW), and extremely low birth weight (ELBW) (World Health Organization, 2001), although other definitions and groupings have been used. Table 2.1 displays the definition of each of these weight categories. The birth weight should be measured within the first hour of life, as after this time the infants start to lose weight (World Health Organisation, 1992).

Table 2.1: Categorisation and definition of low birth weight

Classification	Weight
Low Birth Weight	Less than 2500g (up to and including 2499g)
Very Low Birth Weight	Less than 1500g (up to and including 1499g)
Extremely Low Birth Weight	Less than 1000g (up to and including 999g)

Source: ICD-10 (World Health Organisation, 2004a)

The artificial divide between 'Low Birth Weight' and 'Normal Birth Weight' is motivated by the finding that infants who weigh less than 2500g are 40 times more likely to die in the neonatal period than those weighing over this amount. This relative risk increases to about 200 times if neonatal mortality is compared between infants who are very low birth weight (VLBW) and those who are normal birth weight (McCormick, 1985). There is also an effect of LBW in the post-neonatal period, although the effect is attenuated somewhat from that seen in the neonatal period. Abell (1992) states that VLBW babies are 94 times more likely to die in the first year as those who are of normal weight, whilst LBW babies are seven times as likely to die within the first year. Many other authors have estimated the increased risk of mortality for LBW infants, and the results show a consistent trend of excess risk for this group (Ashworth and Feacham, 1985; Rinke, 1985; Rogers, 1989; Ashworth, 1998). Increased risk of mortality is also seen for infants who do not have LBW, but weigh less than 3000g (Ashworth, 1998). It is estimated that in the whole world about 14% of babies are born with LBW, but 60-80% of infants who die in the first month of life have LBW (Lawn *et al.*, 2005). It has been estimated that moving a single LBW infant out of the LBW category and into the normal birth weight group would save $510 in a low-income country, a not insubstantial figure. This is due to a reduction in mortality, the need for less medical attention and greater productivity throughout life (Alderman and Behrman, 2006).

It is clear that there are some problems with this classification system, as comparisons are made between normal and LBW groups and the continuum of increasing risk as birth weight falls is obscured. Children born weighing 2550g are not much less likely to die than children born weighing 2450g, yet they are placed in different categories. Research articles criticising this classification system have been written (Wilcox, 2001; Hertz-Picciotto, 2003), and attempts to improve on it have been made (Solis *et al.*, 2000) . However the method proposed by Solis *et al.* (2000) is not applicable to developing countries as adjustment for gestational age is required, which is usually either unreliable or unavailable in poorer countries. It is also difficult to turn this alternative classification into targeted policy outcomes.

The contribution of LBW to infant death varies between countries, and is linked to the period within the first year where the burden of mortality falls. In countries where the infant mortality rate is high and there are a concomitantly high proportion of infant deaths in the post-neonatal period, the main causes of death are related to environmental factors and infections. In these countries it is estimated that LBW contributes to less than half of the deaths in the first year of life (Puffer and Serrano, 1973). However, as mortality falls in the post-neonatal period, due to improvements in environmental conditions, and the burden of mortality shifts to the neonatal period, LBW proportionally becomes a larger contributor to mortality (Southgate and Pittard, 2001). Further advances in reducing the infant mortality rate are only possible if the proportion of LBW infants who survive is improved, or if the number of children born with LBW is reduced (McCormick, 1985).

The proportion of LBW infants varies widely between countries, with developed countries having lower proportions than developing countries (UNICEF, 2004; World Health Organisation and United Nations Children's Fund, 2004). In general, the percentage of LBW infants born in developed countries is below 10%, whilst for developing countries the percentage is above this figure (Villar and Belizan, 1982a). Current estimates show that the countries with the highest percentage of LBW infants are Yemen, Sudan, India and Bangladesh, with estimated percentages between 30% and 32%. This can be compared to industrialised countries such as Sweden, France, U.S.A. and the U.K. where the percentage of LBW infants ranges from 4% to 8% (UNICEF, 2004). The great heterogeneity of estimates between countries in the proportion of infants with LBW strongly indicates one reason why infant mortality rates are still extremely variable between countries.

A major problem in the calculation of the proportion of LBW infants within a country is encountered if the birth weight data that are recorded are of poor quality. In developed countries there is usually a good and reliable system for the recording of births, and most births take place within the formal health care system. Therefore the proportion of children born with LBW is calculated from almost the full population of newborn children, and can be taken as fairly accurate. However, in developing countries there is much missing information. Many babies are born at home, and the vital registration systems within these countries are sometimes not developed enough to record all births. Also, some mothers in parts of the world refuse to have their children weighed due to local cultural values and beliefs (Pratimidhi *et al.*, 1986). Moreover, the equipment used to measure the weight of children when they are weighed may be old and inexact, or the traditional birth attendants who may attend the birth may not be literate (Magzoub *et al.*, 1994) or have the required equipment to obtain birth weight (Ahmed *et al.*, 2000). As a result, the calculation of the percentage of LBW children is fraught with difficulties due to the lack of a representative sample for the whole population. A number of researchers have devised strategies to counter these problems, and these will be discussed below.

2.2. Collecting Birth Weight Data

Due to the incomplete nature of vital statistics data collected in many countries and regions of the world, various strategies need to be employed in order to obtain a representative picture of the distribution of birth weight. As shall be seen in the following chapters, the proportion of babies who are not weighed at birth, or at least are not reported to be weighed at birth, can be extremely high. The issue for researchers is how to deal with this missing data, and also to assess whether the information that has been collected is reliable and representative of the full population. Yet before this is discussed for developing countries, the validity of obtaining birth weight information directly from a mother needs to be considered.

2.2.1. Validity of Retrospectively Collecting Reports of Birth Weight

Many large population-based epidemiological studies rely on maternal recall to provide pregnancy related information such as birth weights. Maternal recall provides a 'cost-effective, efficient way to obtain such information' (Tomeo *et al.*, 1999, p. 774), and many studies have attempted to assess the recall for accuracy. This is simple to assess in developed countries where there are reliable records against which the recall can be judged.

In a study conducted in Newcastle-upon-Tyne, U.K., which compared birth weights reported by parents to the hospital records, indications were that birth weights were recalled with a fair amount of accuracy, with the mean difference between actual and recalled birth weight being only 11g, with the recalled weight being lighter. These birth weights were recalled up to 15 years after the birth, indicating reliability over time. A very few parents (0.3%) reported weights which were a large distance away from the true weight, with over a kilo difference between the reported and actual birth weights. Most reports (91%) were within 200g of the actual birth weight (O'Sullivan *et al.*, 2000). Gayle *et al.* (1988), in Tennessee, U.S.A., found that 89% of birth weights were recalled within 1oz (28.3g) of the weights recorded on the birth certificate. Other studies into the recall of birth weight have also found similar results (Robbins, 1963; Joffe and Grisso, 1985; Seidman *et al.*, 1987; Troy *et al.*, 1996; Whincup *et al.*, 1996; Lederman and Paxton, 1998; Sanderson *et al.*, 1998). Seidman *et al.* (1987) found that recall was more accurate for children under 4 years old, although Olson *et al.* (1997) found that there was no change in the reliability of birth weight reports up to 8 years after the birth. Studies which investigate recall after a long length of time still find close concordance with the correct birth weight. Recall of birth weights after 16 years (Burns *et al.*, 1987), 17 years (Lucia *et al.*, 2006), between 1 and 29 years (Lumey *et al.*, 1994) and between 35 to 70 years (Catov *et al.*, 2006) has been seen to be reliable.

Few studies have shown discordance between maternal reports and official records. A study by Oates and Forrest (1984) found that only half the reports of birth weight by the mothers were accurate, but the sample size in this study was small (N=47). A further study which casts doubt on the validity of maternal recall is a recent study from Taiwan (Li *et al.*, 2006). Only 15.9% of mothers classified the birth weights of their infants into the correct 500g weight band, with 65.9% of infants being placed in a weight category higher than their medical record suggests. However, mothers were only asked to categorise the weights into these 500g intervals and were not asked the exact birth weight. This categorisation may lead the mother to make rounding errors or to assess that the accuracy was not vital for the study they were taking part in. Mothers in Taiwan are known to report the birth weights to friends and family after the birth, and some even keep a record of the weights of the infant at monthly intervals[1]. Unless the mothers questioned for Li *et al.*'s (2006) study misunderstood the question and reported the most recently recorded weight and not the birth weight, it is difficult to understand the result of this study. Yet the number of alternative studies indicating that birth weights are recalled well may suggest that this finding is an aberration and not symptomatic of all maternal reports.

Ekouevi and Morgan (1991) looked at the reliability and validity of reported birth weights in three retrospective surveys conducted in the U.S.A.. These surveys were compared with each other and with complete vital registration data in order to assess whether the surveys actually represented the situation in the population as a whole. The individual birth weights were not matched to the official records, but the overall trends in the population studied. Their conclusions were that the results were 'generally encouraging' (p. 144), with the trends in the surveys echoing those in the vital statistics data, and with comparability between the three surveys in question where evaluations were possible. They hypothesised that retrospective reports are fairly accurate if the information being sought is important and not sensitive.

Many of the research papers investigating maternal recall report that, in general, recall of birth weight is good. However, there are some groups of mothers that are less accurate than others in their recall. For example, Gayle *et al.* (1988) found that lower accuracy of recall was associated with many characteristics, such as education, age, marital status, race and parity. Lower education, maternal age under 18 years at the time of birth, Black race and not being married all reduced the accuracy of the reports, as well as having more than three previous births. Medical aspects were also seen to

[1] Personal Communication with Rick Lin from Taiwan

be important, with low birth weight infants, premature infants and infants with a low Apgar score after 1 or 5 minutes all having less accurately recalled birth weights. Variation in accuracy between ethnicities and socio-economic status has also been seen in other studies (Walton *et al.*, 2000; Tate *et al.*, 2005). The influence of infant survival is also related to maternal recall, with one study showing that recall of the weight of infants who have died is extremely poor (Lumey *et al.*, 1994). A linked finding is that the current health status of the child is related to the accuracy of recall of events in infancy. The precision of recalled birth weight is influenced by behavioural problems, with higher problem scores associated with less accurate reporting (McCormick and Brooks-Gunn, 1999). Overall, general recall of events related to pregnancy, labour and early infancy is seen to be good many years after the event, even for sensitive questions (Githens *et al.*, 1993; Tomeo *et al.*, 1999), although subjective assessments of areas such as pain during labour is not reliable over time (Waldenström, 2003). As birth weight is not subjective it is thought that this finding does not invalidate the accuracy of birth weights recalled in retrospective surveys.

O'Sullivan *et al.* (2000) also found that there was evidence of rounding of the birth weights in hospital records, to 0 and 5 gram intervals. This was not replicated in the recalled birth weights, as they were mainly recalled in pounds and ounces and thus did not equate to the same metric intervals as in the medical records. Birth weights from hospitals were also recorded to the nearest 10g in a study in the Netherlands (Lumey *et al.*, 1994). However, this rounding in the hospital records of birth weight raises the issue of the weights being grouped at round numbers during retrospective recall, leading to heaping. Heaping at common values is seen in many survey variables, including gestational age (Pickering, 1992), age (Bairagi *et al.*, 1982), coital frequency (James, 1981), breastfeeding duration (Diamond *et al.*, 1986; Trussell *et al.*, 1992; Singh *et al.*, 1994) and self-reported weight (Rowland, 1990). Digit preference was also observed in official records of birth weight in Canada, with a preference for multiples of 10g detected (Edouard and Senthilsevan, 1997). Heaping was seen to be much less common for birth weights under 1000g, probably due to the need for greater accuracy in the weight for drug doses to be calculated and greater awareness by the mothers of the actual weight. In the U.K. heaping was seen in the

National Child Development Study (NCDS) from 1958, with birth weights commonly reported as being of whole, half and quarter pounds (Sasieni and Royston, 1996).

There are four different points at which errors may occur if birth weight is being obtained from a mother in a retrospective survey (Hewson and Bennett, 1987). Firstly, there may be variability in the actual birth weight recorded by the doctor/midwife. This may be due to differential accuracy of weighing scales, old equipment not giving an accurate recording, or the doctor/midwife not actually reading the weight from the scale correctly. The next point at which an error may occur is when the weight is written onto the records, given to the mother or extracted from the records to use in a study. Nurses may round the weight they report to the mother as they believe an accurate report is not necessary. The third potential point of error is between the birth and recall, where mothers may forget the birth weight. Finally there may be a discrepancy between the recalled birth weight and the weight actually given in response to the question asking for the birth weight. Mothers may round the weight as the importance of giving a precise response is not stressed by the interviewer. Discrepancies between official records and maternal recall may be due to the final two points, although all four areas will lead to incorrectly recalled birth weights. However, in developed countries it is clear that the collection of birth weight information by asking mothers for this information produces data which are accurate and can be used in epidemiological investigations.

2.2.2. Birth Weight Data in Developing Countries

The act of asking mothers for their infant's birth weights in developed countries in retrospective surveys is clearly valid and reliable. Yet the problems faced in developing countries when obtaining birth weights are different, as it is mainly those who are born within an institution who are weighed at birth (Miller *et al.*, 1993). Estimates of the birth weight distribution within these countries used to simply rely on collecting information from these institutions and extrapolating the rates and trends seen in these data to the full population. The World Health Organisation used to monitor the trends in LBW in this manner (World Health Organization, 1984). However, the obvious problem with collecting statistics only from hospitals is that the children born in institutions are unlikely to be a representative sample of the total population (Miller *et al.*, 1993). There are two reasons for this: firstly, mothers' who give birth in hospital are usually from a higher socio-economic group than the main population, and therefore have better nutrition and general health (Ebomoyi *et al.*, 1991), and secondly because it can be hypothesised that births with complications are more likely to occur in hospital. The first reason will reduce the proportion of LBW infants seen and the second will increase it. There is no way of knowing if these two opposite effects are equal in magnitude and a representative sample of the full population will be provided. Therefore, although collecting data from hospitals and other institutions regarding birth weight information is quick and easy compared to alternative methods, the data collected are not representative (Boerma *et al.*, 1996). Also, as varying proportions of mothers deliver with a skilled birth attendant who may accurately weigh the infant in different countries (World Health Organisation, 2004b), there is no comparability of LBW estimates between countries when they are calculated in this way, as mothers who give birth in hospital represent a different stratum of the population in each country.

In order for a representative and more reliable sample of weights to be obtained, a population based sample is therefore more advantageous, although usually harder to implement and obtain. Prospective studies usually have a small sample size or are again restricted to those children who will be born in a hospital, thus undermining the representativeness of the study (Da Vanzo *et al.*, 1984). Therefore the main alternative option is to conduct large scale retrospective surveys, and ask the respondents to report the weight of their children. Although this method of collecting birth weight data does not solve the problem that many children are not weighed at birth, it should be more representative than a simple hospital based study as it will include weights from children born at home and weighed by a health visitor or suchlike. As illustrated, this method of obtaining birth weights is seen to be accurate in developed countries.

Retrospective reports of birth weight in developing countries have been investigated for reliability in Peru (Moreno and Goldman, 1990), the Dominican Republic (Miller *et al.*, 1993) and a selection of South American countries (Robles and Goldman, 1999), with varying conclusions on the accuracy of these surveys. Moreno and Goldman (1990) found that those with a reported birth weight did show the expected relationships with a number of known covariates and with infant mortality, and thus the individual reports of numerical weights were fairly reliable. However, 32% of infants did not have a reported birth weight and the omission of these infants from the estimation of the proportion of infants with LBW and in models using birth weight will potentially cause bias in the estimates.

Miller *et al.* (1993) studied reports of both birth weight and prematurity status in the Dominican Republic. These two variables are inextricably linked, for obvious reasons, and will be further investigated later in the chapter. They compared the birth weight and prematurity distributions with results from other studies in Latin American and Caribbean countries to assess the accuracy of the reports. The birth weight distribution followed the expected pattern with the modal birth weight falling between 3000g and 3499g, with only a few births weighing under 1500g. However, they found a high proportion of births weighing over 4000g which exceeded estimates from most other surveys, and a lower than expected proportion of LBW infants when compared with other Caribbean islands. About 10% of the infants in the survey did not have a reported birth weight. However, they concluded that this was not a large problem in this instance with respect to the general reporting of birth weight. Therefore, again the evidence is encouraging that birth weight can be obtained from retrospective surveys in developing countries.

One study that does not have such an optimistic conclusion was conducted by Robles and Goldman (1999) which assessed the accuracy of the birth weight information from six Demographic and Health Surveys (DHS) in South America. The assessment was conducted by studying the patterns shown within the data and checking for consistency and coherency. They concluded that reports of birth weight in the countries studied are subject to a large amount of error. One major source of error is that birth weights are reported for infants who were probably never weighed, as mothers or unqualified helpers estimate the weight of the newborn without using scales. A further source is that some children are weighed at post-partum check-ups, and the mother has reported the weight recorded at these check-ups as the birth weight. The authors reached these conclusions due to the large proportion of infants who were born at home and yet still had a reported birth weight. The two hypothesised sources of error will cause the proportion of LBW infants to be lower and the mean birth weight to be higher than expected as estimations of weights are usually heavier than the actual birth weight, and weighing at a post-partum check-up could take place over a month after the birth. There is also a large amount of heaping at 500g or 8oz intervals, depending on the unit of measurement of weight used in the country. The amount of heaping varies by the educational status of the mother and by the place of delivery. Heaping of birth weight data were common among infants of mothers with low levels of education and those who were born at home. Birth weights given to mothers after both home and hospital births may be rounded, although the higher levels of heaping seen in home births imply that some estimation of birth weights is happening at home. The authors recommend that surveys should collect information about the source of the birth weight information, such as whether the report came from a hospital record or from the memory of the mother (Robles and Goldman, 1999).

The above assessments of the accuracy and reliability of birth weight indicate that there may be some problems with using survey data in the estimation of population based estimates of birth weight in developing countries. One of the major issues with the use of retrospective surveys is the amount of missing data in developing countries. Also, as noted previously, those who do report a birth weight are also likely to be a select sub-group of the population under question (Moreno and Goldman, 1990; Miller *et al.*, 1993). Much important and interesting information will be discarded if those infants without a birth weight are not used in analyses. In order that a fuller sample from the survey is used some authors have used subjective accounts of an infant's size at birth as a proxy for the birth weight to investigate LBW (Da Vanzo *et al.*, 1984; Moreno and Goldman, 1990; Boerma *et al.*, 1996; Eggleston *et al.*, 2000; Blanc and Wardlaw, 2005). It may be hypothesised that as a size assessment is a subjective measure the response may not be reliable, but, as already stated, Waldenström (2003) notes that as long as subjective assessments of events around childbirth are not regarding sensitive information, they are likely to be valid.

In recent DHS surveys a question regarding size at birth has been asked. This usually takes the form of the mother placing the child into one of five size categories: very small, smaller than average, average, larger than average or very large. This information is asked of infants born in the five years before the survey, minimizing recall bias. Da Vanzo *et al.* (1984) were the first researchers to utilise this information, using the Malaysian Family Life Survey (MFLS), which also asked a question regarding the size of the infant, although only to those mothers who did not report an actual birth weight. Those infants without a reported weight and who were described as being of average size were assigned the mean weight for those who had a reported birth weight. Infants without a recorded weight and who were described as being of larger or smaller than average size were assigned weights plus or minus one standard deviation from the mean weight respectively. Those infants described as very large or very small were given weights plus or minus two standard deviations from the mean. Therefore each infant had a weight assigned; either reported by the mother or imputed using the method above.

By comparing results using the full data set to those obtained using only those who have a reported birth weight Da Vanzo *et al.* (1984) concluded that serious biases and spurious relationships have been reduced. The mothers' perception of size at birth has similar relationships to biological and socioeconomic variables as the exact birth weights. However, the authors also acknowledge that there is no certainty regarding the accuracy of the reported birth weights, which is obviously vital if this method is to work and, as noted, Robles and Goldman (1999) have questioned this accuracy. A further problem with this study is that only those mothers who did not give a birth weight were asked to report the size of their child, and thus there is no assessment of the accuracy of these estimates in the population as a whole. If all respondents were asked to approximate their child's size at birth in the MFLS, irrespective of whether there is a birth weight recorded, then validation of the perception of the size at birth could have been carried out.

The 1986 Peru DHS included a question for all mothers regarding the size of their child at birth for all births in the preceding five years of the survey, as well as asking all mothers for the actual birth weight. There were few missing responses for the perception of the babies' size, although 32% of infants did not have a reported birth weight. Moreno and Goldman (1990) analysed these data with an emphasis on calculating the proportion of babies born with LBW. The average weight within each category of mothers' perception increased as the size increased; very small infants had a smaller mean birth weight than smaller than average infants, and so on. Also, most infants who had LBW were classified as being very small, although about 4% of infants who were classified by mothers as being of above average or very large size were seen to actually have LBW. Overall, a quarter of the variation observed in reported birth weights is explained by mother's perception of size at birth.

Infants with a reported birth weight differ significantly from those without a birth weight (Da Vanzo *et al.*, 1984; Moreno and Goldman, 1990; Eggleston *et al.*, 2000), and it is seen that those with a birth weight are of a higher socioeconomic status, and therefore are likely to have a heavier weight at birth. This is corroborated by the subjective assessments of size as more children without a recorded weight are placed in the below average and very small categories. Thus strength is lent to the argument that the mothers' perceptions can be used as a proxy for birth weight (Moreno and Goldman, 1990). Multivariate analyses of the factors associated with LBW are seen to be similar to the factors associated with being described as very small. To estimate the proportion with LBW, a logistic regression equation that predicts low birth weight for those with a recorded birth weight was applied to those without a recorded birth weight, and as a result the proportion with LBW in the whole population increased by over 20% (Moreno and Goldman, 1990).

The method used by Moreno and Goldman (1990) above has been recreated, with minor variants, by other authors. Boerma *et al.* (1996) applied the proportion of LBW infants within each size category for babies who were weighed to the group of infants who were not weighed to obtain estimates of the proportion of babies with LBW for 15 different DHS surveys. The use of the proportion of infants with LBW led to an issue with the treatment of those infants whose weights were heaped at 2500g, just above the threshold of LBW. In strict terms these infants should not be treated as LBW, as they weigh above the threshold for LBW, 2499g. However, it is clear that some of these infants will have been of LBW, and their weights rounded up either by the mother or in the hospital at birth. Correspondingly, there will be a number of infants whose weights have been rounded down to 2500g. In countries where there is much heaping the treatment of these infants can have a large effect on the estimate of the proportion with LBW. Boerma *et al.* (1996) treated half of those with a weight of 2500g as LBW. The authors concluded that the mothers' estimates of the size at birth of their child are 'reasonably good indicators of birth weight at the aggregate level'

(p. 215). However, the use of the very small category to indicate LBW at an individual level was not seen to be advantageous as there was a large amount of misclassification by the mothers of infants into unsuitable size categories.

The benefits of a mother's perception of the size at birth are not universally acknowledged. Eggleston *et al.* (2000) studied the agreement between reported birth weight and birth size in Ecuador. During data collection the size of the child was classified into four categories: very small, small, medium and large, although during coding of the response the medium and large infants were combined and subsequently could not be separated, leaving three size categories. Perception of size on an aggregate level was consistent with birth weight, with the very smallest infants having the lightest mean birth weight, although only 35% of infants with LBW were actually assessed by their mothers as being very small. However, the authors found that only 23% of the variance in birth weight is explained by the size at birth, and argue that this indicates poor agreement between the two variables. Yet it could be maintained that the explanation of 23% of the variance using only three categories actually signifies good agreement between birth size and weight.

Further arguments by Eggleston *et al.* (2000) that mother's perception is a bad proxy of birth weight include the fact only 35% of infants who had LBW were classified as very small by their mothers. If the proportion of infants with LBW is estimated by the proportion of infants who are classified as very small then the prevalence of LBW will be underestimated. Yet this conclusion does not take into account that previous authors (e.g. Boerma *et al.*, 1996) do not calculate the proportion of infants with LBW by using only those infants classified as very small. The combination of reported birth weights with the assessments of size for those infants without a reported birth weight takes into account the differences between infants with and without reported birth weights, which is another concern of Eggleston *et al.* (2000). In the Ecuadorean study infants without a reported birth weight are seen to be placed into smaller size categories than infants with a reported birth weight, and therefore using the adjustment procedure used by Boerma *et al.* (1996) accounts for these differences in characteristics in infants. Therefore the conclusion that 'maternal assessments of birth size are poor proxy indicators of birth weight' (p. 373) appears to be unfounded given the analyses conducted in the paper.

The largest study which uses a mother's perception of a baby's size as a proxy for birth weight was conducted by Blanc and Wardlaw (2005), who analysed data from 88 countries. They used the proportion of infants which did have a reported weight within each size category and combined these with infants who did not have a birth weight to estimate LBW in the complete population. Using this method increased the proportion with LBW in virtually all countries in the analysis, and the authors conclude that the estimates for the proportion with LBW presented in the paper are the most accurate available. However, the proportion of missing birth weight data does affect the accuracy and the validity of the estimates, with countries with a high proportion of missing data having less accurate estimates. One criticism of this study is in the decision to place 25% of the infants heaped at 2500g into the LBW category, and not 50% as was done by Boerma *et al.* (1996). This figure was used after studying the distribution of weights between 2000g and 2999g and estimating the proportion which would fall beneath the 2500g boundary. Yet there will be heaping of weights on 2000g which will affect the results. Furthermore, applying the same percentage to all countries does not take into account of the birth weight distributions in each country. A larger proportion of infants reported as weighing 2500g will actually weigh less than 2500g in a country with a light mean birth weight than in a country with a heavy mean birth weight. Ignoring this country variation may affect the estimated proportion of infants with LBW.

The use of mother's perception of their infant's size to provide population level estimates of mean birth weight and the proportion of infants with LBW is obviously a useful exercise. Due to those with a birth weight not being representative of the full population (Ebomoyi *et al.*, 1991; Miller *et al.*, 1993; Eggleston *et al.*, 2000; Blanc and Wardlaw, 2005) using this technique allows full coverage of the population. However, obviously there are some assumptions that need to be made in order for this method to be applied (World Health Organisation and United Nations Children's Fund, 2004). The first assumption is that LBW is as likely for those with a recorded birth weight as for those without a recorded birth weight within each size assessment category. This assumption is likely not to hold due to the above mentioned unrepresentative nature of those with a recorded birth weight. Infants without a recorded birth weight are more likely to have a child who is of LBW. Applying the proportion with LBW in each perception category to those without a recorded birth weight may therefore still underestimate the true proportion of infants in a country with LBW. The second assumption is that the relationship between birth weight and mothers' perception of size is the same irrespective of whether the mother can remember the birth weight or has the birth weight recorded on a health card. There are obvious problems with this assumption – it is clear that knowing the birth weight may influence perception of size, especially if the mother knows weights of children born to other mothers. The mother can then judge the size relative to other children based on the weight rather than giving an assessment of the physical size of the infant.

However, even though the assumptions that the method of combining a mother's perception of their child's size with birth weight are likely to be violated, it is thought that after applying this method the accuracy of the estimates of the proportion of children with LBW and the mean birth weight in a country is improved. Estimates can vary due to the method of classifying LBW and how heaping at 2500g is dealt with. However, it is unknown how a mother decides on the size of their child when asked, and whether this is influenced by a recorded birth weight, if available. Yet some authors use the mother's perception of the size of their child at birth as a proxy for birth weight when there is much missing birth weight information (Das Gupta, 1990; Rodrigues and da Costa Leite, 1999; Magadi *et al.*, 2001; Ghosh, 2006; Magadi *et al.*, 2007). Little research has been conducted into the size at birth variable and it is unclear whether the use of mother's perception as a proxy for birth weight is a valid method to use when there is much missing birth weight data.

A number of the above studies also indicate that the quality of the actual birth weight data that is reported in surveys is poor, with a high proportion of heaping of weights on multiples of 500g (Moreno and Goldman, 1990; Boerma *et al.*, 1996; Blanc and Wardlaw, 2005). This amount of rounding is likely to happen as the mother forgets the exact weight of the child, and either remembers the closest round figure or truncates the weight. A further possibility is that the rounding is conducted by the medical personnel when weighing the infant or giving the weight to the mother. Also noted was a rise in the amount of heaping as time from the birth increased, indicating that accuracy of the recall of weights worsened as time elapses. Greater heaping was observed for weights recalled from the mother's memory than weights which have been recorded on a health card (Blanc and Wardlaw, 2005).

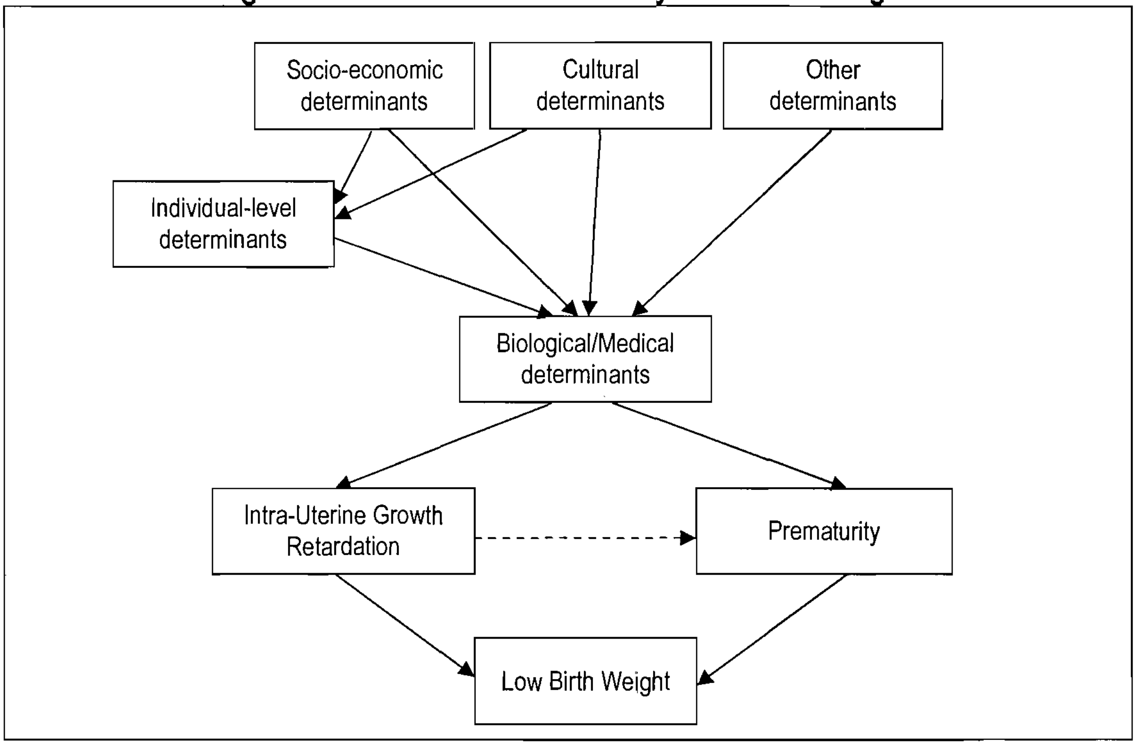
In summary, the collection of birth weight information in developing countries is subject to many problems. Hospital surveys of birth weights cannot be used to estimate country wide estimates due to those born in hospitals being a privileged sub-group of the population, and thus retrospective surveys offer the best way of collecting this information. In order that estimates are representative for the whole population under study, the combination of birth weight with an assessment of a child's size can easily be conducted, although assumptions need to be made relating to the relationship between perception of size and actual birth weight. These estimates can be treated as the 'best estimates' of such parameters as mean birth weight and the percentage of infants with LBW in the absence of full enumeration of birth weight.

2.3. Causes of Low Birth Weight

To explore the reliability of birth weight information from developing countries it is important to have an understanding of the causes of variations in birth weight, and also of the causes of LBW. Factors associated with birth weight are often similar to the factors which are related to the recording of the weights in retrospective surveys. This thesis will also study the determinants of a mother's perception of size of a baby at birth, thought to be highly related to birth weight. Knowledge of the determinants of birth weight will allow greater understanding of the determinants of mother's perception of size. These determinants need to be viewed within the context of developing countries, where the ability to collect this information may be limited. Thus many correlates of birth weight may not be readily available or reliably collected in developing countries, and so proxy measures will be required to mirror these factors. Difficulty in collecting these correlates will also be discussed below, alongside the determinants of birth weight and LBW.

Much literature has been produced regarding the determinants of birth weight and on the study of the causes of LBW. In order to explore the determinants of birth weight in a simple and systematic way a framework for the study of LBW is proposed (Figure 2.1).

Figure 2.1: Framework for the study of low birth weight



The framework displayed in Figure 2.1 indicates that there are two different causes why an infant has LBW: prematurity or intra-uterine growth retardation (IUGR), or a combination of both factors. The causes of IUGR and prematurity are either biological or medical in origin, and therefore these biological and medical determinants can be viewed as proximate determinants of LBW (Kramer, 1987). The proximate determinants are influenced by individual-level factors, while socio-economic and cultural determinants, on an individual, family, regional and national level also provide the background determinants to the framework, and are direct and indirect causes of the biological and medical determinants. A number of other factors which cannot be placed in any of the other categories are also related to the biomedical determinants of low birth weight. Each of the groups of determinants noted in Figure 2.1 will be briefly discussed below to provide a summary of the causes of LBW.

2.3.1. Prematurity, IUGR and LBW

The proposed framework (Figure 2.1) indicates that LBW is caused by either a short gestational period or the lack of growth of the infant within the womb during the pregnancy. Prematurity is defined as a gestational age of less than 37 weeks (World Health Organisation, 2004a) while IUGR is defined in a number of ways. One common method is to classify all those below a certain weight percentile for their gestational age, or those below two standard deviations below the mean weight for their specific gestational age, as IUGR (Kramer, 1987). The most common percentile used is the 10th percentile (Goldenberg *et al.*, 1989), although the actual weight that this represents depends on the reference population taken. Reference populations can be stratified by gender and race, and some include infants born with congenital abnormalities and some do not (Goldenberg *et al.*, 1989). Some infants can obviously be both premature and have IUGR if they are born before 37 weeks of gestation and are in the lowest percentiles of weight for their gestational age. The causes of prematurity differ from the causes of IUGR (Fedrick and Anderson, 1976; Fedrick and Adelstein, 1978), and the consequences of these two different types of LBW also show some disparity, which will be discussed later.

IUGR can be subdivided into two separate groups which depend on an infant's relative body proportions at birth. Wasted IUGR infants are of normal length and head circumference for their gestational age, but are thinner than expected. In comparison, stunted IUGR infants are proportionally smaller in their weight, length and head measurements (Southgate and Pittard, 2001). In developing countries it is seen that most IUGR babies are stunted (Villar and Belizan, 1982b; Kline *et al.*, 1989), indicating undernourishment of the mother throughout the pregnancy. Wasting is caused by later onset of undernourishment, mainly in the third trimester of the pregnancy (Ashworth, 1998). It is also seen that the chances of giving birth prematurely or giving birth to an IUGR infant is closely related to previous premature or growth retarded births (Bakketeig *et al.*, 1979). Indeed, gestational age and birth weight are likely to be highly correlated between births to the same mother, irrespective of the length of the pregnancy and birth weight of the infant (Fedrick and Anderson, 1976; Berkowitz, 1981; Starfield *et al.*, 1991).

In developing countries, it is difficult to identify whether an infant with LBW is premature or IUGR, especially when the information is collected in a survey. With many countries not having a coherent prenatal care program the assessment of gestational age is extremely difficult. Some surveys ask for the date of the last menstrual period (LMP; de Onis *et al.*, 1998), and this, coupled with the date of birth of the infant, will lead to an estimate of gestational age. However, reports of the LMP are known to be unreliable, as dates given by pregnant mothers are subject to digit preference and there may be some confusion over when the last menstruation occurred, especially if menstruation is irregular (Savitz *et al.*, 2002). In developing countries women may have extremely irregular menstrual periods, or even none at all, due to poor nutrition, but can still get pregnant (David, 1980). Also, in a society which lacks calendars and date prompts and a has high level of illiteracy, LMP estimates may be extremely inaccurate (Savitz *et al.*, 2002). Due to these problems, and also for ease of interpretation, in the past LBW was used as a proxy for a short gestational age, although this is no longer done due to the knowledge that LBW is multifactorial in its causes (Da Vanzo *et al.*, 1984). Information on the LMP is not routinely collected by retrospective surveys, and thus the identification of a LBW infant as either IUGR or premature from retrospective surveys is difficult. Even a simple question which only asks the mother to state if the child was premature or not (and not to state exactly how premature the infant was) is reported to be unreliable as there is discordance between a mother's definition of prematurity and the official definition (Miller *et al.*, 1993). As a result, most studies that use retrospective surveys from developing countries analyse LBW infants as a homogenous group. However, it is observed that a higher proportion of LBW is caused by IUGR in developing countries than in developed countries (Villar and Belizan, 1982a; Abell, 1992). This is due to poor nutrition, malaria and a high incidence of anaemia in these countries, which are seen to be causes of IUGR (Verhoeff *et al.*, 2001). Thus analyses of LBW in developing countries can be treated as mainly an analysis of IUGR, although there will obviously be some LBW caused by prematurity.

2.3.2. Biological and Medical Determinants

For a child to be born premature or with IUGR a biological or medical reason can usually be determined. These exact reasons are not the focus of this study, and therefore an in-depth review of all these factors is beyond the scope of this thesis. However, a brief summary is warranted. The following factors are grouped following the organisation of the meta-analysis by Kramer (1987).

Obstetric factors that are associated with LBW infants are related mainly to previous pregnancies. Factors include parity of the mother, birth intervals between infants, prior spontaneous abortions and prior stillbirths and neonatal deaths. First born infants are at greater risk of having LBW (Fedrick and Adelstein, 1978; Horon *et al.*, 1983; Kliegman *et al.*, 1990), although this effect is highly confounded with maternal age and socioeconomic status. Birth order is positively related to birth weight (Cote *et al.*, 2003), and thus children of a high birth order are seen to have a heavier birth weight, except if the birth order is very high (Kramer, 1987). Younger women who are of high parity are more likely to have had closer spaced births than others of the same age with a lower parity, which raises the risk of LBW (Kline *et al.*, 1989). First born infants have mothers who are often young, especially in poorer areas of the world, and in some cases may be reproductively and physically immature which leads to a lower birth weight (Geronimous, 1986; Alam, 2000), although younger mothers are often more socially disadvantaged which confounds the relationship (Horon *et al.*, 1983; Kliegman *et al.*, 1990).

There is known to be an effect of both short preceding and succeeding birth interval on infant mortality, and it has also been observed that short preceding intervals are related to LBW. Strong evidence for the link between birth interval and mortality came from an analysis of 39 surveys that had been conducted under the auspices of the World Fertility Survey (Hobcraft *et al.*, 1983; Hobcraft *et al.*, 1985). Two main mechanisms through which short birth intervals have an effect on infant mortality have been hypothesised, and it is simple to understand how the same mechanisms may influence birth weight. The theories are maternal depletion and sibling competition, which do not appear to be mutually exclusive.

Maternal depletion theory states that a short birth interval does not allow a mother to recover sufficiently from the rigours of childbirth (Jelliffe and Maddocks, 1964; Gribble, 1993). Essential nutrients lost during pregnancy, childbirth and post-partum periods are not replenished before they are required to be used again in the subsequent pregnancy. One of the obvious outcomes from the maternal depletion syndrome is an increase in the proportion of infants born with LBW. Competition for resources increases the number of infants with IUGR, and this will increase the proportion of stunted infants due to the scarcity of resources throughout the pregnancy. For infants born with short birth intervals it is seen that there is a larger proportion of infants born with IUGR than who are premature (Ashworth & Feacham, 1985), and that the IUGR infants in developing countries are more likely to be stunted than wasted (Villar and Belizan, 1982b; Kline *et al.*, 1989). The other mechanism through which birth intervals influence infant morality is sibling competition for scarce resources. This mainly occurs after birth and therefore cannot influence the birth weight. However, this mechanism can be extended to include competition between mother and foetus during pregnancy for scarce resources.

It has been suggested that the influence of birth intervals on infant mortality is only through the medium of birth weight (Spiers and Wang, 1976). Mothers who do not have the requisite time to recover from a previous birth and who live in a region where there is inadequate nutrition to build up the required body stores are at risk of giving birth to a LBW infant. A case-control study into causes of infant death in North Carolina found that when the matching criteria for cases and controls did not include birth weight, short birth intervals were related to infant mortality, irrespective of cause of death. However, if birth weight was used as a matching variable then this effect disappeared. This was taken as evidence that birth intervals work through birth weight to influence mortality and that birth intervals by themselves have little impact (Spiers and Wang, 1976). In a study in Tehran, the incidence of low birth weight was seen to rise as the birth interval decreases from 24 to 9 months (Fortney and Higgins, 1984).

Maternal nutrition, both during pregnancy and after birth, is important for the health of the child, although the influence on birth weight obviously occurs during pregnancy. The main effect of nutrition on birth weight is through intra-uterine growth, as the infant may not obtain the nutrients required for full growth. Different aspects that are thought to influence the chances of LBW are intake of calories and weight gain of the mother during pregnancy (Prada and Tsang, 1998; Hosain *et al.*, 2006). Linked to this is the amount of energy expended by the mother during the pregnancy and if the nutritional intake is adequate for any work that is conducted (Kramer, 1998).

Weight gain during pregnancy is important for a number of reasons, most of which can be expected to be correlated with the weight of the foetus. However, the general nutrition of a mother pre-pregnancy is also important during the pregnancy, as existing energy stores are used by the foetus for growth (Kramer, 1998). If a mother is underweight and is not obtaining the required nutrients for her own use before pregnancy and the amount of nutrients consumed do not rise during pregnancy, then the child will not have the required nutrients for sufficient growth, and is likely to be light at birth (Tafari *et al.*, 1980). Indeed, in a number of countries, including India, Kenya, Ethiopia and Iran, it is seen that there is a custom of decreasing food intake in the last trimester of pregnancy (Hutter, 1996), obviously affecting weight gain and thus the birth weight of the infant. Nutritional status is often closely associated with socio-economic status in developing countries, with undernutrition more prevalent in those with an unfavourable socio-economic background (Kramer, 1998).

Closely related to weight gain during pregnancy is the caloric intake of the mother during pregnancy. In general, the higher number of calories consumed per day by the mother during pregnancy, the lower the chance of the child having IUGR. However, this is obviously closely related to the amount of calories burned during the day, and thus maternal activity during pregnancy. The more active the mother is, the higher the levels of calories are burnt and the higher amount that is needed for adequate growth of the foetus (Berkowitz, 1981). In developing countries expectant mothers are often required to undertake strenuous work, and thus require a larger amount of calories to compensate, which is often not available (Homer *et al.*, 1990). Coupled with often poor general nutrition prior to the pregnancy, the chances of LBW due to strenuous work during pregnancy are greatly heightened (Tafari *et al.*, 1980).

Maternal illness during the actual pregnancy may influence both the growth of the foetus and the chances of prematurity (Kline *et al.*, 1989). Finding the causal pathways in the way that illnesses influence birth weight is difficult due to many confounding factors that are present, with mothers of lower socio-economic status being more likely to become ill. However, malarial infection during pregnancy has been seen to be important determinant of LBW (Sullivan *et al.*, 1999), with an estimated 19% of LBW in endemic malarial regions caused by malaria (Guyatt and Snow, 2004). It has been noted that infants born to mothers with malaria are on average 179g lighter than the corresponding average for non-malarial mothers (McGregor *et al.*, 1983).

The gender of the foetus is strongly related to weight at birth, with male newborns having a heavier weight than females. The mean difference in weight is quite large, although the difference between the genders does depend on location and the overall distribution of birth weights. The effect of gender is moderated by the gender of previous births, with newborn males with older brothers weighing less than newborn males with older sisters (Cote *et al.*, 2003). In countries where the mean birth weight is low, smaller differences are seen between males and females (Waldron, 1998). In his meta-analysis of 66 studies, Kramer (1987) concluded that, on average, males are 126.4g heavier than females in developed countries, and 93.1g heavier in developing countries, although there is no indication on the selection criteria used for placing the countries where the studies occurred into developing or developed categories. The difference in weights between males and females is due to intrauterine growth and not prematurity (Kramer, 1987).

The majority of multiple births are classified as LBW. Compared to singletons, twins have a relative risk of 10.3 of being LBW, while triplets have a relative risk of 18.8 (Luke and Keith, 1992). This is caused mainly due to the restrictions placed on intrauterine growth by the multiplicity of foetuses (Kramer, 1987). The proportion of multiple births in a region or country will therefore affect the proportion of infants with LBW, and must be considered when studying the percentage of infants with LBW. This is a consideration in more developed countries where fertility treatment techniques are increasingly common, and these are known to have a higher likelihood of resulting in multiple births (Reynolds *et al.*, 2003).

The biological and medical causes which determine LBW are not spread evenly throughout populations, but are concentrated mainly amongst the more disadvantaged members of the community (Villar and Belizan, 1982a), obviously apart from factors such as gender and multiple births. Lower socio-economic groups are likely to have poorer nutrition, greater illness (with a lower potential for cures to be obtained) and use more energy at work than mothers in higher groups. It is therefore important to understand the background factors that influence the biological and medical determinants of birth weight in order to appreciate the full picture of how birth weight is determined.

2.3.3. Individual Level Determinants

If the individual attributes of the mother are studied, then physical stature, age and personal habits all are seen to affect the weight of the child. The height and weight of the mother have an important role determining the child's weight (Mohanty *et al.*, 2006). Mothers who are small in height may have small infants due to physical constraints placed on the foetus during growth (Kramer, 1987). Furthermore, if a mother has a small stature caused by genetic factors this deficit can be passed onto the child (Langhoff-Roos *et al.*, 1987). Kramer (1987) estimated that for every extra centimetre of height the average weight of an infant rises by 7.8g, a not insubstantial amount. Maternal height works through IUGR to influence birth weight, and does not seem to affect prematurity. The weight of the mother before pregnancy is also highly linked to the weight of the child at birth (Emanuel *et al.*, 1972; Fedrick and Anderson, 1976; Berkowitz, 1981; Abrams and Newman, 1991; Teramoto *et al.*, 2006). Body weight is, in part, genetically determined, and this may directly influence the size of the foetus (Robson, 1978; Langhoff-Roos *et al.*, 1987).

Maternal age is closely related to other factors which influence birth weight, such as parity and body stature, as discussed above. It is seen that birth weight is generally lower for children born to mothers aged below 25 and above 40 years (Maher and Macfarlane, 2004a; Maher and Macfarlane, 2004b), although when other factors are controlled for there is seen to be no independent effect of age on birth weight. However, for older women age may interact with other risk factors, if present, to heighten risk of preterm birth (Fedrick and Anderson, 1976). Da Vanzo *et al.* (1984) found that maternal age of over 35 was significantly related to LBW in Malaysia, and the same result has been seen in Germany (Reime *et al.*, 2006).

Personal habits, such as smoking and alcohol consumption, are strongly related to birth weight (Chiolero *et al.*, 2005). Smoking during pregnancy is now known to cause IUGR through a number of pathways (Abel, 1984), with the major risk occurring if smoking occurs during the final trimester of the pregnancy (Butler *et al.*, 1972; Berkowitz, 1981; Bener *et al.*, 1996; Bernstein *et al.*, 2005). The smoker does not even have to be the mother, as paternal smoking also increases the chance of an infant having LBW through passive smoking (Ojembarrena *et al.*, 2005). Alcohol consumption of more than two drinks a day is also related to IUGR, and greater effects are seen if drinking occurs towards the end of the pregnancy (Chomitz *et al.*, 1995). Yet it is also thought that low levels of alcohol consumption a day, or just small amounts at the weekend can protect against LBW (Mariscal *et al.*, 2006).

The characteristics of the father are also seen to be important in the determination of birth weight. The father's own birth weight is seen to be related to the child's birth weight (Langhoff-Roos *et al.*, 1987; Davey Smith *et al.*, 1997; Magnus *et al.*, 2001). Further relationships have been seen between paternal height and weight, even controlling for maternal height and weight (Morrison *et al.*, 1991; To *et al.*, 1998) and paternal age, with infants of older fathers having a lower birth weight on average (Reichman and Teitler, 2006). However, even though they are significantly related, it is seen that paternal characteristics are not as important in determining birth weight as maternal characteristics. A final paternal factor that has a relationship with birth weight is alcohol abuse in the month of conception, with lower birth weights being seen in children of fathers who regularly drink to excess around the time of conception (Little and Sing, 1986).

2.3.4. Cultural Determinants

An interesting relationship is seen between birth weight and cultural and ethnic origin. Many studies have investigated the association between race and birth outcome in developing countries, and found that the incidence of LBW varies widely between racial groups both within a country and also between countries (Carlson, 1984; Da Vanzo *et al.*, 1984; Rogers, 1989; Kallan, 1993; VanLandingham and Hogue, 1995). However, it is important to disaggregate the effects of race from socio-economic effects such as wealth and education. Many racial groups which are disadvantaged in the distribution of birth weight are also the poorest and the least educated, which will be seen below as important indicators of LBW. Race can also have effects on determinants of birth weight such as the norms for the length between births (Gyimah, 2005).

The magnitude of the effect of race on birth weight is difficult to quantify due to the number of confounders involved in the relationship. Also, there can be confusion regarding the causal pathways leading to LBW. For example, as Kramer (1987) indicates, women of Indian origin may be generally smaller in stature than those of other ethnicities and thus have smaller babies, as seen above. Therefore, the direct cause of lower birth weight is the smaller stature, and ethnicity is an indirect cause. Thus reported differences in the birth weights of infants between racial groups may be overestimated due to the incomplete controlling for these confounders and other variables which are on the causal pathway to LBW.

In the U.S.A. it appears that White infants have the highest birth weight, although there is no significant difference between the birth weights in the White and most Hispanic ethnicities. Puerto Ricans and Blacks have significantly lower birth weights (Cramer, 1995; Hessol *et al.*, 1998). The U.K. shows similar disparities between ethnicities, with Asian mothers having lighter infants than White mothers (Davies *et al.*, 1982; McFadyen *et al.*, 1984). In Malaysia it was noted that Indian infants weigh significantly less than Malays or Chinese by more than 200g, and have an increased chance of being LBW (Da Vanzo *et al.*, 1984).

Closely linked to race is religion, which is also associated with birth weight (McFadyen *et al.*, 1984; Dhall and Bagga, 1995). Obviously religion is somewhat determined by race and other socio-economic determinants, and the likelihood of an independent effect of religion on birth weight appears slight. However, some religions may have different rituals and customs related to the mother during pregnancy, such as food supplements or a reduction in the amount of work that the pregnant mother is expected to do.

The disparities in the weight between racial groups are obviously important to acknowledge, but the causes of these differences are difficult to fully understand. The residual differences after controlling for confounders may indicate a true genetic element to birth weight, or they may be due to an unknown confounder which is not adequately controlled for in the model. However, it does appear that there may be some independent effect of race on birth weight, and thus it is important to utilise this information when assessing birth weight in a population.

2.3.5. Socio-economic Determinants

The socio-economic determinants form another element in the framework for studying LBW. These again do not exert a direct effect on LBW, but work through biological and medical determinants, although they also have a large effect on individual level factors that influence birth weight. Such determinants include the general wealth of the family, educational level of both the mother and the father, marital status, rural/urban location and the use of prenatal care. In this section each of these factors and their influence on LBW will be discussed separately.

The general economic status of a family is an important determinant of the birth weight of an infant. Income has been observed to be related to birth weight in Japan, with a higher income associated with a higher birth weight (Teramoto *et al.*, 2006), while general poverty, defined in a number of different ways, has been seen to be strongly related to birth weight and the incidence of LBW (Stein *et al.*, 1987; Kliegman *et al.*, 1990; Starfield *et al.*, 1991; Hughes and Simpson, 1998). In the U.S.A., Dooley and Prause (2005) found that mothers who became unemployed during pregnancy gave birth to infants with lower birth weights, although it is not clear whether this was due to the loss of income or stress associated with losing a job. The effects of poverty do not have a direct influence on birth weight, but influence the proximate determinants of birth weight. Those who are economically disadvantaged are more likely to suffer from diseases (Hughes and Simpson, 1998) and to have worse general health (House *et al.*, 1990) which will directly influence birth weight. Furthermore, poorer mothers in developing countries are likely to have a lighter pre-pregnancy weight and to gain less weight in pregnancy (Berkowitz, 1981), again directly influencing birth weight.

The educational level of the mother has a large independent effect on many aspects of childbearing and the health of the child, especially in developing countries. Educated mothers are more likely to have wider spaced births (Trussell *et al.*, 1985; Awang, 2003), give birth in hospitals (Matthews *et al.*, 2005) and to gain more weight during the pregnancy (Hickey, 2000). These relationships are all indicative of the strong positive relationship between maternal education and socio-economic status. No direct link has been found between education and the birth weight of the infant (Kramer, 1987), and thus it is clear that all the effect of education is manifested through other factors.

Paternal education is also seen to be related to birth weight, and again this is through the association with socio-economic status. In developing countries it is clear that higher education for males is a consequence of, and leads to, greater wealth and higher status (Parker and Schoendorf, 1992). This will reflect on the whole family unit, and thus improve the conditions for all and leading to, on average, a higher birth weight. Well-educated males are also more likely to have children with well-educated females, and thus the effect is magnified. Again, there is no direct link between paternal education and birth weight but the effect occurs through intermediary variables (Parker and Schoendorf, 1992). In the U.K. father's social class (determined by occupation) was seen to be related to birth weight (Maher and Macfarlane, 2004b).

A further determinant that is thought to have an effect on birth weight is the marital status and living arrangements of the mother. In developed countries it is seen that infants born to unmarried mothers have a lower mean birth weight than those born from wedlock (Ventura, 1995). A reason explaining this relationship is that unmarried mothers are more likely to be poorly educated, have a lower income and be younger than their married counterparts (Cramer, 1987). Yet even controlling for these factors some studies find that the birth weight for unmarried mothers is still lower (Bennett *et al.*, 1994; Bird *et al.*, 2000), although other studies do not find this relationship (Kramer, 1987). However, a simple distinction between unmarried and married mothers does not capture the full complexity of the relationship. Differential effects are seen by factors such as education, age, and the relationship that the mother has with the father (Bennett, 1992; Bennett *et al.*, 1994; Bird *et al.*, 2000).

In developing countries, mothers who live in urban areas are usually in better health than those who are rural dwellers, and child survival rates are usually higher (Hinrichsen *et al.*, 2002). Birth weights are also likely to be higher in urban areas. This is likely to be due to two main mechanisms. Firstly, family sizes are smaller in urban areas, and this allows greater care to be given to the mother while pregnant, and secondly real wages are higher and health care better than in rural areas (Lowry, 1990; Timaeus and Lush, 1995). However, these benefits are not accrued by all urban dwellers. Increasing disparities are seen between the urban rich and the urban poor, with the poor having similar or worse health than their rural counterparts (Timaeus and Lush, 1995; Brockerhoff and Brennan, 1998). These differences are difficult to measure as it is seen that it is the environment around the individual that is important in the health of the child rather than the socio-economic status of the family. For instance, even if a family is wealthy yet there is no piped water or sanitation in the household, then health status is worse than would be expected for the observed wealth of the family (Timaeus and Lush, 1995). Thus urban and rural residence is related to birth weight, through intervening variables, although the improvement in birth weight due to urban living is not universal.

Another hypothesised cause of differences in birth weight is the use of prenatal care services (Letamo and Majelantle, 2001). Earlier and more frequent prenatal care can result in the earlier diagnoses of complications during pregnancy and therefore modify the biological and medical determinants of low birth weight (Jewell and Triunfo, 2006). Mothers' behaviour, such as smoking, alcohol consumption and insufficient weight gain can also be changed before effects of these behaviours are felt too keenly in the growth of the foetus (Leveno *et al.*, 1985).

The conditions within the household are also influential. Infants born into households which use cooking fuels which are highly pollutant (such as wood, dung or straw) have reduced birth weights compared with households using gas or electricity after taking account of potential confounders (Mishra *et al.*, 2004; Ghosh, 2006). The biomedical mechanisms through which the pollutants work to affect birth weight are not stated in the study, but they are likely to be similar to the pathways by which general pollution in the region or area is related to birth weight. Studies in São Paulo, Brazil (Medeiros and Gouveia, 2005) and Sydney, Australia (Mannes *et al.*, 2005) showed that exposure to high levels of carbon monoxide, suspended particles and nitrogen dioxide during the first trimester of pregnancy was associated with a decreased birth weight.

2.3.6. Other Related Determinants

Many different variables have been found to be associated with birth weight, some of which do not fall into the categories of biomedical, individual, socio-economic or cultural determinants. Some of these other variables will be discussed in this section. The effect of pollution on birth weights can be classified in this group of determinants, although this effect was discussed above.

One factor which is mainly outside of the control of the mother is the altitude that the pregnancy occurs at (Tripathy and Gupta, 2005; Camelo *et al.*, 2006; Hartinger *et al.*, 2006). It is seen that neonates born at a high altitude (defined as above 2000m) have a 2 to 3 times higher risk of having LBW than those born at sea level (Yip, 1987). This is mainly due to IUGR, and is thought to be due to a restriction in the amount of oxygen that the foetus obtains. This is a similar effect to that of smoking on birth weight, as one of the effects of smoking is to reduce the amount of oxygen available. The reduction in the birth weight of children occurs at all weights, and thus the birth weight distribution is shifted downwards towards lighter weights (Giussani *et al.*, 2001), and it is also seen to be independent of socio-economic status (Camelo *et al.*, 2006). Tripathy and Gupta (2005) argue that the genetic potential for birth weight is only manifested at a low altitude, although it does appear that there is a protective effect for ethnicities who have resided for a long length of time at higher altitudes (Hartinger *et al.*, 2006).

A further cause of LBW that is outside of the control of the mother is the season of birth. This can be through two mechanisms. Firstly, IUGR can be caused in areas where there is subsistence agriculture, and at certain times of the year there is more food than at others. Infants born soon after a lean food period are more likely to be wasted than infants whose third trimester in the womb occurred at the same time as a period when there was bountiful food. Seasonality is also seen to affect the chances of prematurity in developed countries. The incidence of prematurity is not constant through the year, but fluctuates. There is no convincing argument why this occurs (Cooperstock and Wolfe, 1986), and this effect has also been seen in developed countries, especially Australia (McGrath *et al.*, 2005a; McGrath *et al.*, 2005b).

A final variable which is related to birth weight is location. Two studies which indicate that different areas have different birth weights were conducted in the U.S.A. (Thompson *et al.*, 2005) and in seven countries in Europe (Graafmans *et al.*, 2002). The study in the U.S.A. showed that the proportion of infants with LBW varies widely in different regions of the country, even after controlling for known risk factors and ethnicity. The study in Europe aimed to identify if the optimal birth weight (defined here as the weight at which perinatal mortality is lowest). Major differences were seen in the birth weight distribution across all countries in the analysis, although the study did not take into account of the differences between the countries in ethnicity or other factors which are related to birth weight that may be present or absent in different proportions in the various countries (Graafmans *et al.*, 2002).

There are potentially many more determinants which may influence birth weight by working though the factors noted above. More general factors will in turn influence the individual, cultural and socio-economic determinants of birth weight. For instance, the general economic status of the country will influence the socio-economic status of the inhabitants and the access to prenatal care. Environmental conditions will affect the amount of food available in general and therefore the nutrients available to expectant mothers.

2.4. Consequences of LBW

Some consequences of LBW have been introduced in earlier sections of this chapter. Infants born with LBW have a far higher risk of death in the neonatal and post-neonatal period than those born weighing more than 2500g. However, risk of mortality is not the same for all LBW infants, and there are other consequences of LBW which can persist into later life. This section will investigate the short and long term risks associated with LBW, and elucidate the different outcomes of LBW caused by IUGR and prematurity.

2.4.1. Birth Weight and Mortality

Although birth weight is a major determinant of infant mortality (McCormick, 1985; Paneth, 1995), the relationship between the two variables is not a simple linear one, but curvilinear. As birth weight increases from very low levels mortality decreases. The lowest viable weight is usually taken as 500g in order for standardisation of mortality between countries to occur (Phelan *et al.*, 1998), although babies have been known to survive below this weight. An optimal birth weight is noted where mortality is lowest, and this has been reported as being of different weights depending on the population and the period of mortality studied. McCormick (1985) reported that the optimal weight for the lowest infant mortality was between 3000g and 3500g, while the optimal weight for early neonatal mortality in three Scandinavian countries was between 3501 and 5000g (Saugstad, 1981). The optimal birth weight differs between countries, as shown by Graafmans *et al.* (2002). The weight at which perinatal mortality was lowest in seven European countries or regions ranged from 3755g in Flanders to 4305g in Norway. Above this optimal level there is a small increase in the mortality rate for the heaviest births, although the rate does not rise to anywhere near the same level as the mortality rate for LBW infants (Wilcox and Russell, 1986). Further to this, if gestational age is also considered, there is an optimal combination of gestational age and birth weight that reduces the risk of mortality to the lowest level (Solis *et al.*, 2000). This links with the idea of prematurity and IUGR: those who are born before term and those who are born at term but have not grown sufficiently have an elevated risk of mortality in different periods throughout the first weeks and months of life.

The effect of birth weight on mortality is not only confined to the first year of life, but is seen to be related to mortality throughout infancy (Abell, 1992). A number of studies have indicated that increased risk is observed for infants weighing less than 2500g compared to those weighing more than 3500g after controlling for gestational age between the ages of 1 and 4 years of age (Victora *et al.*, 1992; Hirve and Ganatra, 1997; Samuelson *et al.*, 1998). Indeed, it has also been seen that small size at birth, as measured by birth weight and length at birth, is related to higher mortality levels in adulthood (Kajantie *et al.*, 2005).

There are four different categories of infant if the concepts of prematurity (as defined as birth before 37 weeks of gestation) and inter-uterine growth retardation are combined. A child is either of normal size and born at term, born prematurely, born without adequate growth in-utero or born early without adequate growth. Each of these groups have different short and long-term risks associated with mortality and morbidity (Kramer, 1987). Compared with an infant born at term and within the normal weight limits all other groups have a raised risk of mortality, although it is seen that IUGR infants have lower mortality than a premature infant of the same weight (McCormick, 1985). For any given weight, it is seen that the longer the period of gestation the higher the chance of the infant surviving. Further to this, there are some infants who are premature yet weigh more than 2500g and are therefore not classified as LBW. These infants are termed 'heavy preemies'. These infants suffer from an infant mortality rate two to three times higher than the corresponding rate for full term infants weighing over 2500g (Frisbie *et al.*, 1996).

In developing countries most deaths of LBW infants are due to IUGR, whilst in developed countries the major burden of death falls on premature infants (Ashworth, 1998; Kramer, 1998). This is due to the relative proportions of LBW babies that have IUGR or were premature, with there being many more IUGR babies born in developing countries due to malnutrition. As stated previously, Villar and Belizan (1982) report that if the proportion of LBW infants in a country exceeds 10% then the majority of LBW is caused by IUGR. This is seen in Bangladesh, where the proportion of infants with LBW is estimated to be 30% (Blanc and Wardlaw, 2005), and it is seen that 75% of the infants weighing 2000g-2500g were born at term (Yasmin *et al.*, 2001). However, irrespective of the cause, one study in Puerto Rico estimated that, in theory, if LBW was eradicated, 62% of infant deaths in the country would be averted (Becerra *et al.*, 1993). Obviously LBW cannot be eliminated, but the study highlights the large effect of LBW on mortality.

It is not universally accepted that the strong association between birth weight and mortality implies causation. Wilcox argues in a series of articles that the LBW classification is of no use, and that an underlying confounder (potential confounders may be malformations or infections), which decreases birth weight and increases mortality, is responsible for the association (Wilcox and Russell, 1986; Wilcox, 2001; Basso *et al.*, 2006). Mortality in the early neonatal, neonatal and post-neonatal periods is associated with many other factors aside from birth weight. These will be noted in Chapter 8, which studies the relationship between mortality in these periods and a number of covariates.

2.4.2. Birth Weight and Morbidity

Mortality is the most extreme consequence of a low birth weight, but the effect of birth weight is not only confined to mortality. Infants who are born with LBW and do not die have greater morbidity, both in the short and long-term. Infants who are born with VLBW are 25 times more likely to suffer from cerebral palsy than babies with a higher birth weight (Paneth, 1995), with 7.7% of these births suffering from some disability (Escobar *et al.*, 1991). Many other chronic defects and illnesses are also seen in greater proportions in LBW infants, such as blindness, deafness, epilepsy and lung disease (Overpeck *et al.*, 1989; McCormick *et al.*, 1992). Chronic illnesses such as these are more likely to be due to prematurity rather than IUGR (Paneth, 1995), and as such is less of an issue in developing countries as in developed countries. The main risk group for long term morbidity are VLBW infants, who are almost always born preterm and most of these have suffered from some level of IUGR (Hack *et al.*, 1995). In a meta-analysis of studies regarding the outcomes of surviving VLBW infants it was seen 25% of these infants were disabled (Escobar *et al.*, 1991), while LBW was strongly associated with newly diagnosed disabilities between the ages 7-16 (Power and Li, 2000).

Aside from morbidity in infancy and late childhood other effects of birth weight are also seen. ELBW infants are seen to have a greater level of behavioural problems in a study of four countries (Hille *et al.*, 2001), although the authors do admit that these may be caused by differential treatment of the ELBW infants by the parents. Increased behavioural problems have also been seen in VLBW children, coupled with lower psychosocial health (Indredavik *et al.*, 2005). Poorer school performance is observed in infants weighing less than 3000g and who are only slightly premature

(Kirkegaard *et al.*, 2006), implying that the even small deviations from the optimal birth weights can influence outcome in later life. Lower school achievement for IUGR infants has also be reported (Peng *et al.*, 2005), and for all infants weighing less that 2000g, irrespective of the cause of the lower birth weight (Chaudhari *et al.*, 2004). Graduation from high school is reduced for those with very low birth weights, and IQ is depressed compared to those with higher birth weights (Hack *et al.*, 2002).

Birth weight is not just important in childhood and has been linked to long-term health. The Barker hypothesis states that 'fetal undernutrition in middle to late gestation, which leads to disproportionate fetal growth, programmes later coronary heart disease' (Barker, 1995, p. 171). This conclusion was drawn from a study conducted in Hertfordshire, U.K., where risk for heart disease fell as birth weight increased (Osmond *et al.*, 1993) and has been replicated in other studies (Davey Smith *et al.*, 1997). It has since been observed that foetal conditions are related to other outcomes in later life, and not just heart disease. Associations with diabetes (Spencer, 2004; Reyes and Manalich, 2005), breast cancer (Michels and Xue, 2006), respiratory disease, obesity (Reyes and Manalich, 2005) and blood pressure (Barker, 2006; Davies *et al.*, 2006) have been found. Also found is an association between birth weight and depression (Gale and Martyn, 2004) and neurosensory impairments (Hack *et al.*, 2002).

2.5. Summary

The aim of this literature review was threefold. Firstly, to explain the problems relating to the collection of birth weight and related information in less developed countries, and to explore the strategies that have been used to deal with any missing birth weight data. Secondly, to examine briefly the main causes of birth weight differentials and of LBW, and finally, to study some of the consequences of different levels of birth weight. The majority of the studies regarding the causes and consequences of birth weight differentials use data from developed countries, mainly due to issues seen in obtaining representative birth weight data from developing countries. The lack of nationally representative studies into birth weight in developing countries hinders the understanding of the causes of mortality and morbidity in these countries. Thus strategies to mitigate for the poor quality of birth weight data need to be developed. This thesis aims to advance the development of these strategies.

To summarize, the evidence is that there is a large problem with missing birth weight data in developing countries, and thus estimates of the proportion with LBW in a country and the mean birth weight are thought to be underestimates. Techniques, using responses from mothers regarding their perception of their baby's size at birth as a proxy for birth weight, although imperfect, are thought to provide more realistic estimates of LBW. These techniques are useful in order that an accurate assessment of the progress towards international targets relating to LBW is obtained. Birth weight itself is multifactorial in its causes, but the proximate causes are usually biological or medical in origin. However, there are individual, socio-economic and cultural factors that have an effect on these proximate determinants. It is difficult to review all variables which have been associated with either LBW or birth weight in the literature due to the sheer number of these variables. The consequences of LBW in both the childhood and adulthood periods are seen to be important, and in some cases, severe. Mortality is the ultimate consequence of LBW, and obtaining an unbiased relationship between birth weight and mortality in developing countries is difficult due to the amount of missing and inaccurate data in these countries. An analysis of the birth weight data from surveys conducted in developing countries, and a greater understanding of variables which are potential alternatives to birth weight is necessary in order that the causes and consequences of birth weight can be studied in these countries.

Chapter 2: Key Points

- Infants with a low birth weight are more likely to die than those of a heavier weight.
- Low birth weight is caused by either prematurity (<37 weeks gestation) or intra-uterine growth retardation.
- Collecting birth weight data using retrospective surveys in developed countries is seen to achieve good accuracy. In developing countries the accuracy is harder to assess but it is thought that the data are of relatively poor quality.
- Combining birth weight data with mother's perception of size is seen to improve estimates of the proportion of infants with low birth weight.
- Low birth weight is related to a number of factors, including biological and medical, individual level, cultural and socio-economic determinants.
- Birth weight is related to survival status in childhood and morbidity and mortality in later life.

Chapter 3

Data and Methods

The purpose of this chapter is to introduce the data that will be used to investigate birth weight and related variables in selected developing world countries. The main statistical methods used throughout the thesis will also be described. The first section describes the selected countries and the sampling methods used in the surveys for these countries. The different types of questionnaires used in each of the surveys will be described, and the number of respondents within each country presented. Further to this, the variables used in the study will be stated, and the rationale behind the choice of these explanatory variables discussed. The coding of derived variables used in this study will be elucidated, before an explanation of the exclusion criteria for those respondents and children who were not included in the analysis provided. Finally, the different statistical methods used in this thesis will be reviewed.

3.1. Data Sources and Organisation of the Data

The data used for this study come from Demographic and Health Surveys (DHS) conducted between 1997 and 2002. The DHS programme is a worldwide research project which has been initiated and funded by the U.S. Agency for International Development (USAID) in order to 'evaluate population, health and nutrition programs' (ORC Macro, 2005a). Surveys have been conducted by the DHS programme since 1984, although before this time similar studies were carried out by the World Fertility Survey programme. Since 1997 the surveys have been expanded in order to include more questions and to collect biomarker data in some countries. These expanded surveys are called *MEASURE* DHS+. Countries involved in the DHS programme usually conduct a survey every five years, which allow trends to be observed over time (ORC Macro, 2005b).

For this study 15 different surveys were selected from around the world. Countries were selected in order to obtain coverage from different regions and continents included in the DHS programme. A full list of the surveys used in this study is presented in Table 3.1, with the year that the survey was conducted, and the number of households interviewed in each of the countries. India is included as a country in this analysis, even though a DHS was not conducted. In India the National Family Health Survey (NFHS) was used. This is a DHS equivalent survey which asks similar questions and uses a similar sampling methodology and structure to the DHS.

Table 3.1: Countries included, year of survey and number of households interviewed

Country	Year	No. of Households
Africa		
Gabon	2000	6203
Malawi	2000	14213
Mali	2001	12285
Mozambique	1997	9282
Tanzania	1999	3615
Zambia	2001/02	7126
Zimbabwe	1999	6369
Asia		
Cambodia	2000	12236
India [a]	1998/99	92486
Kazakhstan	1999	5844
Vietnam	2002	7048
South/Latin America		
Bolivia	1998	12109
Haiti	2000	9595
Nicaragua	2001	11328
Peru	2000	28900

[a] India conducted a National Family Health Survey (NFHS), a DHS equivalent

3.1.1. Survey Design

The methods used to select the sample in each of the countries used are not exactly alike, although major similarities are seen. In general, the selection of households in the DHS follows a multistage design, with a two- or three-stage stratified sample being taken. Stratification is conducted by dividing each country into rural and urban areas. In most countries the sampling frame from the previous census is used, and from this frame primary sampling units (PSU's) are selected for inclusion in the survey. These PSU's usually correspond to villages or areas used for health treatment purposes, and are selected into the sample with a probability proportional to the population count within the PSU. Further to this, in some countries a proportion of enumeration areas (EA's) within each PSU are selected, again with a probability proportional to the population count within that EA. Finally, all the households in the selected EA's are enumerated and used as the sampling frame, from which the households to be interviewed are systematically selected with equal probability. In some countries there are regions which are sparsely populated. In order to obtain reliable estimates of demographic and health statistics in these regions a minimum sample size is allocated, irrespective of the actual number of households in the region. Due to this, the samples obtained are not self-weighting, and sample weights are required to obtain national-level estimates. In India each state conducted a separate survey using the above sampling methodology. Each individual state's survey then was collated into one large file for the whole of India. The survey weights within each state were then adjusted to take account of the differential population sizes within each state.

In the surveys selected in this study, data were collected through household and individual questionnaires. The household questionnaire asked background information on all members of the household, including sex, age, education and marital status. Further questions were asked relating to accidents and illnesses in the home over the previous year. Also included on the household questionnaire were questions regarding the facilities available in the house, such as the water supply, construction material, toilet facilities, electricity and gas supply, and ownership of some specified consumer goods such as a radio, television and refrigerator. The individual questionnaire was given to all women aged 15-49 in the selected households, and obtained information on reproductive and contraceptive history, pregnancies, postnatal care and breastfeeding, immunizations and general health of the children, marriage and sexual activity, fertility preferences, husband's background and the employment status and occupation of the woman. Questions on HIV and other sexually transmitted infections, maternal mortality, the woman's status in the household and the relationships between the household members that exist in the home were also asked. Some surveys also had extra questionnaires which asked a sub-sample of the men in the households a series of questions using a different questionnaire. The information from the male questionnaire was not utilised in this study.

3.1.2. Variables Used in the Thesis

The main data used in this study are related to birth weight and the mothers' perceptions of their babies' sizes, contained in a section related to pregnancy, postnatal care and breastfeeding on the individual questionnaire. Information on the pregnancy was asked for all births in the five years preceding the survey, except in India and Vietnam. In Vietnam the information was reported for all births in the previous three years. In India the period for detailed information about births was since January 1995, which was three to four years before the time of the survey, depending on the date of the individual interview. In all countries, except India, information about all the births in this time period were enumerated in detail and the information regarding birth weight, perception of size and other details regarding the birth and the child were recorded. In India, only information regarding the two last births which have taken place since January 1995 was recorded, even if the mother had more than two children in this period. The number of children born to each mother and included in the survey is shown in Table 3.2.

Table 3.2: Number of births in the 5 years before the interview

Country	Number of Births to Mothers in 5 Years Before Interview 1	2	3	4	5	Total Births in last 5 years
Africa						
Gabon	1728	1033	175	19	2	4405
Malawi	4407	3122	377	30	5	11926
Mali	4075	3624	540	36	2	13097
Mozambique	1871	924	123	8	1	4122
Tanzania	1173	798	142	5	-	3215
Zambia	2389	1897	244	13	2	6877
Zimbabwe	2063	689	63	2	1	3643
Asia						
Cambodia	3711	2020	312	34	3	8834
India [a]	24930	4048	-	-	-	33026
Kazakhstan	825	212	29	1	1	1345
Vietnam [b]	1125	96	-	-	-	1317
South/Latin America						
Bolivia	2691	1711	354	31	1	7304
Haiti	2444	1592	322	23	-	6685
Nicaragua	3447	1402	221	18	-	6986
Peru	8000	2376	295	15	-	13697

[a] Only last two births after January 1995 recorded
[b] Only births in the last three years recorded

The main reason why detailed questions about infants are restricted to the last five years is to minimise recall bias. As noted in the previous chapter, recall of information such as birth weight is more accurate if a shorter time has elapsed between the birth and the interview than a longer time, with some degradation observed in the quality of birth weight data recalled four years after the birth (Seidman *et al.*, 1987). A number of questions were asked about the children born in the relevant time period, including information about the pregnancy, delivery, breastfeeding, immunizations and the health of the child. These questions are very specific to the individual children, and thus a long timescale between the events in question and the question may lead to misclassification and confusion between different children by the mother. Indeed, some questions, such as relating to antenatal care and health checks after the birth, were are only requested for the last birth to the mother. This was done in order to reduce recall bias even further.

3.2. Construction of the Data File

All DHS data are recoded by the company that organises the survey (ORC Macro) into a number of different formats, depending on the questionnaires that have been used. One recode is into a child file, where each line in the data file represents one child born in the five years previous to the survey (except India and Vietnam, as explained earlier). The mothers' details are replicated across each of her births alongside selected household information. Therefore for each child there is a complete record of their birth details, their mothers' details and their household details.

As this study is looking at a number of countries, the covariates in the models have been chosen for consistency over all countries where possible. Further consideration was given to variables that the literature has reported to be linked to birth weight. Due to these two constraints, only a limited number of variables were used in the modelling process in the initial part of this study. The variables used in the first part of the thesis can be grouped under four main headings:

1. **Demographic Factors**: gender of the child; birth order of the infant; age of the mother at birth of the child

2. **Socio-Economic/Cultural Factors**: maternal education; paternal education; marital status; religion; place of residence (urban/rural)

3. **Medical**: place of delivery (home/hospital); if prenatal care was obtained; survival status of the index child

4. **Mode of Response**: method of reporting birth weight (from a mother's memory or read off a health card)

Although these variables are mostly common across all countries, some of the categories within the variables differ e.g. religion. Place of delivery differed in each country, with some countries recording simply whether the birth occurred in either a home or an institution, while others classified the location into more detailed categories such as home, private or public hospital or a community centre. This was recoded manually, where needed, into home and institutional delivery categories. Furthermore, although the attempt was made to obtain variables that were recorded in each country a few countries did not record information on some of the covariates. Tanzania did not ask any questions regarding paternal education, and Bolivia and

Nicaragua did not ask questions related to religion. The lack of questions regarding religion in these two countries is not seen as a problem as 95% and 73% of people in Bolivia and Nicaragua respectively are Roman Catholic. Most of the remainder of the population are Protestant (CIA, 2005b; CIA, 2005a). As nearly all of the inhabitants are Christian the fact that religion is missing is not a large problem regarding interpretation of the results.

All variables included in the analysis were categorised following standard classifications and to obtain a good distribution of children across the categories. Missing information was a feature for some of the covariates in some countries, and to exclude these individuals with missing data from the analysis would reduce the statistical power of the tests conducted. However, the proportion or missing data on these variables was small, and so each variable with missing data was studied separately to assess the most appropriate method to cope with the missing data. For place of delivery, infants with missing data were included in the home birth category, while for prenatal care those with unknown information were placed in the 'did not receive prenatal care' group. The proportion of missing data for the place of delivery was consistently under 1%, and thus this reclassification is not thought to have much of an effect on the results. Regarding paternal education, in some countries this was only collected for married mothers, and those who were never married were not asked the question. All these missing data were placed in a separate category.

All analyses throughout this thesis are based on only single births, and births that resulted in twins are excluded. Multiple births generally are lighter and have higher mortality (Fedrick and Anderson, 1976; Fedrick and Adelstein, 1978), and so that the results were not influenced by differential proportions of twins in each country these infants were dropped from the data set. The percentage of twins recorded ranges from about 1.0% in Vietnam to 4.2% in Gabon and Malawi. Table 3.3 displays the number of infants in the final analysis for each of the countries, excluding twins.

Table 3.3: Number of single births under analyses by country

Country	Number of Births	Country	Number of Births
Africa		*Asia*	
Gabon	4221	Cambodia	8643
Malawi	11432	India	32611
Mali	12673	Kazakhstan	1317
Mozambique	4002	Vietnam	1303
Tanzania	3101	*South/Latin America*	
Zambia	6658	Bolivia	7210
Zimbabwe	3527	Haiti	6473
		Nicaragua	6846
		Peru	13508

The 15 countries were not used throughout this entire thesis and the reasons why countries were not used will be explained later in the thesis. Detailed investigations were restricted to only three countries; Cambodia, Kazakhstan and Malawi. These countries were selected as there were differing amounts of missing birth weight information in each country. For these three countries further variables were investigated in addition to the ones noted above, including:

1. **Demographic Factors**: preceding birth interval; number of siblings born since the index child

2. **Socio-Economic/Cultural Factors**: mother currently working; wealth quintile; ethnicity

3. **Medical**: mother currently smoking at the time of the survey

4. **Other:** time from birth to the interview

Birth interval is classified in following the convention set down by Hobcraft *et al.* (1983). Four categories were used: first births, a birth interval to the previous child of under 2 years, a birth interval of between 2 and 4 years, and a birth interval of more the 4 years. The question on the survey regarding mothers work is a simple binary variable which notes whether the individual is working, aside from housework, at the time of the survey. This may be paid work, or work in kind. The program to generate the wealth quintiles was taken from the DHS website (ORC Macro, 2005a) and was only available for selected countries and hence was not used in all analyses. These quintiles are generated from responses made in the household questionnaire regarding ownership of specific consumer items, the construction materials used for the house and other indicators which imply the wealth of the family. In different countries the questions used to generate the wealth index change, or there are different weights assigned to the variables in order to represent the important factors relating to wealth in that specific country. After obtaining an index from these indicators, quintiles are generated. The methodology behind the generation of the wealth quintiles was developed by the World Bank, and has been replicated for use with the DHS responses (Filmer and Pritchett, 1998).

3.3. Data Quality and Limitations

The accuracy of the results in any study is dependant on the accuracy of the data that are collected. This can be assessed by the amount of heaping on common values and the proportion of data that is missing from the responses. Heaping indicates that the data collected is not precise (Roberts and Brewer, 2001) and shows observer (or recall) error (Edouard and Senthilsevan, 1997). Coupled with this, if the data that are missing do not form a random subset of those who have been sampled a form of bias is introduced into analyses (Schafer, 1997).

The distribution of birth weight was studied amongst those who did report a birth weight. All weights were recorded in grams in the data file, even if the birth weight was stated by the mother in Imperial measurements (pounds and ounces). A full analysis of the distribution of the birth weights is conducted in Chapter 4. However, it was noticed that in some countries there were a number of very heavy babies, weighing up to 9000g. After studying the distributions it was decided to treat all weights over 6000g as incorrect, as these were deemed to be highly unlikely birth weights and are likely to be inaccurately recorded (Maher and Macfarlane, 2004a). The same cut-off weight was used by Gayle *et al.* (1988) when validating maternal recall of birth weights and Robles and Goldman (1999) in their assessment of birth weight data in six South American countries. A high proportion of births over 4000g is a cause for concern in an assessment of the quality of birth weight in the Dominican

Republic (Miller *et al.*, 1993), while births weighing over 6000g are extremely rare (Martin *et al.*, 2003). The children who did have weights over this amount were still included in the analysis, but their birth weights were recoded as missing. Table 3.4 notes the number of infants in each country that this affects. It is clear that Haiti stands out as an outlier, having many infants reported as weighing over 6kg. This will be discussed further in the next chapter (see Box 4.1).

Table 3.4: Number of infants with reported weights over 6000g by country

Country	Number of Children	Country	Number of Children
Africa		*Asia*	
Gabon	0	Cambodia	0
Malawi	0	India	13
Mali	0	Kazakhstan	0
Mozambique	0	Vietnam	0
Tanzania	0	*South/Latin America*	
Zambia	0	Bolivia	4
Zimbabwe	0	Haiti	74
		Nicaragua	3
		Peru	0

The final investigation in this thesis looks at the determinants of mortality in the first year of life, in the early neonatal, neonatal and post-neonatal periods (Chapter 8). For this study the dataset was reduced to include only those infants who were born a year or more before the date of the interview. This was done to avoid the problem that some infants aged less than one year old at the time of the survey would subsequently die before their first birthday. Restricting the dataset to only those infants of a year or older means that all infants used in this investigation will have been exposed to the full period of risk.

3.4. Statistical Methods

There are a number of statistical methods utilised throughout the thesis. For clarity, certain methods will be explained within each chapter when they are utilised. However, the major techniques used throughout the thesis will be explained in this section. These techniques relate to the modelling of the data. The analytical modelling procedures used are standard logistic regression and multilevel logistic regression, multinomial logistic regression, and standard ordinal regression and multilevel ordinal regression. Each of these different techniques and their rationale will be explained below. Missing data methods, used in the investigation of the causes of mortality in the first year of life, will be described in Chapter 8.

3.4.1. Logistic Regression for Binary Data

Many of the analyses in this thesis utilise logistic regression due to there being a binary response variable, indicating the presence or absence of a specific factor. The standard logistic regression method is used in the determination of the characteristics of those who do and do not report birth weight, the characteristics of those who recall birth weight from memory as opposed to recall from a health card, and the determinants of low birth weight. Coupled with this, the analysis of the determinants of infant mortality leads to the analysis of a binary variable, with the child either living or dying in a specific period of analysis.

A binary outcome for the i^{th} individual is denoted as y_i, where $y_i = 0$ or 1. The probability that $y_i = 1$ is given as π_i. If there are K explanatory variables, denoted for each individual as x_{ki} (where $k = 1,\ldots,K$), the general model for a binary response is

$$f(\pi_i) = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_K x_{Ki}, \qquad (3.1)$$

where $f(\pi_i)$ is some transformation of π_i. This transformation is required as the range for π_i is (0, 1), as it represents a probability, and thus the simple application of a linear model may produce probabilities where $\pi_i < 0$ or > 1. A function is chosen, called the link function, which transforms the π_i to have a range $(-\infty, \infty)$.

There are a number of choices for the link function, but the most widely used due to ease of interpretation is the logit transformation. The logit transformation is shown below:

$$f(\pi_i) = \log\left(\frac{\pi_i}{1-\pi_i}\right),$$

where $\left(\frac{\pi_i}{1-\pi_i}\right)$ is the odds of $y_i = 1$.

Using the logit link function, the model for binary data is given as:

$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_K x_{Ki}. \tag{3.2}$$

To obtain the odds that $y_i = 1$, exponentials of each side of the equation in (3.2) are taken. To obtain π_i, the expression that is required is:

$$\pi_i = \frac{\exp(\beta_0 + \beta_1 x_{1i} + \cdots + \beta_K x_{Ki})}{1 + \exp(\beta_0 + \beta_1 x_{1i} + \cdots + \beta_K x_{Ki})}. \tag{3.3}$$

The exponential of each coefficient, β_k, is interpreted as an odds ratio which will give the effect of a one-unit increase in x_k on the odds that $y_i = 1$, ceteris paribus.

For all categorical covariates used in this study, a reference category was defined for ease of interpretation of the odds ratios. Dummy variables were created for all categorical variables, and thus each of the groups within the variable in question, except for the reference category, have a coefficient, β_c ($c = 2,\ldots,l$), where l are the number of categories in the variable. Each of these dummy variables is a binary variable. The exponential of the coefficient for a dummy variable (β_c) is interpreted as the odds ratio of the effect of an individual being in category c relative to the odds of being in the category $c = 1$.

To fit a logistic model, maximum likelihood estimation is used. In order to test the significance of the parameters in the model, two different tests are commonly used, the Wald test and the Likelihood Ratio Test. The Wald statistic compares estimates of parameters against their standard errors in order to test whether the particular explanatory or dummy variable's coefficient is zero. If the Wald test is significant, then we conclude that the coefficient value given in the model is not zero. The formula for the Wald test for large samples is given as

$$z = \frac{\hat{\beta}}{se(\hat{\beta})}. \tag{3.4}$$

Asymptotically, the square of z has a chi-squared distribution with degrees of freedom equal to one. The Wald test has been criticised by some authors when used in discrete probability models, such as logistic models (Collett, 2003). It is seen that significant regression coefficients when calculated using the Likelihood Ratio test may not be significant when using the Wald test, and that the Likelihood Ratio test is more reliable for small sample sizes (Agresti, 1996).

The Likelihood Ratio test mentioned above assesses the significance of an explanatory variable by conducting a hypothesis test between the full model (F) and a simpler reduced model (R) which does not have the variable of interest included. The test calculates the ratio of the maximised value of the likelihood value for F to the maximised value for the likelihood value for R. The log of this ratio statistic is given as:

$$LR = -2[\log L(\hat{\beta}_R) - \log L(\hat{\beta}_F)]. \tag{3.5}$$

For large samples LR is compared to χ^2 distribution with the degrees of freedom equal to the difference in the number of parameters between the full and reduced models.

The selection of most models was conducted by entering the explanatory variables of interest into the model. Due to comparisons being made between countries insignificant variables were left in the model. However, when country comparisons were not being conducted forward selection was used, adding the explanatory variable which explained the highest amount of variation in the data, assessed by studying the p-value from the LR test. In all models the Wald statistic was calculated to assess the significance of each parameter in the model. Furthermore, as explained earlier, the

DHS data were collected using complex survey methods. These methods were not ignored in the analysis, but the stratification variable, urban/rural, was entered into all models irrespective of significance to reduce bias to parameter estimates that occurs if this hierarchical structure is ignored (Madise *et al.*, 2003).

3.4.2. Multilevel Logistic Regression for Binary Data

One of the assumptions of the logistic regression model described in the previous section is that all the outcomes in the analysis are independent. However, this assumption is easily violated in social survey data. For example, in the study of the birth weight of infants, children born to the same mother are more likely to be similar than children born to different mothers. Furthermore, women living in the same household are subject to the same conditions and thus their birth outcomes are likely to be more similar than those from different households. The lack of independence can be extended to a local and national level, with mothers from one area experiencing similar nutritional and climactic conditions for instance, which may have an effect on birth weight and other child outcomes. Ignoring this correlation between different mothers may result in the standard errors for the parameters being downwardly biased, and thus tests for significance of these parameters may lead to erroneous conclusions.

In order to allow for the hierarchical structure of the data, the logistic model can be extended with the use of random effects which estimate the correlation of observations within a cluster, however a cluster is defined. To illustrate this, if our response variable is given as y_{ij}, which equals 1 if the individual i in district j has the response of interest, and 0 otherwise. The probability that $y_{ij} = 1$ is denoted as π_{ij}. Using this, expression (3.2) can be extended to a two-level random intercept model to become:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{0j} + \beta_1 x_{1ij} + \cdots + \beta_K x_{Kij}, \qquad (3.6)$$

where $\beta_{0j} = \beta_0 + u_{0j}$.

It is seen in (3.6) that the intercept term, β_{0j}, is composed of two terms, a fixed component β_0, and a random error component for the individual district, u_{0j}, which is assumed to be normally distributed with mean 0 and variance σ^2_{u0}. If there is no correlation between the individuals in any of the districts the model reduces to the standard logistic model. To test for correlation at the district level a hypothesis test can be conducted on σ_u, with the null hypothesis that $\sigma_u = 0$ and the alternative hypothesis that $\sigma_u > 0$. Due to σ_u being constrained to be positive, the test used is a modified likelihood ratio test (Snijders and Bosker, 1999). The magnitude of σ_u indicates the size of the district effects, with larger values indicating greater correlation between individuals in the area under analysis.

The two-level model, seen in expression (3.6), can be easily extended to include three or more levels. The model can also be extended to allow the coefficients to vary between regions, meaning that there will be a different relationship between an explanatory variable and a response variable depending on the district where an individual resides.

Estimation of the multilevel models throughout this thesis was conducted in MLwiN Version 2.02 (Rasbash *et al.*, 1999). Quasi-likelihood methods are used within this program, using a second order Taylor series expansion which transforms a discrete response variable into a continuous variable, from which likelihood estimates can be generated. This is needed as maximum likelihood methods for binary responses, and for all discrete responses, are computationally intense (Rasbash *et al.*, 2004). In most of the investigations conducted in this thesis the main focus are the fixed effects rather than the random variation. To estimate the parameters of the fixed effects it is generally thought that estimation using iterative generalised least squares (IGLS) is better, while restricted IGLS (RIGLS) is more appropriate for estimating random variances (Twisk, 2006) . Thus the IGLS procedure was used in most of the studies in this thesis. The occasions where RIGLS was used will be noted.

The quasi-likelihood procedures used are either marginal quasi-likelihood (MQL) or penalized quasi-likelihood (PQL). MQL can underestimate the values of the parameters, and thus in general a second order (due to the Taylor series expansion being used) PQL estimate is calculated (Goldstein, 2003). However, convergence problems are sometimes seen when using second-order PQL methods, and thus MQL is used to obtain starting values for the parameters, followed by second-order PQL estimation (Rasbash *et al.*, 2004).

3.4.3. Logistic Regression for Nominal Data

In some instances, the response variable under investigation is categorical, as above, but there are more than two categories. Therefore the binary logistic model is not applicable. Different methods are needed, and the method chosen depends on whether the response categories are ordered or unordered. This section describes the models to be used when the order of the categories in the dependent variable is irrelevant, while the next section describes the models which can be applied to ordered responses. Both types of models are generalisations of the binary models presented above.

If it is assumed that the response variable, Y, has T categories where it is irrelevant in which order the categories are listed. The probability of a response being in each category is $\{\pi_1,\ldots,\pi_T\}$, where $\sum_t \pi_t = 1$. If a sample of size n is taken, the probability distribution which identifies the probability for allocating each of the observations to the categories is a multinomial distribution. If there are two categories $(T = 2)$ then the distribution is binomial, and the procedure shown in Section 3.4.1. can be used. For simplicity the description of the multinomial model below uses one explanatory variable, but this is easily generalised for multiple explanatory variables.

In order to model multinomial data, one category is arbitrarily defined as the reference category against which the other categories are compared. Logit equations are then specified for $T-1$ pairs of categories, which contrast each of the categories with the reference category. If the last category (T) is taken as the reference category, and there is one explanatory variable, x, the multinomial logistic regression model, using a logit link, is defined as:

$$\log\left(\frac{\pi_t}{\pi_T}\right) = \beta_0^{(t)} + \beta_1^{(t)} x \qquad t = 1, \ldots, T-1. \qquad (3.7)$$

The complete model therefore has $T-1$ logit equations, and each of these equations have a different intercept and slope parameter. Therefore the separate effects for each response category paired with the baseline category can be estimated. The equations in (3.7) for each of the response variables should be estimated simultaneously for optimal efficiency (Agresti, 1996). Each equation gives the log odds that the response is t, given that the response falls in either t or T.

The interpretation of the coefficients in the model is usually conducted with reference to the baseline category. $\beta_1^{(t)}$ is the additive effect seen when there is a one-unit increase in x on the log-odds of being in category t as opposed to the reference category T. However, the multiplicative effect rather than the additive effect of a one-unit increase in x is usually simpler to interpret, which is calculated by $\exp(\beta_1^{(t)})$.

An alternative method of interpreting the model is to calculate the response probabilities related to different values of x. The formula for calculating this is:

$$\pi_t = \frac{\exp(\beta_0^{(t)} + \beta_1^{(t)} x)}{\sum_t \exp(\beta_0^{(t)} + \beta_1^{(t)} x)} \qquad t = 1, \ldots, T \qquad (3.8)$$

For the reference category, the coefficients $\beta_0^{(T)}$ and $\beta_1^{(T)}$ are zero. Hence,

$$\pi_t = \frac{\exp(\beta_0^{(t)} + \beta_1^{(t)} x)}{1 + \sum_{t=1}^{T-1} \exp(\beta_0^{(t)} + \beta_1^{(t)} x)} \qquad (3.9)$$

and the probability of being in the reference category is obtained through subtraction:

$$\pi_T = 1 - \sum_{t=1}^{T-1} \pi^{(t)}. \qquad (3.10)$$

The individual parameters can be tested by using the Wald statistic (3.4), and the Likelihood Ratio test is used to test overall model fit (3.5).

Multinomial logistic regression will be conducted when looking at the chances of a mother being correct in the assessment of her child's size when comparing this with actual birth weight. This could obviously be conducted on a binary basis with people either being correct or incorrect in their assessments, but also could be conducted for different classifications of incorrect assessments.

3.4.4. Logistic Regression for Ordinal Data

In the circumstances where the response categories can be ordered, data can be modelled using ordinal logistic regression. This will be used when modelling the mothers' perception of their child's size. This variable has five categories ordered between 'Very Small' and 'Very Large'.

The modelling process involves the estimation of cumulative logit models. If it is assumed the response variable, Y, has T ordered categories, the chances that the response falls in category t or below is:

$$P(Y_i \leq t) = \pi_i^{(1)} + \cdots + \pi_i^{(t)} \qquad t = 1, \ldots, T. \qquad (3.11)$$

Obviously, $P(Y_i \leq T) = 1$ and thus the final response category does not need to be modelled. To obtain logits for these cumulative probabilities the formula used is

$$\text{logit}[P(Y_i \leq t)] = \log\left(\frac{\pi_i^{(1)} + \cdots + \pi_i^{(t)}}{\pi_i^{(t+1)} + \cdots + \pi_i^{(T)}}\right) \qquad t = 1, \ldots, T-1\ . \qquad (3.12)$$

Each cumulative logit is similar to the binary logit models noted above for a dichotomous outcome (see section 3.4.1.). The model for the t^{th} cumulative logit is in effect a binary logit model where categories 1 to t have been combined to form one category, and categories $t+1$ to T are combined to form another category.

To model the ordinal data a proportional odds model with a logit link is used, where the effect of the explanatory variable x on Y is the same for all categories of the response. The model, for one explanatory variable is:

$$\text{logit}[P(Y \le t)] = \beta_0^{(t)} + \beta_1 x \qquad t = 1,\ldots,T-1 \text{ .} \qquad (3.13)$$

For ease of interpretation, odds ratios are calculated for a fixed response category. Given two values for the explanatory variable, x_1 and x_2 an odds ratio can be calculated:

$$\frac{P(Y \le t \mid X = x_2) / P(Y > t \mid X = x_2)}{P(Y \le t \mid X = x_1) / P(Y > t \mid X = x_1)} \qquad (3.14)$$

If the log of (3.14) is taken then the result equals $\beta(x_2 - x_1)$. This is proportional to the distance between the x values, which applies to each possible point within t. If there is a unitary difference between x_1 and x_2 then for every unit increase in x the odds of obtaining a response that is less than or equal to t is multiplied by e^{β}.

3.4.5. Multilevel Logistic Regression for Ordinal Data

Further to the ordinal logistic model described in the above section, this can be extended to accommodate the multilevel structure of the data. This model is a simple generalisation of the single level model. In a similar way to equation (3.6), there is assumed to be correlation between units within a sampling unit such as households, villages and regions. Therefore, if it is assumed that there is clustering at one level, say individuals with a region, the proportional odds model in (3.14) can be extended to allow for this random effect at the regional level. This is shown for response Y with one explanatory variable, x, below:

$$\text{logit}[P(Y \le t)] = \beta_{0j}^{(t)} + \beta_1 x \qquad t = 1,\ldots,T-1, \qquad (3.16)$$

$$\beta_{0j}^{(t)} = \beta_0^{(t)} + u_{0j}^{(t)}.$$

where:

$\beta_{0j}^{(t)}$ is a random intercept for the t^{th} category in region j;

β_1 is a fixed effect of x on Y across all categories and levels;

$u_{0j}^{(t)}$ is the error term associated with category t in region j, assumed to be distributed $N(0, \sigma_{u0}^2)$.

Interpretation of this model is similar to that of the simple ordinal regression model, with interpretation of the magnitude of σ_{u0}^2 to assess the district effect, as was explained above for multilevel binomial logistic regression.

3.4.6. Residual Analysis of Multilevel Models

The multilevel models developed in this thesis were all assessed to ensure that the underlying assumptions of the models applied. One assumption is that the residuals at each of the levels in the model (apart from at the lowest level) are normally distributed and have a constant variance. This can easily be checked through the plotting of these residuals on a histogram and a quantile-quantile plot. This was done for each multilevel model, but the results will not be presented unless the results are not as expected and need further clarification. For the single level logistic, ordinal and multinomial models there are no distributional assumptions of assumptions about the distribution of the variance which need to be satisfied. For these models the residuals were only checked for outliers.

3.5 Summary

This chapter has highlighted the salient issues regarding the data and statistical methods that are to be used throughout this thesis. Further statistical methods will be explained as and when needed. In Chapter 8 there is a discussion of missing data and the mechanisms that are related to and techniques that can be used to cope with missing data. This discussion will highlight the methods that are used in this thesis to cope with missing birth weight data in the analysis of infant mortality.

It is clear from the discussions conducted in Section 3.3 that there are issues in some countries with the data quality of birth weight information, as shown by high levels of infants weighing over 6000g. The data quality of the birth weight variable will be further examined in the next chapter.

Chapter 3: Key Points

- Data for this thesis are taken from recent Demographic and Health Surveys in 15 countries
- Infants born in the 5 years before the survey date (in most countries) have detailed information recorded in the surveys, including information about birth weight
- A number of demographic, socio-economic, cultural, medical and other variables were selected for use throughout the thesis
- Infants with birth weights more than 6000g were treated as having a missing birth weight
- The main statistical methods used in the thesis included logistic, ordinal and multinomial regression. Multilevel analysis was conducted where appropriate.

Chapter 4

How Accurately Is Birth Weight Reported?

The need for accurate and reliable information and statistics in developing countries, especially in the health sphere, is increasing. Health information is the 'foundation for policy-making, planning, programming, and accountability' (Health Metrics Network, 2006). The use of birth weight in monitoring various international development indicators and goals highlights the need for trustworthy statistics regarding birth weight. Furthermore, birth weight can be viewed as both an outcome of various explanatory factors and a predictor of outcomes, such as mortality and morbidity. As such, it is vital to understand how accurately and reliably birth weight is recorded in surveys such as the DHS, a good source of health information in developing countries. Previous studies have indicated that there is likely to be heaping on certain weights, and that there may be different distributions of weights between countries, racial groups and educational levels.

The proportion of children who are weighed at birth varies widely between countries. Even when a child is weighed at birth, this does not mean that the birth weight will be accurately recorded in a survey, if it is recorded at all. A mother may report a birth weight to the interviewer using one of two methods; recalling directly from her memory or reading the weight from a medical record. These medical records, usually given to the mother in the form of a health card, may be assumed to give more accurate birth weights than weights reported from maternal memory. However, even medical records differ in accuracy. Accuracy may depend on the equipment used to weigh the child and the level of precision used during the weighing and recording process by the medical staff. With respect to birth weights which are not stated on a health card and must therefore be recalled from memory, accuracy may be compromised by mothers forgetting the birth weight of their child and guessing at the weight. This may lead to incorrect birth weights being recorded. Alternatively the mother may remember an incorrect weight that was given to her by a doctor. A further issue with birth weights which have been measured yet which are not recorded on a health card is that the mother may not remember the weight at all and not even hazard a guess at it. As a result of this there will be missing observations on the birth weight variable in the survey.

The aim of this chapter is to investigate birth weight data in the 15 countries noted in the previous chapter, and to study the trends and relationships seen in birth weight in these different countries. The proportion of missing data in each country will be studied for associations with a number of selected variables, followed by an investigation into the amount of heaping on specific birth weights. This will give an indication of the general accuracy of retrospectively recorded birth weights in the DHS for each of the countries. Different summary statistics for birth weight will be compared across countries, and a comparison of the different distributions of birth weight conducted.

Low birth weight (LBW) is a main focus of goals set by the WHO and the UN (United Nations, 2002). The proportion of LBW children will be estimated for each country using the DHS, and compared to estimates of the proportion with LBW from other studies, where available. Differences in the estimated proportion of infants with LBW depending on how the heaped data is treated will also be discussed. The proportion will also be estimated with respect to how the birth weight was reported in the survey, either from memory or health card. Finally, an investigation into the determinants of LBW will be completed, using logistic regression to model the data.

4.1. Proportion of Missing Birth Weight Data

In all of the selected countries a certain proportion of infants do not have birth weight recorded in the survey. Table 4.1 presents the percentage of children who have missing birth weight data in each of the selected countries' surveys. The proportion of infants without a recorded birth weight ranges from 2.9% in Kazakhstan to 90.7% in Haiti. In eight of the 15 countries over half of the infants in the survey do not have a recorded birth weight.

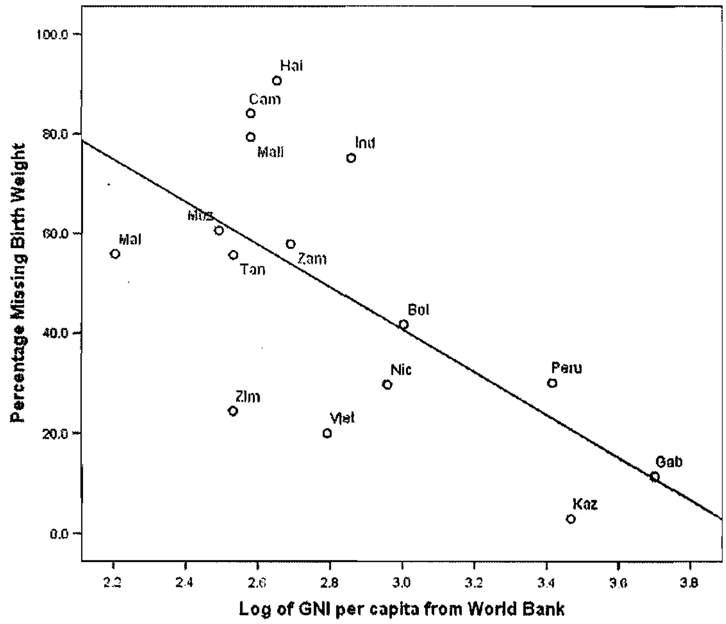
Table 4.1: Percentage missing birth weight data by country

Country	% Missing
Kazakhstan	2.9
Gabon	11.4
Vietnam	20.0
Zimbabwe	24.4
Nicaragua	29.6
Peru	30.0
Bolivia	41.7
Tanzania	55.7
Malawi	55.9
Zambia	57.9
Mozambique	60.6
India	75.1
Mali	79.4
Cambodia	84.1
Haiti	90.7

It may be easily hypothesised that the amount of missing birth weight information in each country is related to the wealth of that country. A richer country is likely to have better health infrastructure with the net result that a higher proportion of births are weighed. The relationship can easily be seen if the percentage of infants in each country with missing birth weight information is displayed against Gross National Income per capita (GNI per capita; Figure 4.1). GNI per capita is used because it includes the value of all goods and services produced by domestically owned companies, divided between the mid-year population. Therefore, companies operating abroad but sending profits back will count in the GNI, and as such it is a good indicator of the wealth of a country.

As expected there is a strong negative relationship between the logarithm of GNI per capita and the percentage of infants with missing birth weight information, with increasing GNI per capita being associated with a lower percentage of missing birth weight data. The Pearson correlation coefficient for the relationship between the logarithm of GNI and the proportion of missing birth weight data is -0.643 (p=0.01).

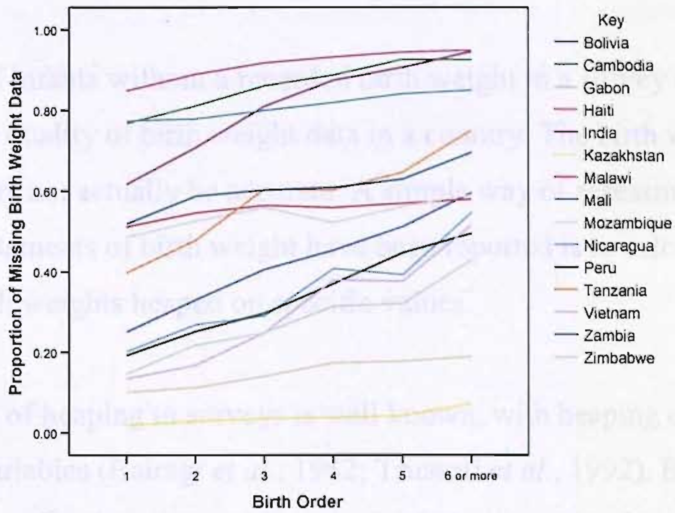
Figure 4.1: Scatterplot of the percentage of infants with missing birth weight data by log GNI per capita with an estimated regression line



Source for GNI: World Bank (http://www.worldbank.org/data/databytopic/gdp.html)

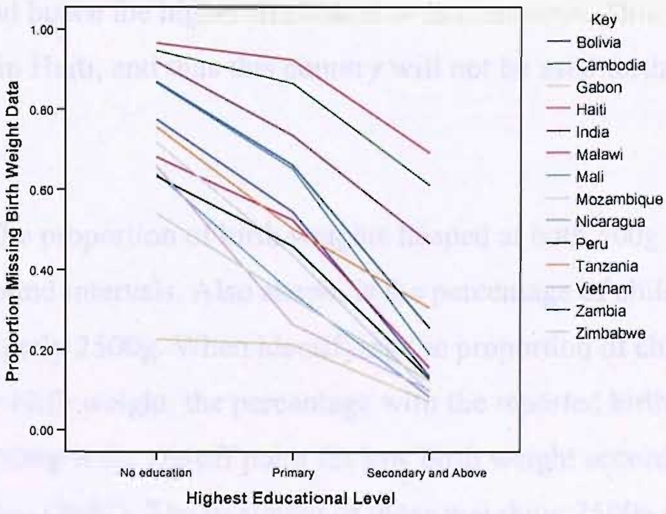
A further association can be seen between the birth order of an infant and the proportion of infants without a reported birth weight. Figure 4.2 shows the trend for each country as birth order changes, and it is clear that as parity increases, the chances of the child having a recorded birth weight decrease. Apart from a minority of countries, children of a higher parity have a lower chance of having a recorded birth weight than those of a lower parity. This may simply be due to a mother who has more children having more birth weights to remember. This relationship may also be explained by the fact that families with a large number of infants are likely to be poor, and therefore the infants are unlikely to be born in a place where they will be weighed. This will lead to a higher proportion of high birth order infants not having a reported birth weight.

Figure 4.2: Proportion of missing birth weight data by birth order



The relationship between the proportion of missing birth weight and the highest educational level of the mother is again as expected (Figure 4.3.). As education rises, the amount of missing birth weight data falls. The only country that does not follow this trend is Kazakhstan. This is due to there being almost complete coverage of secondary education in the country (only 3 mothers do not have at least a secondary education). As a result Kazakhstan is not included in Figure 4.3. India is a good example of the relationship between education and the missingness of birth weight. Overall 75% of infants in the survey do not have a reported birth weight. For infants with mothers who have had no education, 92% do not have a reported birth weight, while for infants born to mothers with at least a secondary education this falls to 46%.

Figure 4.3: Proportion of missing birth weight data by educational level



4.2. Heaping of Birth Weight

The proportion of infants without a recorded birth weight in a survey does not give the full picture of the quality of birth weight data in a country. The birth weight that has been recorded may not actually be accurate. A simple way of assessing how precisely the individual statements of birth weight have been reported is to calculate the proportion of birth weights heaped on specific values.

The phenomenon of heaping in surveys is well known, with heaping observed on many different variables (Bairagi *et al.*, 1982; Trussell *et al.*, 1992). Boerma *et al.* (1996) have shown that there is much heaping at 500g intervals of birth weight in the DHS. However, in some countries, e.g. Nicaragua, weights are still recorded in pounds and ounces (Imperial measurements), and these units are the predominant units of weight used by the general population. Weights reported by the mother in Imperial units are converted to grams when recorded in the survey. The amount of heaping at 500g intervals for these countries will therefore not represent the true level of clustering, as pounds and half pounds do not convert to multiples of 500g. It is also possible that some mothers do not use the standard weight measurements, i.e. in a country which is predominantly metric the mother uses pounds and ounces, and therefore the amount of heaping at both 500g intervals and the metric equivalent of pounds and half pounds was calculated for all countries in the analysis. A further problem in countries which use Imperial measurements is in the conversion of birth weights from pounds and ounces to grams. This introduces another step into the survey process and hence the higher likelihood of human error. This is hypothesised to have occurred in Haiti, and thus this country will not be used further in this study (see Box 4.1).

Table 4.2 shows the proportion of birth weights heaped at both 500g intervals and at pound and half pound intervals. Also shown is the percentage of children having a birth weight of exactly 2500g. When identifying the proportion of children who are designated as low birth weight, the percentage with the reported birth weight of 2500g is important, as 2500g is the cut-off point for low birth weight according to the World Health Organisation (2001). The treatment of those weighing 2500g will have a large effect on the proportion of LBW infants in a country. Due to the different units of weight measurement being used in the various countries, and the possibility that some mothers in predominantly metric countries may report the birth weight in pounds and ounces, a formal analysis of digit preference of birth weights ending in '0' and '5', such as Whipple's Index or Myers's Blended Method (Siegel and Swanson, 2004) was not conducted. These methods were thought not to add anything further to the simple study of the proportion of birth weights heaped on the values noted above.

Box 4.1 – Recorded Birth Weights in Haiti

Haiti is a country which still uses the Imperial measurement system, and many infants are still weighed in pounds and ounces. This is indicated by the DHS questionnaire providing the ability to record birth weight in both grams and pounds/ounces (Cayemittes *et al.*, 2001). The questionnaire also asks the interviewer to convert weights which are reported as ¼, ½ or ¾ of a pound into ounces. The conversion from pounds/ounces to grams (which is the unit of measurement reported in the data file) is conducted at a later point of time. However, this conversion does not seem to have been conducted correctly, with many infants in the survey having weights which are considered as being unlikely.

Haiti has a large proportion of missing birth weight information (90.7% missing), and only 615 infants have a reported birth weight. Out of these, 74 infants had a reported birth weight of 6000g or more, representing 12.4% of those with a reported birth weight. As a comparison, in the U.S.A. in 2002 the percentage of infants who weigh over 5000g at birth is only 0.13%. This is a lower percentage than infants who weigh under 500g (Martin *et al.*, 2003). Furthermore, according to the survey in Haiti, five infants were reported as weighing 9kg. The heaviest ever birth weight recorded is just over 10kg (Guinness World Records, 2005), and thus having such a large proportion of extraordinarily heavy children seems unlikely. These details indicate that data quality is extremely low for birth weight in Haiti. The possible reason for this is that an error has been made in the conversion of weights from Imperial to metric measurements, but attempts to understand the mechanics behind this error were not successful.

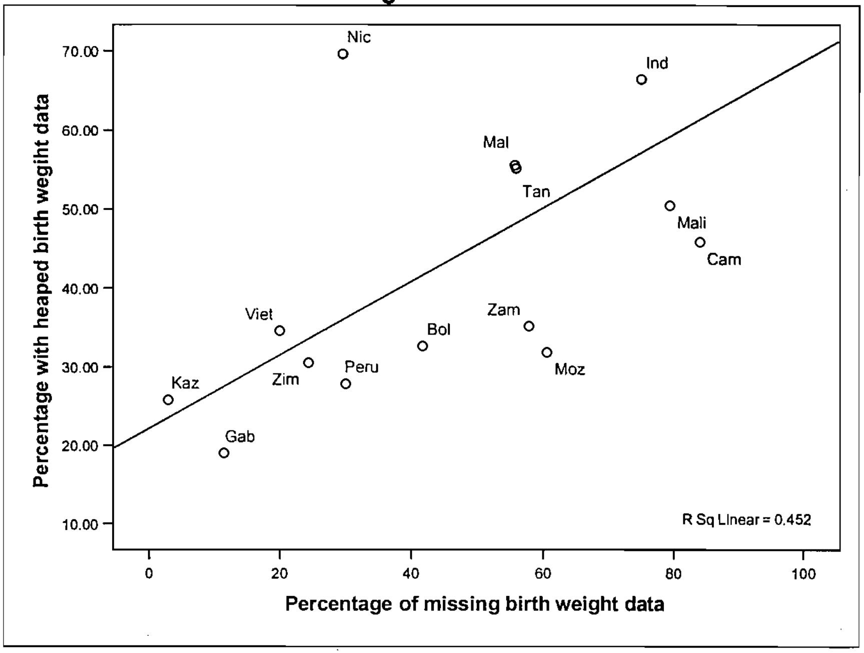
Table 4.2: Percentage of weights clustered at multiples of 500g/half-pound and at 2500g

Country	% Heaped 500g/½lb	% Heaped at 2500g
Gabon	19.0	3.6
Kazakhstan	25.8	2.1
Peru	27.8	3.9
Zimbabwe	30.5	4.8
Mozambique	31.8	5.7
Bolivia	32.6	3.0
Vietnam	34.5	4.2
Zambia	35.1	4.8
Cambodia	45.8	7.1
Mali	50.4	7.4
Malawi	55.1	10.4
Tanzania	55.5	8.4
India	66.4	18.7
Nicaragua	69.6	0.4

The percentage of weights heaped at 2500g does not take into account the weight measurement system which is utilised in that country (either metric or Imperial). Thus Nicaragua has a very small percentage of babies recorded as weighing 2500g. The closest Imperial measurement to 2500g, which is five and a half pounds, converts to 2495g. Therefore, all children heaped on the weight of 5lbs 8oz will be classified as being of low birth weight. The proportion of heaping on 500g/½lb weights ranges from 19.0% in Gabon, to 69.6% in Nicaragua. The high proportion of heaped data in Nicaragua shows that even though Imperial measurements are used, levels of heaping are extremely high.

From Tables 4.1 and 4.2 it is clear that countries with a high proportion of missing data also have a high level of heaped weights. If the percentage of missing data is plotted against the percentage of data which is heaped the relationship is strongly positive (Figure 4.4). The outlier in this scatterplot is Nicaragua, which has a fairly low level of missing data but a high percentage of heaping.

Figure 4.4: Scatterplot showing the relationship between heaping and missingness of birth weight for countries



To obtain a measure of the association between heaping and the proportion of missing data in each country the correlation between the variables was calculated. This was observed to be 0.673 (P=0.008). A simple linear regression indicates that for every percentage point increase in the proportion with missing birth weight data there is a 0.47 percentage point increase in the amount of weights heaped at 500g and half pound intervals. The relationship between these two measures may be due to a lack of facilities within the country, a lack of training in the hospitals, a lack of importance placed on the accurate recording of actual birth weight or poor general socio-economic status and maternal education.

4.3. Comparison of the Distribution of Birth Weight between Countries

Previous studies have shown that there is considerable heterogeneity between countries in their birth weight distributions (World Health Organization, 1984; 1992; Blanc and Wardlaw, 2005). Table 4.3 gives the summary statistics for birth weight in the different countries in this study, ordered by mean birth weight.

Table 4.3: Summary statistics for children with a recorded birth weight in grams

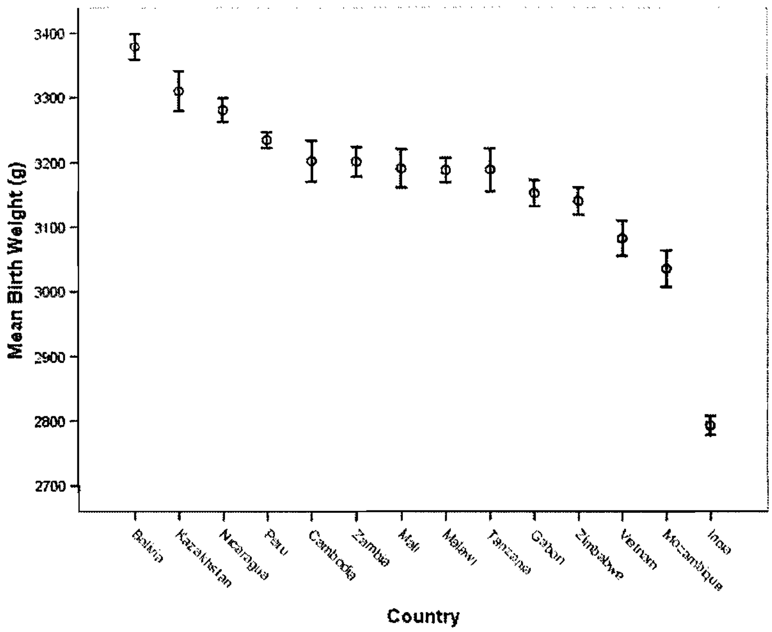
Country	*Number of Infants*	Mean	St Dev	Min	Max
India	*8134*	2793	670	500	6000
Mozambique	*1577*	3036	572	500	6000
Vietnam	*1043*	3082	452	1200	4800
Zimbabwe	*2668*	3140	559	1000	5500
Gabon	*3740*	3152	623	1000	6000
Malawi	*5042*	3188	673	1000	6000
Tanzania	*1374*	3188	629	1000	6000
Mali	*2607*	3190	777	500	6000
Zambia	*2805*	3201	629	980	6000
Cambodia	*1375*	3202	607	800	6000
Peru	*9452*	3235	599	500	6000
Nicaragua	*4819*	3281	649	500	6000
Kazakhstan	*1279*	3311	567	1000	5500
Bolivia	*4205*	3379	654	800	6000

Table 4.3 indicates that there are large differences in mean birth weights between countries. For the individual countries, the mean birth weights range from 2793g in India to 3379g in Bolivia – a difference of 586g. The variation in the weights also differs greatly, with a standard deviation in Vietnam being 452g, whilst in Mali it is 777g. It is also clear that the maximum and minimum weights are almost all heaped. This, in part, is due to the truncation of the weights at 6000g, but this only affects three countries (Bolivia, India and Nicaragua). Minimum weights are also mainly heaped at 500g intervals, which indicates either the poor quality of the data or the measurement imprecision associated with such heavy or light weights.

It is clear that India is dissimilar to the other countries in the analysis due to the mean being so different to the mean birth weight in other countries. Indeed, the difference between mean birth weight in India and the second lightest country, Mozambique, is 243g. To place this in context, the difference between Mozambique and the country with the second heaviest mean birth weight, Kazakhstan, is 275g. It is well documented that, on average, Indian children do have lower birth weights than in the majority of the rest of the world (Sachdev, 1997). The mean birth weight of 2793g found in this study is very similar to the estimates found in other studies (World Health Organization, 1992).

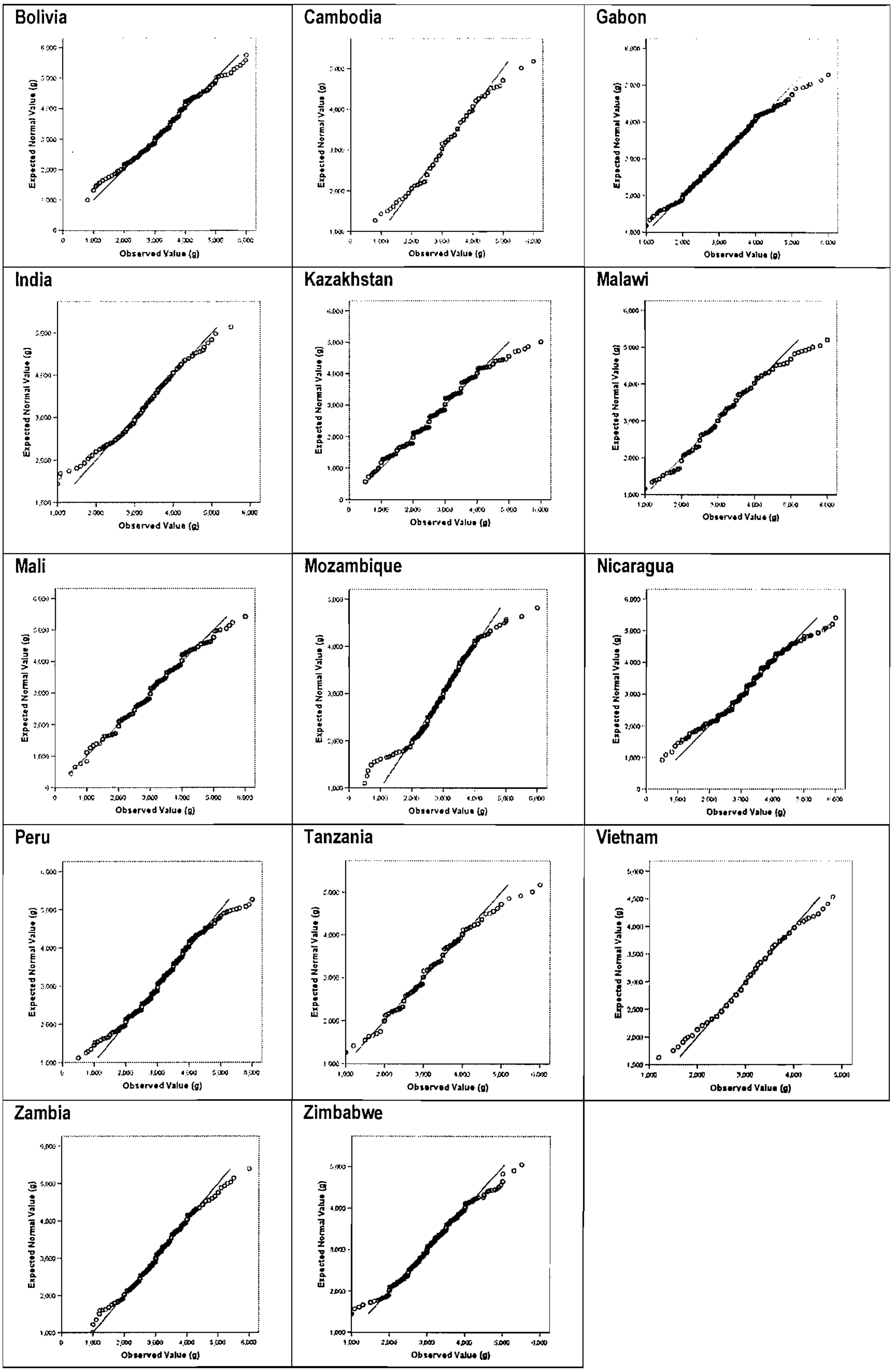
Due to the large sample sizes in each of these surveys the 95% confidence interval for the mean birth weight in each country covers only a small range. Figure 4.5 shows the mean birth weight for each country including a 95% confidence interval, and indicates the variability of the mean weights over the countries. It also clearly shows that India is an outlier when compared to the other countries in this analysis.

Figure 4.5: Error bar chart (95% C.I.) of mean birth weight for 14 countries



From Figure 4.5 it is not clear whether the different countries have the same birth weight distribution, and are just centred on a different mean, or if the distributions for each country are actually different. Quantile-Quantile (Q-Q) plots were produced to assess whether two countries have a similar distribution of birth weight. These indicate that some countries do differ from others in their distribution, although these differences are not seen to be large. The Q-Q plots for all countries, plotted against the other countries quantiles are given in Appendix A. It is also interesting to plot the birth weight distribution against a theoretical normal distribution to assess normality. The results of doing this are shown for all countries in Figure 4.6. These plots indicate that in all countries the reported birth weights are normally distributed over the central range of the data, but extreme birth weights (<2000g and >5000g) deviate from the normal distribution. In some countries, such as Mozambique and Nicaragua, this deviation at the extremes is severe, while in others, such as Bolivia and Mali, there is not much difference from the theoretical normal distribution. Birth weight is normally

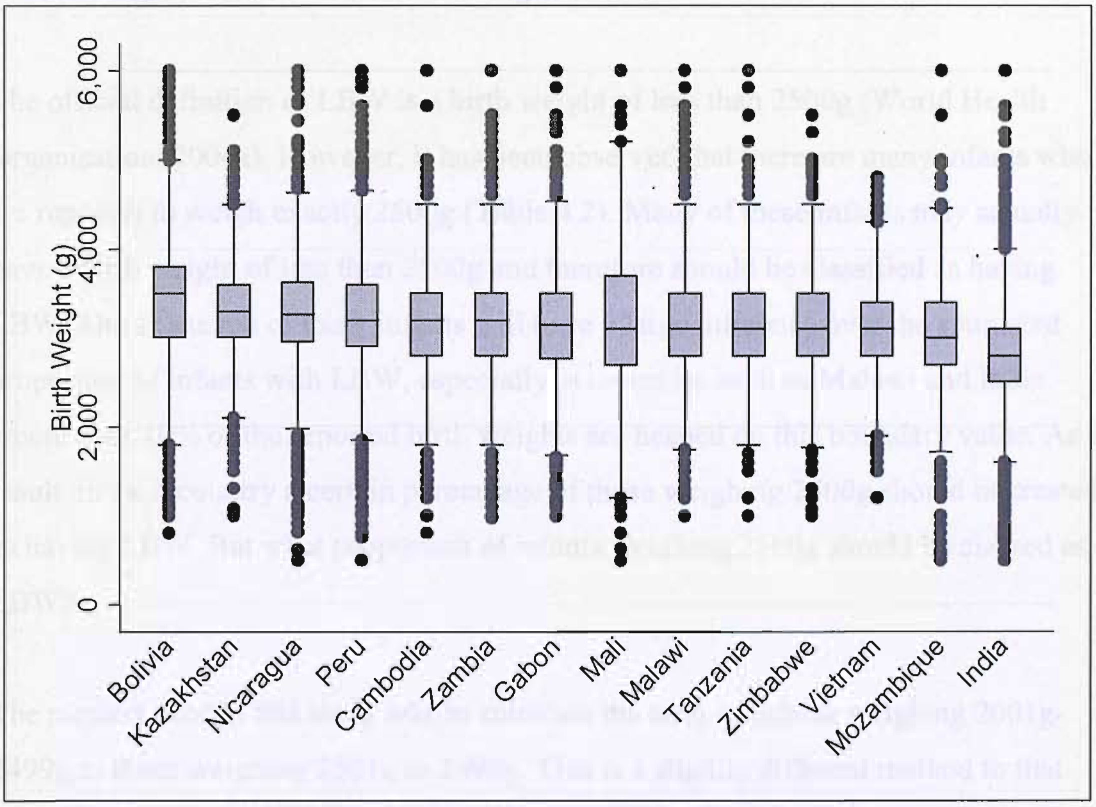
Figure 4.6: Q-Q plots of birth weight for 14 countries against theoretical normal distribution



distributed in the population, albeit with a long left hand tail for the lighter weights (Wilcox, 2001).

The Q-Q plots in Figure 4.6 indicate that there is some concordance with the normal distribution for most of the countries. However, Table 4.4 indicates that there is variation between the countries in the spread of the data, as shown by the different estimated standard deviations. The Levene statistic for homogeneity of variances indicates that there are significant differences between the variances between the various countries, which is to be expected with the large sample sizes in the data sets. Box plots of the birth weight within each country indicating the distribution of the data again shows that there are differences between the distributions of weights in each country in the spread of birth weight (Figure 4.7).

Figure 4.7: Box plots displaying the distribution of birth weight by country



Due to the amount of heaping in the datasets only Gabon has a median value which is not a multiple of 100g (results not shown). However, Figure 4.7 shows that many of the countries are similar in their distributions. For example, Malawi, Tanzania and Zimbabwe are extremely alike, with the same median and a similar spread. To this group of countries, although with a different median, can be added Zambia and Mozambique, indicating that the distributions shown in this region of Africa are fairly alike. Furthermore, countries such as Nicaragua, Peru, Cambodia and Gabon are very similar, albeit with some small differences in the median and the inter-quartile range (IQR). The countries which do appear to have a different distribution are Bolivia, with a greater IQR and higher median; Kazakhstan, with smaller whiskers on the box; and Mali, with a very large IQR. Finally, India has a box which is shifted down towards the lighter weights and has many more outliers. However, in general, the distributions look similar across countries, which is encouraging for the ability to make comparisons between countries.

4.4. Low Birth Weight

4.4.1. Proportion of Low Birth Weight Infants

The official definition of LBW is a birth weight of less than 2500g (World Health Organisation, 2004a). However, it has been observed that there are many infants who are reported to weigh exactly 2500g (Table 4.2). Many of these infants may actually have a birth weight of less than 2500g and therefore should be classified as having LBW. The exclusion of these infants will have a large influence over the estimated proportion of infants with LBW, especially in countries such as Malawi and India, where over 10% of the reported birth weights are heaped on this boundary value. As a result, in each country a certain percentage of those weighing 2500g should be treated as having LBW. But what proportion of infants weighing 2500g should be classed as LBW?

The method used in this study was to calculate the ratio of infants weighing 2001g-2499g to those weighing 2501g to 2999g. This is a slightly different method to that used by Blanc and Wardlaw (2005) and Boerma (1996). By using the range 2001g-2999g (excluding the infants heaped on 2500g) it is hoped that only unheaped and therefore more reliable birth weights will be used. The proportion of infants who are reported in the survey as weighing exactly 2500g, but are hypothesised to weigh less than this amount and therefore should be classified as having LBW, is shown in Table

4.4. The average proportion over all the countries was not used as it is hypothesised that different proportions of those weighing 2500g should actually be classified as LBW in each country, depending on the mean birth weight in that country and the group of infants with a reported birth weight. The results indicate that Cambodia is an outlier, as fewer than 10% of those weighing 2500g will be classified as having LBW. This is due to the high proportion of missing data and the level of heaping in this country, causing there to be very few infants who weigh between 2001g and 2499g.

Table 4.4: Proportion of infants weighing 2500g to be classified as LBW

	% 2500g to be classified as LBW
Cambodia	9.6
Vietnam	14.8
Tanzania	19.2
Zimbabwe	19.6
Kazakhstan	20.0
Mozambique	21.0
Peru	21.9
Zambia	23.0
Nicaragua	23.9
Bolivia	24.6
Gabon	28.5
Malawi	31.0
India	35.1
Mali	38.3

The proportion of children in each country within this study who have LBW according to their recorded birth weight is noted in Table 4.5 using the official definition of LBW (<2500g). Also noted are two other estimates of the proportion of infants with LBW: classifying a certain percentage of infants who weigh as 2500g as actually weighing less than this amount, shown in Table 4.4, and also if all those who did weigh 2500g were defined as having LBW.

The range over the countries of the proportion of infants with LBW, using the standard WHO definition (<2500g), is large. India has the highest proportion of LBW children, with 21.9% of those weighed being classified as LBW. The fact that India has the highest proportion of LBW children is unsurprising, as the mean birth weight is much lower than in other countries. The country with the second highest proportion of babies with LBW is Mali, with 14.2%. Cambodia has the lowest proportion of

LBW children according to the official WHO definition, with 5.6% of the babies who are weighed at birth weighing less than 2500g. This low proportion for Cambodia, as well as for Vietnam and Bolivia seems incongruous, as it is expected that the percentage of infants with LBW in these countries is much higher. Villar and Belizan (1982) estimate that in most developing countries the percentage of LBW infants is over 10%, and in the U.K. and the U.S.A. the estimated percentage of LBW infants is 8% (Blanc and Wardlaw, 2005). The low estimate for Vietnam is also interesting as the mean birth weight in this country is very light (3082g), and therefore it may be hypothesised that there will be a large proportion of infants weighing under 2500g. However it is seen that most birth weights in Vietnam are clustered between 2500g and 3500g, leading to the low mean birth weight observed.

Table 4.5: Proportion of infants with LBW by country

	<2500g	Inc. % of 2500g[1]	≤2501g
Cambodia	5.6	6.2	12.6
Kazakhstan	6.1	6.6	8.2
Vietnam	6.5	7.2	10.7
Bolivia	6.9	7.6	9.9
Peru	8.0	8.8	11.9
Tanzania	7.6	9.2	15.9
Zimbabwe	8.5	9.4	13.2
Nicaragua	9.6	9.7	10.0
Zambia	9.1	10.2	13.9
Mozambique	11.5	12.7	17.3
Malawi	9.7	13.0	20.2
Gabon	12.0	13.1	15.6
Mali	14.2	17.0	21.6
India	21.9	28.4	40.5

[1]See Table 4.4 for percentage of infants weighing exactly 2500g classified as LBW for each country

However, if the other estimates for LBW are studied, which include some or all of those who weigh exactly 2500g as having LBW, the estimates for LBW rise in all countries, some by a large amount. This obviously reflects the amount of heaping on 2500g in each country. Some countries, such as Kazakhstan, Bolivia and Gabon have low levels of heaping at this weight. Nicaragua, which has a high level of overall heaping but the lowest level of heaping at 2500g of any country, has a small level of variation in the LBW estimates. Therefore, if a certain percentage of infants who had a reported birth weight of 2500g are included as LBW, Cambodia still has the lowest proportion of infants with LBW, with 6.2%. India's proportion rises to 28.4% under this criterion, and Mali's level becomes 17.0%. If all the children who weigh 2500g or below at birth are classified as LBW, then the levels obviously rise again, leading to India having 40.5% LBW, Mali 21.6% and Kazakhstan 8.2%.

It is easily argued that some of the children who have a recorded birth weight of 2500g should be classified as LBW. In order not to exclude these children and to get a more realistic idea of the proportion of children who are LBW in each country or state, further analyses will assume a certain percentage of infants as having LBW, using the figures shown in Table 4.4.

4.4.2. Comparisons with Alternative Estimates

How do the estimates noted above compare with other estimates of LBW in the respective countries? It is important to note that most estimates for these countries either come from retrospective surveys, with the attendant problems that this brings, or from hospital studies. Hospital studies into the incidence of LBW raise different issues, as the infants in hospital surveys are usually born into a higher socio-economic group, and therefore in general have a higher average birth weight (World Health Organization, 1992). Selected alternative estimates of the incidence of LBW from other surveys are shown in Table 4.6. All these do not use the same methodology to calculate the percentage with LBW, but are useful for comparison. The incidences entered into Table 4.6 for this current study are the mid range estimates, including a certain percentage of those who weigh 2500g as having LBW.

It is noticeable that there is a fair amount of variation regarding the estimates of LBW over all the years and in the different surveys. However, the estimates produced in this study are consistently lower than the other estimates, apart from in Malawi, Gabon and Mali. The differences seen in the estimates may be due to the time periods which are assessed in these alternative studies. Also, the results from 1982 and 1990 were estimated from a number of smaller surveys. The 1990 estimates were 'derived from the partial information contained in the country tabulations, using a model to take into account specific country factors'(World Health Organization, 1992). This model took into account the distribution of a number of indicators, such as the socio-economic distribution of the population, prenatal utilisation and how recently the survey was conducted, with more recent surveys being given more weight in the model. Therefore, the estimates produced are sensitive to changes in this model, and the results may differ from the estimates from a single retrospective survey, such as the DHS used in this study.

Table 4.6: Comparison of the proportion of children low birth weight in different studies

	Current Study	1982	1990	2004
Cambodia	6.2	-	-	11.0
Kazakhstan	6.6	8.0[a]	7.0	8.0
Vietnam	7.2	10.0	17.0	9.0
Bolivia	7.6	10.0	12.0	9.0
Peru	8.8	9.0	11.0	11.0
Tanzania	9.2	14.4	14.0	13.0
Zimbabwe	9.4	15.0	14.0	11.0
Nicaragua	9.7	-	13.0	12.0
Zambia	10.2	14.2	13.0	12.0
Mozambique	12.7	15.7	20.0	14.0
Malawi	13.0	12.0	20.0	16.0
Gabon	13.1	13.0	12.0	14.0
Mali	17.0	12.7	17.0	23.0
India	28.4	30.0	33.0	30.0

[a] Estimate is for the USSR

Sources: 1982 - (World Health Organization, 1984); 1990 - (World Health Organization, 1992, Table 1); 2004 - (UNICEF, 2004)

4.5. Recall of Birth Weight Information

4.5.1. Characteristics of Mothers who Report Birth Weight

Previous studies (Ebomoyi *et al.*, 1991; Miller *et al.*, 1993; Boerma *et al.*, 1996) have highlighted that there are differences in the characteristics of mothers between those who report a birth weight, and those who do not. These state that the mothers who do report a birth weight are a privileged section of the population, with higher education and socio-economic status. Furthermore, it is seen that these mothers are more likely to live in urban areas and to give birth in hospital.

It is important to investigate whether there are differences between mothers who do and do not report a birth weight. If there are no differences seen between the two groups, then the mean birth weight and the incidence of low birth weight derived from those who have recorded a birth weight can be assumed to also apply to those who did not report a birth weight. However, if there are differences seen in the characteristics of the mothers, it is likely that overestimates of the mean birth weight and underestimates of the proportion with LBW will be made if the estimates calculated are applied to the whole country. This is because the group of children without a reported birth weight are likely to be from a lower socio-economic class, and therefore are more likely to be born with a lighter weight (Boerma *et al.*, 1996).

A logistic regression analysis was conducted for each of the 14 countries to determine whether the two groups of children, with and without birth weight, are similar. An indicator for available birth weight was derived, taking the value '0' if the birth weight was missing and '1' if the birth weight was available for analysis. Potential explanatory variables which were chosen to test for an association with the missingness of the birth weight variable included place of delivery (home/hospital), prenatal care, maternal age, parity, place of residence (urban/rural), maternal and paternal education, marital status, religion, and survival status and gender of the index child. Results of the logistic regression are shown in Table 4.7.

Table 4.7: Significance of characteristics of mothers who reported birth weight

	Place of Delivery	Urban/ Rural	Survival Status	Maternal Education	Paternal Education	Religion	Marital Status	Parity	Age of Mother	Infants' Gender
Bolivia	***	***	***	***	**	N/A	NS	NS	NS	NS
Cambodia	***	***	**	***	***	NS	NS	**	*	NS
Gabon	***	***	***	*	**	*	NS	NS	NS	NS
India	***	***	***	***	NS	***	NS	***	***	NS
Kazakhstan	***	NS	***	N/A	NS	NS	NS	NS	NS	NS
Malawi	***	**	***	***	***	***	NS	NS	NS	NS
Mali	***	***	***	***	***	NS	*	NS	NS	NS
Mozambique	***	***	**	*	***	**	NS	NS	NS	NS
Nicaragua	***	***	NS	***	***	N/A	*	NS	NS	NS
Peru	***	***	***	***	***	N/A	NS	*	NS	NS
Tanzania	***	**	*	NS	N/A	NS	*	NS	NS	NS
Vietnam	***	NS	NS	NS	NS	*	*	NS	NS	NS
Zambia	***	***	***	***	***	NS	NS	NS	NS	NS
Zimbabwe	***	*	***	*	*	NS	NS	NS	NS	NS

* = P<0.05 ** = P<0.01 *** = P<0.001 NS = Not Significant N/A = Not Applicable

Table 4.7 indicates that there are a number of variables that are significantly related to the odds of reporting a birth weight for a child. In all countries, the place where the birth occurred is strongly related to the reporting of birth weight ($p<0.001$ in all countries). Children born in an institution have higher odds of recording a birth weight than children born at home. This is understandable, as scales are likely to be available in the hospitals and the weight may be recorded on health cards. A home birth may obtain such a card, but it may not be until some time after the birth when a health visitor or community nurse attends, and thus the birth weight may not be recorded on the actual card (or the birth weight is noted incorrectly if it is recorded).

Aside from place of delivery, the other explanatory variables do not show a consistent relationship with the probability of an infant having a reported birth weight in all countries. The only exception to this is the gender of the child, which is not significant for any country. However, even though there is this variation in significance between countries, some general trends can be seen. Urban dwellers are more likely to have children with a recorded a birth weight, whilst there is the expected relationship seen with both maternal and paternal education. Uneducated women have lower odds of reporting a birth weight than those with a primary school education, and women with a secondary or higher education have higher odds than both groups of reporting birth weight. The same trend is seen with paternal education.

The survival status of the child is also strongly related to the odds of an infant having a reported birth weight in most countries. Children who have died have lower odds of having a recorded birth weight than infants who are still alive. The significance of age and parity of the mother, as well as marital status and religion varies widely across countries. If age is significant in the model, then the younger the respondent is, the higher the odds of birth weight being reported, and similarly, the lower the parity, the higher the odds of a birth weight being recorded in the survey. Religion is significant in five of the countries. It is likely that the different religious groups in a country are associated with varying socio-economic classes, influencing the chances of an infant having a reported birth weight.

From the above brief analysis it is clear that the section of the population who report birth weights differ in many respects from those who do not, and thus it is likely that estimates produced using the recorded data in the surveys cannot be applied to the entire population. Yet it is still important to investigate whether the reported birth weights are as accurate as possible. The next section takes a closer look at those who have reported a birth weight, and studies the accuracy of these reports.

4.5.2. Reporting of Birth Weight: From Memory or Health Card?

For children who have a recorded birth weight in the survey, the method of reporting of this weight is also noted. The two methods are recall from the mother's memory or read directly from a health card. In many countries soon after birth when a child is weighed or vaccinated, a card is given to the mother containing all the important information regarding the child, including the birth weight. The distribution of the birth weights associated with method of reporting, either by card or from memory, can be analysed to identify whether there is any difference between the distributions of birth weight by reporting method. Table 4.8 shows the mean birth weights, the corresponding standard errors and standard deviations and the sample size for each reporting group. Also shown is the p-value associated with the two-sample t-test used to test if there is a difference between the mean birth weights by reporting method.

Only three of the 14 countries in the analysis do not show a significant difference between the mean birth weights reported from a card and the mean birth weights recalled from memory. Mozambique, Bolivia and India do not display a difference, whilst every other country has a significant difference at the 5% level. Further to this, eight countries display a difference at the 1% level. If the countries with a significant difference between the two types of recall are studied, it is seen that eight of the countries have a higher mean birth weight for memory recall of weight, while the other three have a higher mean for card reports. A sign test shows that this is not a significant trend (p=0.227).

Table 4.8: Summary statistics for birth weight reporting method

Country	Recall	N	Mean	S.E.	S.D.	p*
Bolivia	From Memory	3568	3381	11.2	671.3	0.618
	From Card	637	3369	21.8	550.6	
Cambodia	From Memory	436	3251	29.4	613.3	**0.042**
	From Card	939	3179	19.7	602.6	
Gabon	From Memory	2089	3181	15.4	703.1	**0.001**
	From Card	1651	3115	12.3	501.5	
India	From Memory	4050	2785	10.9	695.2	0.255
	From Card	4084	2801	10.1	644.2	
Kazakhstan	From Memory	1261	3306	15.9	566.3	**0.035**
	From Card	18	3592	124.8	524.6	
Malawi	From Memory	3608	3207	12.0	720.3	**0.000**
	From Card	1434	3137	14.1	534.3	
Mali	From Memory	1598	3219	20.6	825.0	**0.012**
	From Card	1008	3144	21.8	691.2	
Mozambique	From Memory	528	2991	31.7	729.6	0.056
	From Card	1049	3058	14.6	482.2	
Nicaragua	From Memory	4023	3311	10.4	662.2	**0.000**
	From Card	796	3130	19.7	555.9	
Peru	From Memory	7244	3224	7.3	621.3	**0.000**
	From Card	2208	3271	11.0	517.2	
Tanzania	From Memory	633	3283	27.9	702.0	**0.000**
	From Card	740	3107	20.1	547.2	
Vietnam	From Memory	283	3018	29.6	497.5	**0.009**
	From Card	760	3106	15.7	432.3	
Zambia	From Memory	1600	3253	17.0	681.7	**0.000**
	From Card	1204	3132	15.7	544.1	
Zimbabwe	From Memory	1247	3174	18.0	636.9	**0.004**
	From Card	1421	3111	12.7	479.1	

*Two-sample t-test p-value for difference in means

It may be hypothesised that birth weights obtained from a health card should be more accurate than those obtained from memory recall. As there is a difference in the mean birth weights for each reporting method, should estimates of low birth weight and the distribution of the weights be based solely on the data obtained from health cards? To assess this, an investigation of the differences in estimates of the proportion of infants with LBW within a country was conducted, using birth weights recalled from memory or reported from a health card. The proportion of LBW infants estimated using the different reporting methods were compared using a two independent samples test for proportions, to assess if there is a significant difference between the estimates (Table

4.9). The test uses the mid-estimate for the proportion of LBW, with a certain proportion of infants weighing 2500g are classified as having LBW (see Table 4.4).

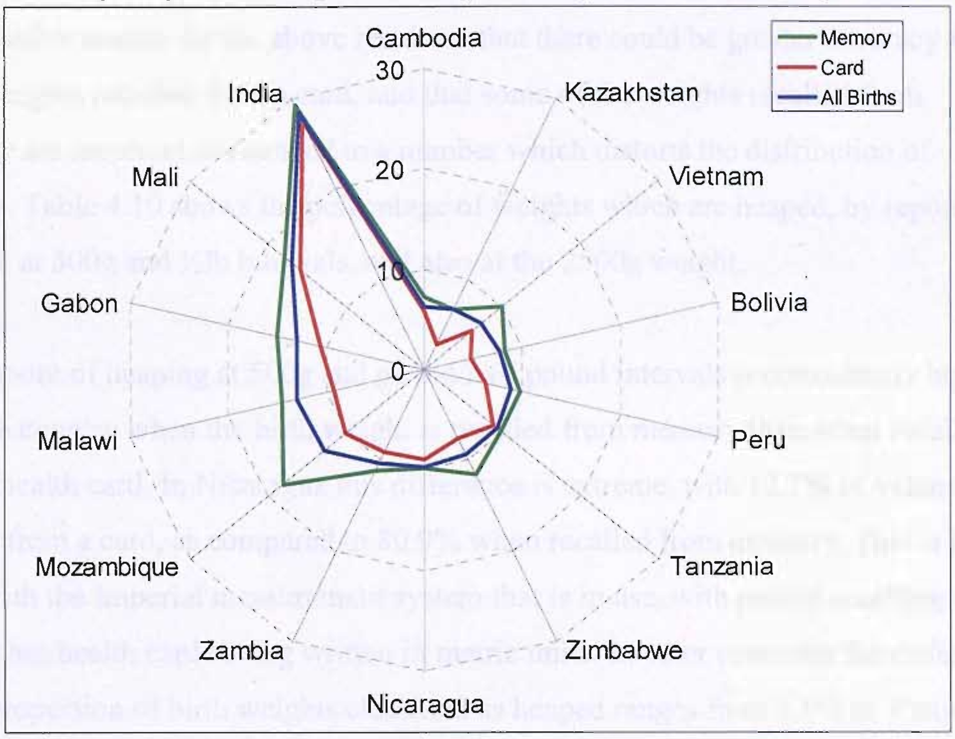
Table 4.9: Estimates of LBW by birth weight reporting method

	Memory Recall				From Card Record				Diff
Country	Count	<2500g	Inc. % of 2500g[1]	≤2500g	Count	<2500g	Inc. % of 2500g[1]	≤2500g	P
Bolivia	3571	7.3	8.1	10.7	637	4.4	4.7	5.7	**<0.001**
Cambodia	436	6.6	7.1	12.7	939	5.1	5.8	12.5	0.619
Gabon	2089	13.6	15.1	18.8	1651	10.1	10.5	11.7	**<0.001**
India	4056	22.5	29.3	41.9	4091	21.2	27.5	39.1	**0.049**
Kazakhstan	1261	6.2	6.6	8.3	18	2.7	2.7	2.7	0.268
Malawi	3608	11.1	14.5	21.9	1434	6.3	9.2	15.7	**<0.001**
Mali	1598	14.8	17.8	22.5	1008	13.2	15.8	20.1	0.174
Mozambique	528	16.4	18.1	24.8	1049	9.1	10.0	13.5	**<0.001**
Nicaragua	4025	9.8	9.8	9.9	796	8.6	8.9	10.1	0.619
Peru	7244	8.6	9.6	13.3	2208	6.0	6.2	7.2	**<0.001**
Tanzania	633	8.0	9.6	16.7	740	7.2	8.8	15.3	0.546
Vietnam	283	9.0	10.0	15.6	760	5.6	6.1	8.9	**0.022**
Zambia	1600	9.8	11.1	15.6	1204	8.3	9.1	11.7	**0.026**
Zimbabwe	1247	10.3	11.5	16.3	1421	6.9	7.6	10.5	**<0.001**

[1]See Table 4.4 for percentage of infants weighing exactly 2500g classified as LBW for each country

In many countries there is a significant difference in the proportion of children who are classified as having a LBW by reporting method. In nine of the 14 countries a difference in the proportion of LBW between the reporting methods is seen at the 5% level is found, whilst in six of these countries the difference is significant at the 0.1% level. In all of the countries it is seen that there is a higher proportion of children classified as LBW if the birth weight is obtained from memory than if obtained from a card. This can easily be seen in Figure 4.8, which plots the estimated percentage of babies born with LBW by reporting method, using the estimation procedure which includes a certain percentage of infants weighing exactly 2500g as LBW. The central point in the graph indicates a LBW percentage of 0%, and the countries are sorted in a clockwise direction by the proportion of LBW calculated for all infants. It can be clearly seen that the line for LBW calculated from memory recall is always outside the line representing the percentage with LBW calculated from card reported weights. It is also obvious that, as noted above, that the LBW percentage in India is much higher than in the other countries in this analysis, as seen from the ‘spike’ in the graph corresponding to this country. Mozambique is also clearly an outlier with a large difference between the percentage of LBW infants by reporting method.

Figure 4.8: Spiderplot showing estimated percentage of LBW babies by recall method



It appears that there are contradictory messages in these results. In many countries the mean birth weight is higher from memory recall than seen in card records, yet there is a higher proportion with LBW for memory recall. Peru and Vietnam have a higher proportion of children born with LBW from those recalled from memory, while the mean birth weight for the same group is significantly lower than those whose weights were reported from a card. This logically seems reasonable, as the mean birth weight for the memory recall group will be lowered by the presence of larger amounts of LBW children. Similarly, the results for Bolivia, India and Mozambique show consistency, with a higher proportion of LBW children recalled from memory, but no difference in the mean weight. Kazakhstan can be treated as an outlier due to the small percentage of infants (1.5%) who had their weight reported from a card.

The results from the other countries are more puzzling. Gabon, Malawi, Zambia and Zimbabwe have a higher proportion of babies born with LBW from those recalled from memory, whilst the mean birth weight is significantly higher for the same group. Cambodia, Mali, Nicaragua and Tanzania also have a higher mean birth weights in the weights recalled from memory, but there is no significant difference in the percentage of infants with LBW (although it is seen that the percentage is lower in the memory recall compared to the card reported group – see Table 4.9).

One possible reason for the above results is that there could be greater accuracy for those weights recalled from a card, and that some of the weights recalled from memory are incorrect or rounded to a number which distorts the distribution of weights. Table 4.10 shows the percentage of weights which are heaped, by reporting method, at 500g and ½lb intervals, and also at the 2500g weight.

The amount of heaping at 500g and pound/half pound intervals is consistently higher for each country when the birth weight is recalled from memory than when recalled from a health card. In Nicaragua this difference is extreme, with 12.7% of values heaped from a card, as compared to 80.9% when recalled from memory. This is likely to do with the Imperial measurement system that is in use, with people recalling in pounds but health cards being written in metric units. In other countries the difference in the proportion of birth weights classified as heaped ranges from 1.1% in Vietnam to 28.7% in Mozambique. It is impossible to conclude in those countries where there is a small difference in the percentage heaped between recall methods whether this is due to greater recall ability by the mothers or less precision by the birth attendants when weighing or noting the weight on health cards.

Table 4.10: Percentage of birth weight heaped by reporting methods

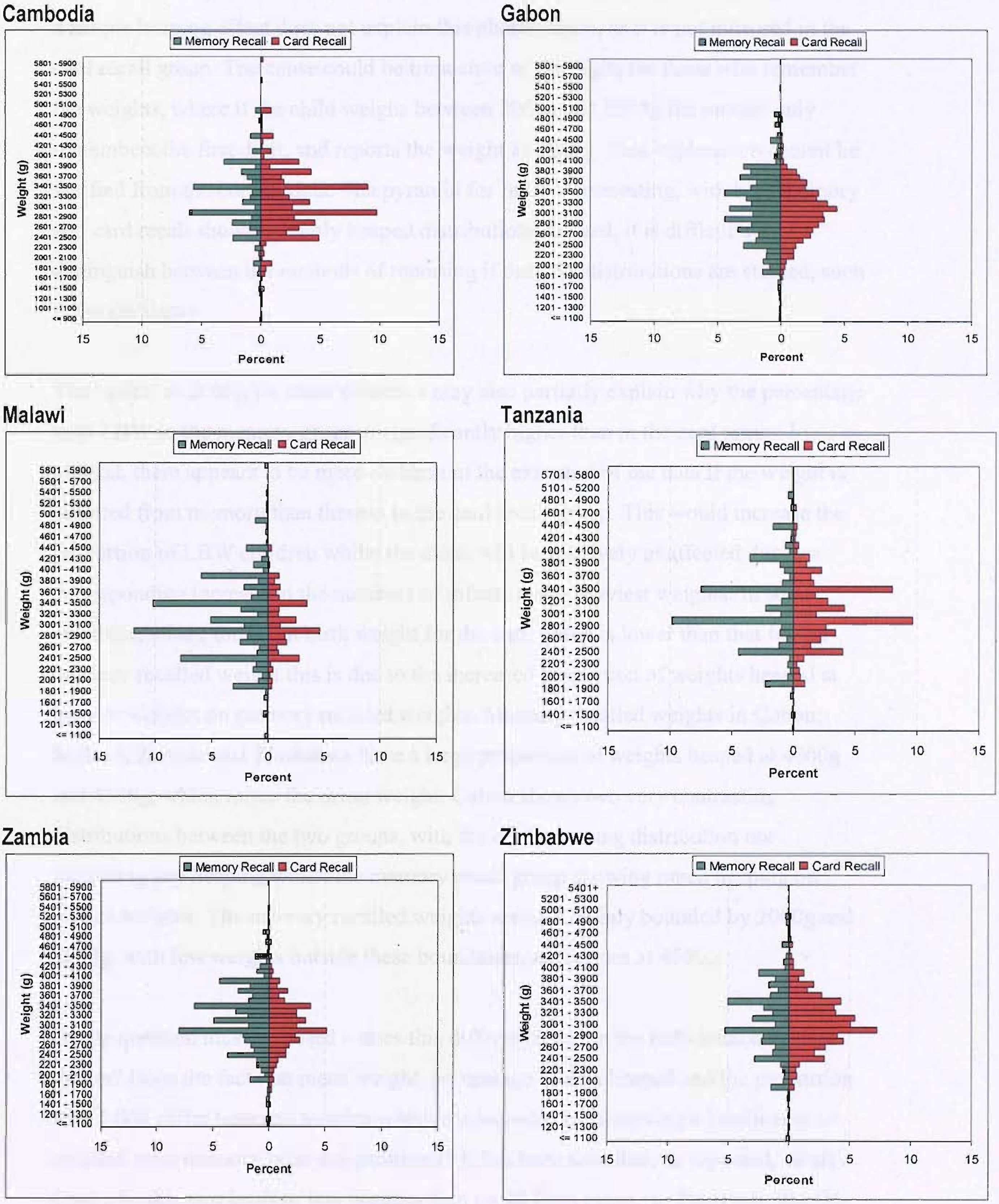
	Heaped at 500g/8oz			Heaped at 2500g		
	Card	Memory	Difference	Card	Memory	Difference
Gabon	9.7	26.3	16.6	1.6	5.2	3.6
Nicaragua	12.7	80.9	68.2	1.5	0.1	*-1.4*
Peru	14.6	31.8	17.2	1.2	4.7	3.6
Zimbabwe	21.5	40.7	19.3	3.7	6.0	2.4
Kazakhstan	22.2	25.9	3.6	0.0	2.1	2.1
Mozambique	22.2	50.9	28.7	4.4	8.3	3.9
Zambia	25.5	42.3	16.8	3.5	5.8	2.3
Bolivia	25.6	33.8	8.2	1.3	3.4	2.1
Mali	33.4	61.1	27.6	6.9	7.7	0.8
Vietnam	34.2	35.3	1.1	3.3	6.7	3.4
Cambodia	42.5	53.2	10.7	7.5	6.2	*-1.3*
Malawi	43.7	59.6	15.9	9.5	10.8	1.3
Tanzania	45.0	67.8	22.8	8.1	8.7	0.6
India	61.8	71.2	9.4	17.9	19.4	1.5

The proportion of heaping at 2500g is also higher, in general, for countries when the weight has been recalled from memory. The largest difference between proportions is a 3.9% difference in Mozambique. However, two countries, Cambodia and Nicaragua, show a higher proportion of heaping at 2500g when the weight is reported from a card than when recalled from memory. In Nicaragua this is understandable, with the possibility that the card was written in metric units by the relevant facility. If the predominant culture is to record, and therefore remember, weight in Imperial units, then if the card is not available the report would be in Imperial units. This would not be heaped at 2500g, but at 2494g (5lb 8oz). This is exactly what is found, with 1.5% of Nicaraguan birth weights recalled from memory heaped at five and a half pounds. In Cambodia, the increased heaping at 2500g for those weights recalled from a card is more difficult to explain. More babies may be noted as weighing 2500g on a card due to it being the threshold for low birth weight. In some countries there may be special measures required to be conducted if the child weighs less than 2500g and is therefore classified as having LBW. Thus there is an incentive to record the birth weight as above this threshold. Alternatively health workers may approximate the birth weights of lighter infants as 2500g as they know that this is the cut-off for LBW.

The distribution of the birth weights for each of the two reporting methods can also explain the incongruity between there being a higher mean birth weight and a higher percentage of infants with LBW for some countries' memory recalled birth weights compared to card reported weights. Figure 4.9 displays 'birth weight pyramids' for a selection of countries. These display the percentage of infants within each 100g birth weight band out of the total number of infants who reported a birth weight, by memory and card recall groups. The birth weight pyramids for those countries not included in Figure 4.9 are displayed in Appendix B.

From these graphs it is clear that the weights recalled from cards are closer to the birth weight distribution expected (i.e. normal). In Gabon, Zambia and Zimbabwe the card recall weights are close to being normally distributed, although some weights do indicate heaping. In general, heaping is mirrored between the two groups, although it is less pronounced for weights reported from a card. One interesting point is a spike in the weights recalled from memory in the 1901g-2000g categories for Malawi,

Figure 4.9: Birth weight pyramids for selected countries



Tanzania, Zambia and Zimbabwe. This spike is also seen in Bolivia, Kazakhstan, Mali, Mozambique and Peru (see Appendix B). This category includes 2000g, but a simple heaping effect does not explain this phenomenon, as it is not mirrored in the card recall group. The cause could be truncation of the digits for those who remember the weights, where if the child weighs between 2000g and 2999g the mother only remembers the first digit, and reports the weight as 2000g. This explanation cannot be verified from the current data. The pyramid for India is interesting, with both memory and card recall showing highly heaped distributions. Indeed, it is difficult to distinguish between the methods of reporting if only the distributions are studied, such is the similarity.

The 'spike' at 2000g for these countries may also partially explain why the percentage with LBW in the memory group is significantly higher than in the card group. In general, there appears to be more children in the extremes of the data if the weight is reported from memory than there is in the card recall group. This would increase the proportion of LBW children whilst the mean will be relatively unaffected due to a corresponding increase in the numbers of infants at the heaviest weights. In some countries, where the mean birth weight for the card group is lower than that for the memory recalled weight this is due to the increased proportion of weights heaped at heavier weights on memory recalled weights. Memory recalled weights in Gabon, Malawi, Zambia and Zimbabwe have a large proportion of weights heaped at 4000g and 4500g, which raises the mean weight. Gabon shows two very contrasting distributions between the two groups, with the card reporting distribution not indicating any heaping whilst the memory recall group showing much heaping on certain weights. The memory recalled weights are also mainly bounded by 2000g and 4000g, with few weights outside these boundaries, apart from at 4500g.

So the question must be posed – does this difference within the individual countries matter? Does the fact that mean weight, percentage of data heaped and the proportion with LBW differ between weights which are recorded by observing a health card or recalled from memory raise any problems? It has been seen that, as expected, recall from a health card leads to less heaping than recall from memory. Therefore, should only weights recalled from health cards be used to calculate such statistics as the proportion with LBW? In order to answer these questions, the people who recall the birth weights by card or from memory need to be systematically examined to see if they are similar. If there are no differences in the characteristics, then it will be possible to use just the birth weights recalled from health cards for further investigations. Logistic regression was conducted, with memory recall being assigned the value '0', and card recall assigned the value '1'. A number of variables were selected to be studied in depth, with further variables entered into the model as control variables. The results of the logistic regression are presented in Table 4.11. Kazakhstan was removed from the analysis as there were too few children who had their weight reported from a card (n=18) to produce an acceptable model.

If the results of the models for each country are compared, there does not seem to be an obvious pattern that differentiates those who report weight from memory or from a card. However, a few general trends can be discerned across countries in Table 4.11. The place of delivery was very important in determining the method of recall. If the child was born in a hospital the odds of reporting birth weight from a health card are significantly increased. Over half of the countries display this relationship, whilst most countries show increased odds of card recall over memory recall for those born in an institution, even if the relationship is not significant.

The relationship between survival status and reporting method is stronger and more universal in general than that seen between reporting method and place of delivery. As expected, weights of children who have subsequently died are more likely to be recalled from memory as opposed to from cards. In most countries the odds of a child having their weight reported from a health card if they had died were over 90% less than if they were still alive. In India, the birth weights for all children who died were recalled from memory, and hence infinite estimates of the odds ratios existed. Three countries do not show a significant difference in the odds depending on survival status, and it is hard to fathom the reasons behind the insignificant results for Cambodia, Mali and Vietnam. However, it is noticeable that in both Cambodia and Mali there is a high level of missing data on the birth weight variable – in Cambodia only 16% of people report a birth weight, whilst in Mali the level is 21%. It is likely that as the group of people who report birth weights in these countries are already a select group that their characteristics are fairly homogenous. Vietnam has a high response rate for birth weight, and therefore does not fit into this explanation.

Table 4.11: Estimated odds ratios for the reporting of birth weight from a health card compared with reporting from memory

		Bolivia	Cambodia	Gabon	India	Malawi	Mali	Mozambique	Nicaragua	Peru	Tanzania	Vietnam	Zambia	Zimbabwe
Maternal Education	None	1.51	0.64	1.21	**0.61*** **	1.1	0.89	**3.05***	0.87	1.43	0.63	1.17	1.25	1.42
	Primary	1.29	0.72	**1.28** **	**0.71*** **	0.88	**0.67***	**2.54***	1.02	0.95	0.60	**0.62***	1.00	1.16
	Secondary +	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
Paternal Education	None	**2.22***	0.79	0.85	0.99	0.99	1.01	1.19	0.88	0.93	-	**0.31***	0.62	0.86
	Primary	1.03	0.92	**0.73***	**1.29** **	1.00	1.09	1.42	1.11	0.93	-	**0.59***	1.14	1.07
	Secondary +	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	-	*1.00*	*1.00*	*1.00*
	No Partner	1.43	1.51	0.79	0.75	0.54	1.11	2.00	1.87	1.02	-	-	1.00	0.67
Place of Residence	Urban	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Rural	**1.41** **	0.83	**0.58*** **	0.95	1.10	**0.71** **	**0.56** **	1.13	**0.53*** **	1.26	1.12	**0.48*** **	**1.51*** **
Place of Delivery	Institution	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Home	**0.53*** **	1.29	**0.57*** **	**0.79***	**0.6** **	1.25	0.95	**0.12*** **	**0.43*** **	0.89	**0.17*** **	0.96	**0.52*** **
Gender	Male	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Female	**1.29** **	1.05	0.92	0.97	0.94	0.97	0.70	0.98	0.94	1.07	1.07	0.99	0.94
Parity	First Birth	1.06	0.79	**0.75***	**1.17** **	0.87	1.05	1.00	0.9	1.16	**0.61***	1.11	0.84	0.87
	2-3 Birth	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	4-5 Birth	**0.63** **	0.96	**1.29***	**0.77***	0.92	1.17	0.91	0.83	0.84	0.74	0.86	**0.64** **	0.88
	6+ Birth	0.89	1.47	1.20	**0.32*** **	0.77	0.96	1.71	**0.67***	**0.62** **	0.83	0.66	**0.55** **	1.01
Age	Under 20	**1.64** **	2.03	1.21	0.86	**1.72*** **	1.02	1.13	0.88	1.22	1.30	0.92	1.00	1.31
	20-29	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	30-39	0.96	0.95	1.00	**1.18***	1.05	1.03	0.81	0.89	1.03	0.84	1.18	**1.34***	1.01
	40-49	0.67	0.64	**0.48** **	1.38	1.06	0.64	0.75	0.92	1.18	**3.61** **	0.88	1.24	1.28
Survival Status	Alive	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Dead	**0.05*** **	1.01	**0.06*** **	-[a]	**0.12*** **	0.68	**0.06*** **	**0.02*** **	**0.10*** **	**0.07*** **	0.79	**0.05*** **	**0.08*** **

[a] Infinite estimate of the coefficient as all infants who died were recalled from memory

* = P<0.05 ** = P<0.01 *** = P<0.001

Place of residence, either urban or rural, has a significant effect on the chances of reporting weight from a card in seven of the 13 countries studied. In five of these countries the results are as expected, with rural dwellers having lower odds of reporting from a card than urban dwellers. However, in Bolivia and Zimbabwe the opposite is true, with higher odds for card reporting in rural areas. A potential reason for this is that cards may be distributed to mothers after the birth when a health visitor or community nurse attends, and this may occur more often in rural areas.

Maternal education is not seen to have a significant relationship with reporting method in many countries. Indeed, only in Gabon, India, Mali, Mozambique and Vietnam are significant relationships observed. Further to this, Gabon and Mozambique show relationships in the opposite direction to that expected, with higher odds for card reporting for mothers with a low level of education when compared to those with a secondary or higher education. It is difficult to understand this result. The other three countries show a relationship in the expected direction, with mothers with lower education having smaller odds of reporting birth weight from a health card. Paternal education is significantly associated in four countries. In Bolivia and India the weights of infants born to less educated fathers are more likely to be reported from a card, while in Gabon and Vietnam this situation is reversed.

There is a difference in characteristics between those who report birth weights from memory and from a health card in all countries except for Cambodia. In general, those who report from a card are of a higher socio-economic background as they are more likely to be born in hospital and live in urban areas, although this is a broad generalisation across all countries. Yet, this does not tally with the observation that those who report from a card have a lower mean weight than those who report from memory. If the card recall group has higher socio-economic attributes, then it would be expected that the mean birth weight would be higher in the card group than the memory recall group. This result, therefore, indicates that the recall from memory may consistently overestimate the actual birth weight of the child, and as a result the proportion with LBW in the majority of these countries may be higher than previously stated. This is impossible to test statistically, but the proportion of infants with LBW in each country needs to be assessed with respect to this possibility.

4.6. Determinants of Low Birth Weight

Birth weight reporting method is seen to be related to the actual value of the birth weight recorded. This is therefore important when studying LBW and a wide range of biological and health determinants in countries without complete official records of birth weights. It is interesting, therefore, to study the determinants of low birth weight to assess whether controlling for other potential explanatory variables reduces the association between reporting method and LBW. The explanatory variables focused on are similar to the variables used previously, including maternal and paternal education, place of delivery, urban/rural classification, gender, birth order and survival status. It is also possible that the relationship between these explanatory variables and LBW differ by method of reporting the birth weight, which will also be investigated in the following section.

4.6.1. Determinants of Low Birth Weight

The investigation into the determinants of LBW was conducted using logistic regression, with those born without LBW being classified as '0', and those with LBW taking the value of '1'. Two separate models were fitted for each country: firstly using the official definition of LBW (<2500g) and secondly using the definition of LBW which includes all those with a weight of 2500g. The model which uses all infants weighing 2500g and less will include many infants who are not actually of LBW, but will highlight the determinants of infants who have a birth weight at the lower end of the weight spectrum. It is thought that there will not be many differences between the two models, but it is important to investigate if the inclusion of those weighing 2500g does change the estimates produced in the models. Table 4.12 presents the odds ratios for LBW for the model studying the determinants of infants weighing under 2500g and Table 4.13 displays the results for those weighing 2500g or less.

Table 4.12: Estimated odds ratios of the determinants of low birth weight (defined as < 2500g)

		Bolivia	Cambodia	Gabon	India	Kazakhstan	Malawi	Mali	Mozambique	Nicaragua	Peru	Tanzania	Vietnam	Zambia	Zimbabwe
Education	None	1.28	1.70	1.46	**1.55*****	0.47	1.26	1.09	0.68	**1.77****	**1.83****	2.48	1.47	1.55	1.92
	Primary	0.97	1.42	1.19	1.18	-	1.19	0.67	0.50	1.25	**1.45****	2.17	1.33	1.30	1.25
	Secondary +	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
Partners Education	None	0.48	0.50	1.28	0.99	-	1.40	1.32	2.46	1.07	1.20	-	2.11	0.55	1.73
	Primary	0.91	1.10	1.32	**1.26***	2.38	1.12	1.50	2.39	1.16	0.88	-	1.39	0.89	1.40
	Secondary +	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	-	*1.00*	*1.00*	*1.00*
	No Partner	2.11	-	**0.61***	1.03	-	2.00	0.82	**3.04***	0.85	0.48	-	-	0.86	1.67
Place of Residence	Urban	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Rural	0.87	**2.08***	0.92	1.02	1.26	1.23	0.76	0.77	1.19	1.14	0.88	**2.37***	1.27	0.86
Place of Delivery	Institution	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Home	**1.51***	**2.37****	0.79	1.22	**5.45****	1.12	**1.82***	1.59	0.96	**1.41****	2.01	2.54	0.72	1.36
Gender	Male	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Female	**1.48****	1.61	**1.27***	**1.18***	1.13	1.18	0.87	1.15	**1.48****	1.10	1.02	1.05	**1.79*****	1.23
Birth Order	First Birth	0.96	0.85	**2.17*****	1.04	1.32	**2.02*****	1.38	0.88	1.12	1.02	1.96	1.56	**2.37*****	**1.59***
	2-3 Birth	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	4-5 Birth	0.81	0.83	0.83	0.98	0.71	1.04	0.74	**0.51***	0.86	1.21	1.40	1.82	0.86	0.68
	6+ Birth	0.90	1.87	1.08	0.89	0.40	0.87	1.03	0.56	0.67	1.01	**4.45****	0.34	0.51	**0.39***
Survival Status	Alive	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Dead	**4.75*****	**3.26***	**2.27*****	**2.34*****	**4.57*****	1.22	1.06	1.49	**3.67*****	**3.23*****	1.42	0.82	1.38	**2.99*****
Recall Type	Memory	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
	Card	**0.63***	0.77	**0.77***	1.03	-[a]	**0.54*****	0.86	**0.49***	0.92	0.84	1.14	0.78	0.89	0.76

[a] Infinite estimate of the coefficient as all infants who died were recalled from memory

* = P<0.05 ** = P<0.01 *** = P<0.001

Table 4.13: Estimated odds ratios of the determinants of low birth weight (defined as ≤ 2500g)

		Bolivia	Cambodia	Gabon	India	Kazakhstan	Malawi	Mali	Mozambique	Nicaragua	Peru	Tanzania	Vietnam	Zambia	Zimbabwe
Education	None	1.51	1.12	1.65	1.57***	0.38	1.55*	1.14	0.82	1.71**	1.67**	1.23	1.70	1.84*	1.96*
	Primary	0.98	1.26	1.20	1.16	-	1.28	0.77	0.71	1.22	1.63***	1.25	0.86	1.31	1.16
	Secondary +	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Partners Education	None	0.34*	1.24	1.13	1.10	1.97	1.32	1.06	2.61*	1.09	1.22	-	1.67	1.07	1.58
	Primary	0.99	1.04	1.16	1.15	-	1.17	1.05	2.39*	1.17	0.97	-	1.49	1.07	1.17
	Secondary +	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00
	No Partner	1.70	-	0.68	1.62	-	1.94	0.91	2.73*	1.06	0.83	-	-	1.24	0.89
Place of Residence	Urban	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Rural	0.98	1.72*	0.90	1.04	1.25	1.09	0.82	1.01	1.21	1.30**	0.94	2.98**	1.28	1.02
Place of Delivery	Institution	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Home	1.76***	1.25	0.92	1.08	7.42***	1.25	1.53	1.51	0.93	1.64***	1.44	2.76*	0.75	1.44
Gender	Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female	1.63***	1.51*	1.46**	1.20**	0.92	1.18*	1.05	1.14	1.48**	1.15	1.18	1.47	1.79***	1.53**
Birth Order	First Birth	1.10	1.06	1.99***	1.04	1.49	1.87***	1.46*	1.28	1.09	1.03	2.30**	1.55	2.03***	1.57**
	2-3 Birth	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	4-5 Birth	0.83	0.74	0.91	0.94	0.99	0.95	0.84	0.46**	0.87	1.15	2.30*	1.93	0.60*	0.79
	6+ Birth	1.04	0.85	1.10	0.92	0.32	0.93	0.86	0.50	0.68	1.16	2.17	0.69	0.39**	0.36**
Survival Status	Alive	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Dead	3.43***	2.04	2.15***	2.01***	5.92***	1.17	1.38	1.45	3.61***	2.59***	1.44	0.42	1.41	2.43***
Recall Type	Memory	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Card	0.53**	1.02	0.60***	0.98	-[a]	0.68***	0.86	0.43**	1.08	0.67**	1.00	0.67	0.77*	0.67**

[a] Infinite estimate of the coefficient as all infants who died were recalled from memory

* = P<0.05 ** = P<0.01 *** = P<0.001

A comparison of the significance and magnitude of the odds ratios between the two models for each country indicates that there are many more relationships that are significantly related to LBW when those weighing 2500g are included (Table 4.13) than when they are excluded (Table 4.12). This indicates that those infants who weigh exactly 2500g influence the estimates and that the heaping of weights on 2500g needs to be considered when studying the determinants of LBW in these countries. Most of the relationships observed are in the same direction for both models.

The relationship between LBW and maternal educational level differs between the different models in the respect that more countries show a significant relationship with LBW when infants weighing exactly 2500g are classified as LBW. The odds ratios in India, Nicaragua and Peru are significantly different from unity using the official definition of LBW, and these estimates for these countries do not change greatly if the wider definition of LBW is used. Six of the 14 countries display a significant relationship at the 5% level using this wider definition. In these countries, those mothers without any education had higher odds of having a child with LBW than those with a secondary or higher education. Paternal education does not display a consistent relationship with LBW across the countries. In Bolivia (using LBW ≤2500g) infants born to uneducated fathers had *decreased* odds of having LBW when compared to infants who had a secondary or higher education, but in Mozambique infants of lower educated fathers have *increased* odds of LBW when compared to the more educated. Using the traditional definition of LBW (< 2500g) significant results are uncommon and appear to follow no real trend. This indicates that paternal education is not strongly related to LBW after controlling for other explanatory variables.

Place of residence, either urban or rural, does not have a strong relationship with LBW in the majority of countries. Indeed, if the official definition of LBW is used, only Cambodia and Vietnam display a significant relationship at the 5% level, with those in rural areas having significantly higher odds of LBW than those in urban areas. If the more liberal definition of LBW is used, place of residence in Peru also displays a relationship with LBW, and in the same direction as Cambodia and Vietnam. However, it is clear that once such variables as place of delivery, method of recall and educational status are controlled for, there is not a strong relationship between place of residence and LBW status for most countries.

The place of delivery, either at home or in hospital, is related to LBW in a minority of countries. In all these countries where a significant relationship is estimated, infants born at home have higher odds of having a LBW. Even in the countries which do not show a significant relationship at the 5% level home births generally have increased odds of LBW, irrespective of the definition of LBW. Gender shows the expected relationships, with females consistently having higher odds of having LBW than males, irrespective of how LBW is classified. The results are not significant in all countries, but in general, the insignificant coefficients are in the same direction as those just stated, especially when infants weighing 2500g are included in the definition of LBW.

Birth order is related to LBW in about half the countries, with first births having higher odds of LBW than infants of a higher birth order. In Mozambique, Zambia and Zimbabwe the higher birth orders also show a reduced chance of being LBW when compared to births of order 2 or 3. Tanzania is an outlier, with higher order births having raised odds of LBW when compared to the reference category. Increased odds of LBW are observed if the infant in question has died before the survey occurred. This relationship is fairly consistent between the models using the different definitions of LBW, although there are minor changes to the significance of the odds ratios in some countries.

Finally, the method of recall is related to LBW in only four countries using the official definition of LBW, and seven if the expanded definition is considered. In most countries, however, there is a consistent effect (albeit sometimes not a significant effect) that infants with birth weights reported by card have lower odds of LBW, irrespective of how LBW is defined. This is expected, as the LBW proportion is always higher for children whose weight was recalled from memory as opposed to from a card, as seen above. The greater number of countries which display a significant relationship using the expanded definition of LBW is to be expected, as many more children whose weights are recalled from memory will be included as having LBW using this definition than infants who are recalled from a card, due to the greater heaping seen in memory recalled weights. In all but two of the countries where there was a significant difference in the proportion of infants with LBW by reporting method (Table 4.9) there is also a significant relationship in the logistic model. The exceptions are India and Zambia.

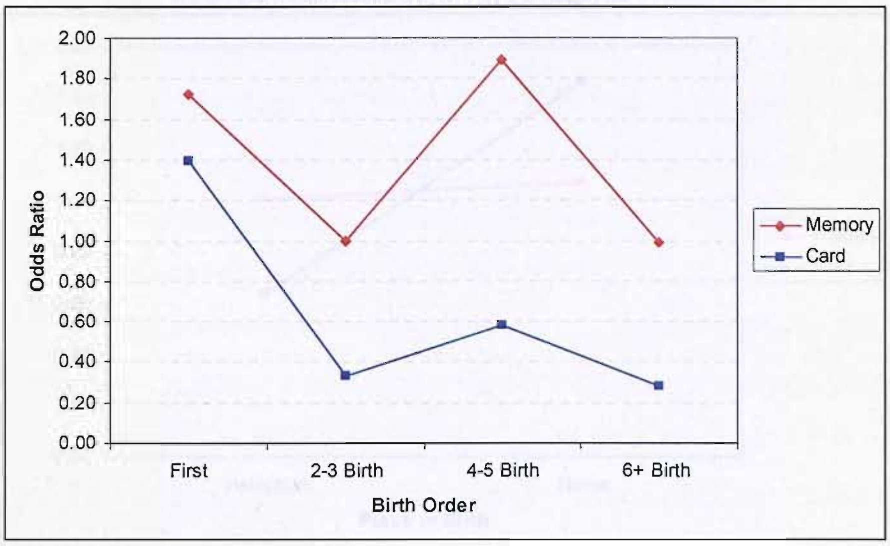
4.6.2. Determinants of LBW by method of recall

It is clear from the results throughout this chapter that there are differences in the weights and characteristics of infants depending on the method by which their birth weight was reported. However, it is not clear from the logistic model studying the determinants of LBW whether there are different relationships between the explanatory variables and LBW depending on the method of birth weight recall, either from memory or from a health card. To investigate whether this was occurring in these countries the interaction effects between reporting method and the other explanatory variables were tested for significance. If they were seen to be significant then these interaction terms were interpreted on the odds ratio scale. The interactions were only tested between variables that were significant in the additive model (i.e. significant in Tables 4.12 and 4.13). Kazakhstan was not included in this analysis as there are low numbers of infants who had their birth weight reported from a card.

It was observed that very few countries had significant interaction terms. In the countries where there was a significant relationship the parameter estimates for the other explanatory variables in the model were not altered greatly. These will therefore not be presented here again and only the estimates of the odds ratios of the interactions will be displayed.

Using the official definition of LBW (< 2500g) only one country, Malawi, showed an interaction between reporting method and one of the explanatory variables, birth order (Figure 4.10). In this instance it was seen that infants with card reported weights had lower odds of LBW for each category of birth order. However, the difference in the odds for first births was significantly smaller than the difference seen for the other categories of birth order.

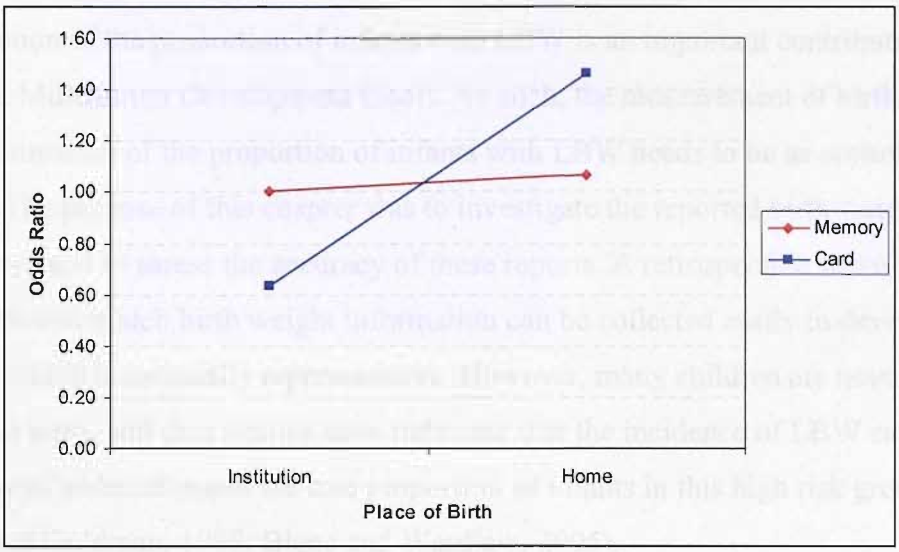
Figure 4.10: Estimated odds ratios for an infant having LBW (<2500g) by birth order and method of reporting for Malawi



If all infants who weigh exactly 2500g are also classified as LBW there are three countries which display interactions between reporting method and other significant variables, Gabon, Malawi and Peru. In Gabon there is an interaction between survival status and method of reporting. There is only a small difference between the odds of LBW for infants who are still alive by method of reporting, but if the child has died the chances of LBW are far higher if the birth weight was reported using a health card. This might be an artefact of the small numbers of birth weights reported from a health card for infants who had died (N=10).

In Malawi the interaction observed is between the place of delivery and reporting method (Figure 4.11). The odds of an infant having a LBW do not differ by place of delivery if the birth weight was recalled from the mother's memory. However, for weights recalled from a health card there are increased odds of LBW associated with home births. Infants who are born at home are likely only to be given a health card if a health visitor calls into the household soon after the birth or if the newborn is subsequently taken to the hospital due to illness. This last method of obtaining a health card may explain the result obtained here, as the newborns who are more likely to be ill after birth are those with a low birth weight.

Figure 4.11: Estimated odds ratios for an infant having LBW (≤2500g) by place of delivery and method of reporting for Malawi



For Peru there are three separate interactions that are significant. Firstly, there is an interaction between reporting method and mother's age at birth. This indicates that infants born to the eldest mothers differ by reporting method in the odds of LBW. The odds of LBW for infants with a card reported weight for the 40-49 age group are much lower than the odds for infants with a memory reported weight. Secondly, educational level also interacts with reporting method, although the magnitude of this is small. Finally, survival status is also related to the odds of LBW by reporting method, with a very large increase in the odds of LBW for all infants who had died. The increase in the odds for infants who had their weight reported from a card are far larger than the increase in the odds for infants with memory reported weights. This is likely to be due to small numbers of infants who had died having their weights reported from a card (N=5).

In general there are no differences in the relationship between the explanatory variables and LBW by reporting method, except for the occurrences noted above. Even though infants with card reported weights are less likely to have a LBW than infants with memory reported weights, the other explanatory variables have the same effect on the odds once type of recall has been taken into account.

4.7. Discussion

The reduction of the proportion of infants with LBW is an important contributor to one of the Millennium Development Goals. As such, the measurement of birth weight and the estimation of the proportion of infants with LBW needs to be as accurate as possible. The purpose of this chapter was to investigate the reported birth weight for 15 countries and to assess the accuracy of these reports. A retrospective survey is the main method in which birth weight information can be collected easily in developing countries which is nationally representative. However, many children are never weighed at birth, and thus studies have indicated that the incidence of LBW calculated from surveys underestimates the true proportion of infants in this high risk group (Robles and Goldman, 1999; Blanc and Wardlaw, 2005).

This chapter has shown that there are concerns over the use of the birth weights recorded in Demographic and Health Surveys for estimating the LBW proportion. Firstly, in some countries in the analysis, there are extremely large amounts of missing data where children have not been weighed at birth, such as in Cambodia and Mali. Further to this, there is a positive relationship between the amount of missing data and the amount of heaping at 500g or 8oz intervals. Even though some of these heaped data will actually be correct, the proportion in some countries is extremely worrying. India and Nicaragua both have over 60% of the available birth weights heaped, which indicates that either the initial recording of the birth weight by a health official is not accurate, or that during recall the mother has rounded the weights, or both. This could affect calculations conducted using birth weight. For example, if two children weighing 2300g and 2700g are both reported as weighing 2500g, then calculation of the percentage of infants with LBW will be influenced. Also, there is a big mortality risk differential between the two weights, and the relationship between birth weight and mortality may be attenuated by this heaping.

It is unsurprising that missing birth weight information is not randomly distributed within each of the countries or between countries. The relationship between the percentage of missing data and GNI per capita indicates that richer countries have less missing information than poorer countries. Countries with a less established health system infrastructure will not weigh as many infants and mothers cannot report a birth weight if it was never taken. The differences in the proportion of infants without a reported birth weight may also be due to varying cultures of remembering health information in different countries. It may be hypothesised that mothers in richer countries will have more of a culture of recording and keeping information such as birth weight, whilst mothers in poorer countries do not see the requirement to keep or remember this information. This suggests that culture plays an important role in the reporting and recording of health statistics, especially birth weight.

Within countries, as a mother has more children it is obviously harder for her to keep track of each of their birth weights. Education is related to both socio-economic status and the knowledge of the benefits of keeping health information. Socio-economic status is likely to be related to the actual chances of an infant actually being weighed at birth, while the knowledge of the benefits of retaining birth weight information will cause the weights to be remembered or the health cards to be stored safely. Whether the infant is still alive also is very important in determining the probability of a reported birth weight. A mother may discard an infant's health card after death or choose not to remember the birth weight if the infant in question has died, or the interviewer may not want to ask for this information for ethical reasons, especially if the death is recent. Other variables that are related to the reporting of birth weight information in each of the surveys are also easy to explain, such as urban/rural residence, the place of delivery and paternal education. It is reassuring that there is no difference in the chances of a reported birth weight by gender, as the sex of the infant should not make any difference to the probability of it being weighed.

It is clear that even in a country such as Kazakhstan, with less than 3% of birth weights missing in the survey, that there are still differences in the characteristics between infants with and without a missing birth weight. Using just the recorded birth weights in any analyses will therefore exclude certain groups of infants, biasing the results. It has been seen (Chapter 2) that infants with a lower birth weight are more likely to die. The reporting of birth weight is related to the survival status of the infant. By only using those infants with a reported birth weight to study mortality, thereby excluding many infants who have died (and thus have a lower birth weight in general), biased results will be obtained. Most variables that are related to the missingness of birth weight information are also known to be related to birth weight (Kramer, 1987), again indicating that using the reported birth weights in calculations will produce biased estimates.

Differences in mean birth weights between countries may be an artefact of the different proportions of missing data in the countries, or due to actual differences in birth weight. Most likely, the differences are due to a combination of both of these causes. A higher proportion of missing data suggests that a more select group of infants have a reported birth weight, and these are most likely to be the richest in a country, and therefore have a higher mean birth weight than those who do not have a reported birth weight. However, differences in birth weight distributions between countries are known to be real in the developed world (Graafmans *et al.*, 2002), and there is no reason to think that this is different in developing countries. The distributions for the countries studied here are seen to be similar, albeit with different means.

It is widely acknowledged that India, and indeed the whole of South Asia, has one of the highest prevalence of LBW in the world (Sachdev, 1997), and also has a low mean birth weight. This is borne out in the estimates produced in this study. The variation in the mean weights and the LBW proportions in the other countries is roughly what is expected, with South American countries and Kazakhstan having the highest mean weights, and African and Asian countries displaying lower mean weights. This is due to better socio-economic conditions and more developed health systems in these regions when compared with those in Africa and Asia (if development is measured by health expenditure per capita in Purchasing Power Parity (PPP) US$ (UNDP, 2003)). The significant difference in mean weights between Vietnam and Cambodia is interesting as the countries are located adjacent to each other, and therefore are likely to share many of the same ecological characteristics which influence nutrition. However, the difference may be due to the extreme amount of missing data in Cambodia (84% missing), whilst Vietnam has only 20% of the birth weight data missing. The Cambodian estimate is therefore likely to represent only an extremely advantaged section of the population, whilst Vietnams' estimate may represent the complete population more accurately.

A further potential reason why mean birth weights may differ between countries is an issue identified by Robles and Goldman (1999). Some infants born at home may not have their weight measured at the time of birth. A health worker may visit the household sometime after the birth, and weigh the infant at this point in time. The visit of the health worker may be after a few weeks, but the measured weight may be used by the mother as representing the birth weight. That this may be occurring can be supported by the extremes of birth weights seen in weights reported from a mother's memory. It is impossible to verify the scale of this problem, if indeed it is happening at all.

Heaping of birth weights on common weight values is known to be an issue, in both developed and developing countries (Boerma *et al.*, 1996; O'Sullivan *et al.*, 2000; Blanc and Wardlaw, 2005). The scale of the heaping is a surprise however, with two-thirds of the reported birth weights in India being reported as being a multiple of 500g, or in half-pound units. If the proportion of infants with heaped birth weight information is added to the proportion of infants without a reported birth weight then in some countries there are only a small amount of infants with a 'reliable' (i.e. unheaped and reported) birth weight.

The heaping of birth weights on 2500g is important when calculating the proportion of infants with LBW. It is clear that some of these infants will actually be of LBW, but will not be counted as such due to the definition of LBW only including those weighing *under* 2500g. This issue has been treated in a number of ways. Boerma *et al.* (1996) simply placed half the infants weighing 2500g into the LBW group. This assumes that there are as many infants weighing above 2500g than below, which is clearly an incorrect assumption. Blanc and Wardlaw (2005) took the ratio of infants weighing 2000g-2499g to those weighing 2501g-2999g in each country, and taking the average of this ratio across all countries calculated that 25% of infants who weigh 2500g should be placed in the LBW category in every country. There are two issues with this method. Firstly, including 2000g in the calculations will include some infants who weigh less than 2000g and therefore inflate the proportion of infants weighing 2500g who will be classified as LBW. Secondly, applying the same proportion to all countries can be viewed as problematic. Countries with a lighter mean birth weight (i.e. India) will have a larger proportion of infants weighing under 2000g-2499g than countries with a heavy mean birth weight (i.e. Bolivia).

The method chosen in this study tries to circumvent some of these issues, although other problems are generated. By taking the ratio of infants weighing 2001g-2499g to those weighing 2501g-2999g the issue of heaped data on 2000g is bypassed, and applying different ratios for each country allows country variation. However, it is seen that is some countries (i.e. Cambodia) the proportion of infants weighing 2500g to be apportioned to the LBW category is very small, due to the low numbers of infants who are reported as weighing between 2001g-2499g. However, even with this small calculated proportion this method can be considered as more accurately representing the proportion of infants who weigh 2500g who are actually of LBW than in the studies by Boerma (1996) and Blanc and Wardlaw (2005).

The actual estimates of LBW are lower than expected in most of the countries, when compared to alternative estimates. This may be due to the method of apportionment of those weighing 2500g to the LBW category. Placing all infants weighing 2500g into the LBW group produces estimates which are closer to those seen in other studies, but this is an unrealistic situation. Great heterogeneity in the proportion of infants with LBW is seen across the countries. It is interesting to note that the mid-range estimates for Vietnam and Cambodia are very similar (8.6% and 9.1% respectively) which indicate that the countries may be similar in their LBW proportions, even though their mean weights are significantly different. It is also clear that apart from India, the only countries with a LBW incidence above 10% are African countries.

The estimates of LBW and the mean birth weight in each country above hide some interesting and puzzling differences. The differences between those who report the weight after referring to the child's health card and those who simply recall the weight from memory are striking. Of the 14 countries in the analysis, 11 show a difference in the mean weight, and nine of the 14 countries show a difference in the proportion with LBW depending on the reporting method. After studying the differences in the characteristics of those who report the weight from a card or from memory, it is clear that these differences are expected. In general, infants born to families with a more privileged background (i.e. urban dwellers, born in a hospital, still alive at the time of the interview) have weights reported from a health card. These characteristics are related to birth weight, and thus differences in mean birth weight and the proportion with LBW for some countries is not a surprise. Interestingly the country with the lowest level of missing birth weight information, Kazakhstan, has few weights recalled from a health card. This may be due to health cards not being commonly distributed to mothers. Yet the fact that most of the weights are recalled from memory indicates that there is a culture of remembering this detail of birth in this country.

The percentage with LBW is smaller in each country if the weight is recorded from memory than from a card, and nine of the countries display a significant difference between the two proportions. The fact that LBW is more prevalent in the memory recall group is understandable due to the characteristics of the infants in each group of reporting method. A further reason for the difference between the mean weights and the percentage with LBW between babies whose weights are recalled from memory and from a card is due to the differing distributions of the weights in the two groups. Weights recorded from a card are more normally distributed than those recorded from memory, even though there still may be much heaping on certain values. In some countries, such as India, there is minimal difference between the amount of heaping on card recalled birth weights and memory recalled birth weights. However, the distributions of the weights are usually more normal when the weights are recorded from a card. It is tempting to only use those weights that are recorded from a card in any future analyses, as the weights appear more consistent, but doing this would restrict the sample to infants with certain attributes.

The causes of LBW are seen to be fairly consistent irrespective of the definition of LBW, although there are more significant relationships seen if all those weighing 2500g are included in the analysis. In general, mothers who live in rural areas, have low education levels, give birth at home and whose child has died were more likely to have had a LBW child. The fact that there are only very few interactions between LBW and the method of reporting birth weight indicate that even though there are differences in the birth weights by reporting method that the relationships between other variables and LBW are similar for each reporting method.

In summary, birth weight data in the DHS are beset with problems. Firstly, there is missing information which is not spread evenly across the respondents. Secondly, those with a reported birth weight are grouped on specific values. The treatment of these heaped values affects greatly the estimated proportion of infants with LBW in each country. Furthermore, differences are seen between the two methods of reporting, and even though weights reported from a health card show less heaping, there is still a substantial amount of weights heaped on 500g intervals. This indicates that at the time of recording the weight onto the card, the weights were already rounded, and presages that actual birth weights are only recorded with a small amount of accuracy by the doctors taking the weights. This may be due to the scales being utilised having a low level of accuracy or the doctors/midwives rounding the weight when writing it onto the card. The improvement of birth weight information in many countries needs to start with increasing the numbers of infants who are actually weighed, and enhancing the quality of the birth weight data for those who are currently weighed. By doing this, better estimates of the proportion of infants with LBW can be made, and the birth weights reported from a health card can be taken as the 'gold standard' when working with birth weight.

Chapter 4: Key Points

- Many countries have a large proportion of infants without a reported birth weight.
- Infants with reported birth weights are not distributed randomly in the population.
- Birth weights which are recorded are highly heaped on specific values
- The proportion of infants with LBW varies widely across countries, and this proportion is affected by how the infants weighing exactly 2500g are treated.
- There are differences in birth weight distributions by the method of reporting birth weight, either from a health card or from memory.
- Weights reported from a health card can be highly heaped.
- The analysis of DHS data in Haiti shows that birth weight information in this country is unreliable and should not be used.

Chapter 5

Can Low Birth Weight Estimates Be Improved?

The calculation of the proportion of infants with low birth weight (LBW) is fraught with problems, as seen in Chapter 4. This is due to biases that result from missing data and heaping. The proportion of infants with LBW is likely to be underestimated and the mean birth weight overestimated in a country when estimating from DHS data. As a result a different method to calculate the proportion of infants and the mean birth weight needs to be considered. In many recent DHS questionnaires an additional question is asked which assesses mother's perception of her child's size at birth. This chapter examines the data collected in response to this question and investigates ways in which to utilise this information to provide more accurate estimates for the proportion of LBW and the mean birth weight in a country. Using the responses to the mothers' perception of her child's size question in the analysis of LBW allows more infants to be included in the calculations, and therefore is thought to provide more reliable estimates.

This chapter will firstly analyse the distribution of mothers' perceptions of a baby's size at birth to assess whether this conforms to that expected and to judge if it is feasible to use this information in further analyses. The mothers' perceptions of their infants' sizes will then be assessed to understand if it can be used as an indicator of

LBW. Analyses first conducted by Boerma *et al.* (1996) will be reproduced here and the results compared. The combination of birth weight and mothers' perception will be conducted to obtain new LBW estimates. This will also be done separately for the different reporting methods.

5.1. Mothers' Perception of their Baby's Size

This thesis examines birth weight in 15 countries. However, in this chapter only 13 countries were considered for the analysis: Haiti was excluded due to the poor data quality (see Box 4.1), and Peru is excluded as the DHS did not collect the information regarding mothers' perceptions of size. On all the other surveys the information was elicited for all mothers regarding the size of all of their children born in the last five (or in some countries the last three) years. The Indian questionnaire only asked about the most recent two births in the last three years, although it is thought that there will be very few mothers who had three or more children in the last three years, especially as twins are excluded from this analysis. The question that was posed in the survey is noted below, and for each child born in the period under analysis the question was posed separately.

> 'When (NAME) was born, was he/she: very large, larger than average, average, smaller than average or very small?'

In the Indian questionnaire the category of very large was not used, and the mothers only had a choice out of four categories. The interviewer was asked to read the entire question before accepting an answer, and they were asked to insist on obtaining the mother's perception if possible. If there was no response, then the interviewer was not to guess the size based on the birth weight information, but should enter 'Don't Know' as the response (ORC Macro, 2002). The question obtained a high number of responses, with very few mothers recording a statement of 'Don't Know' or not responding. The largest proportion of missing data is seen in Mali, where 3.5% of mothers did not report a size for their child (Table 5.1). Gabon, Cambodia and Mozambique also have above 1.5% of the data missing on this variable. In comparison with this, Tanzania and Vietnam both have extremely low levels of missing data, with 0.1% of the mothers not indicating a size. In all, eight of the 13 countries have less than 1% missing data on this variable.

The high response rate to this question allows us to conduct a good analysis of the distribution of replies in the population. Generally, the responses follow the expected distribution, with most mothers saying that their children were of average size, and the lowest proportion of children being placed in the very large and very small categories (Table 5.1). There is a large variation between countries in the proportion placed in the average category though, with 74.4% being placed in this category in Vietnam, compared with only 29.2% in Nicaragua. These different proportions can be seen graphically in Figure 5.1, which displays the distribution of the responses, excluding those who did not report a size, for a selection of the countries under analysis.

Table 5.1: Distribution of mothers' perception by country, ordered by percentage of babies in the average perception category

	Very Small	Smaller than Av	Average	Larger than Av	Very Large	Missing	No. of children
Nicaragua	4.7	26.1	29.2	36.5	2.8	0.6	**6846**
Gabon	4.5	7.3	31.0	30.3	24.6	2.3	**4221**
Mozambique	1.7	18.4	35.7	39.6	3.0	1.7	**4002**
Mali	7.9	13.7	40.3	24.8	9.8	3.5	**12673**
Zimbabwe	4.7	10.1	43.3	28.0	12.6	1.1	**3527**
Cambodia	2.8	10.3	54.8	27.5	2.8	1.9	**8643**
Malawi	3.5	12.2	58.4	16.6	8.6	0.7	**11432**
Zambia	3.1	9.9	61.2	19.4	6.1	0.3	**6658**
Bolivia	8.2	12.1	61.4	17.2	0.5	0.6	**7210**
India	4.8	19.3	61.5	14.0	-[a]	0.4	**32611**
Kazakhstan	4.8	12.9	63.7	13.2	4.7	0.7	**1317**
Tanzania	3.2	6.8	69.1	12.3	8.5	0.1	**3101**
Vietnam	1.4	8.1	74.4	15.0	1.0	0.1	**1303**

[a] Only four categories of size were used in India

In the majority of countries, the distribution of the responses is skewed towards the larger sizes. Excluding India (due to the lack of the very large category), only Bolivia has a higher proportion of children in the smaller than average and very small categories than in the larger than average and very large categories. Yet even Bolivia does have a higher proportion of children placed in the larger than average than in the smaller than average group, and only differs from other countries by having a very low proportion, 0.5%, in the very large category. Two countries which have a higher proportion of babies placed in the larger than average class than in the average class are Mozambique and Nicaragua. Gabon is a further country which has an unexpected distribution, with a high percentage of children placed in each of the largest three categories. Indeed, just under a quarter of the children were classified by their mothers' as being very large – an incredibly high proportion when compared to the other countries in this analysis. These differences in the distribution of mother's perception may be due to each country having different cultural sensitivities regarding a baby's size. In some countries it may be that a large baby is socially desired more than in other countries, and so mothers are more likely to classify their infant as larger than average or very large to conform to these cultural norms, and not because their child was actually large. However, there are other reasons why there may be a high proportion of infants classified into the larger categories, and these will be discussed later.

From Table 5.1 it can be seen that there is a lack of agreement between the percentage of children classified as being very small and the percentage of low birth weight children calculated in the previous chapter (see Table 4.5). This can be clearly seen if these two estimates are plotted (Figure 5.2). The reference line is where the points should lie on if there are equal numbers of infants with LBW and who are classified as being very small. The clustering of the points below this reference line shows clearly that there is a higher proportion of infants with LBW than in the very small category. Only Bolivia has a similar percentage, with 8.2% of children being classified as very small while the LBW proportion is 7.6%.

Figure 5.1: Bar charts showing distribution of mother's perception for selected countries

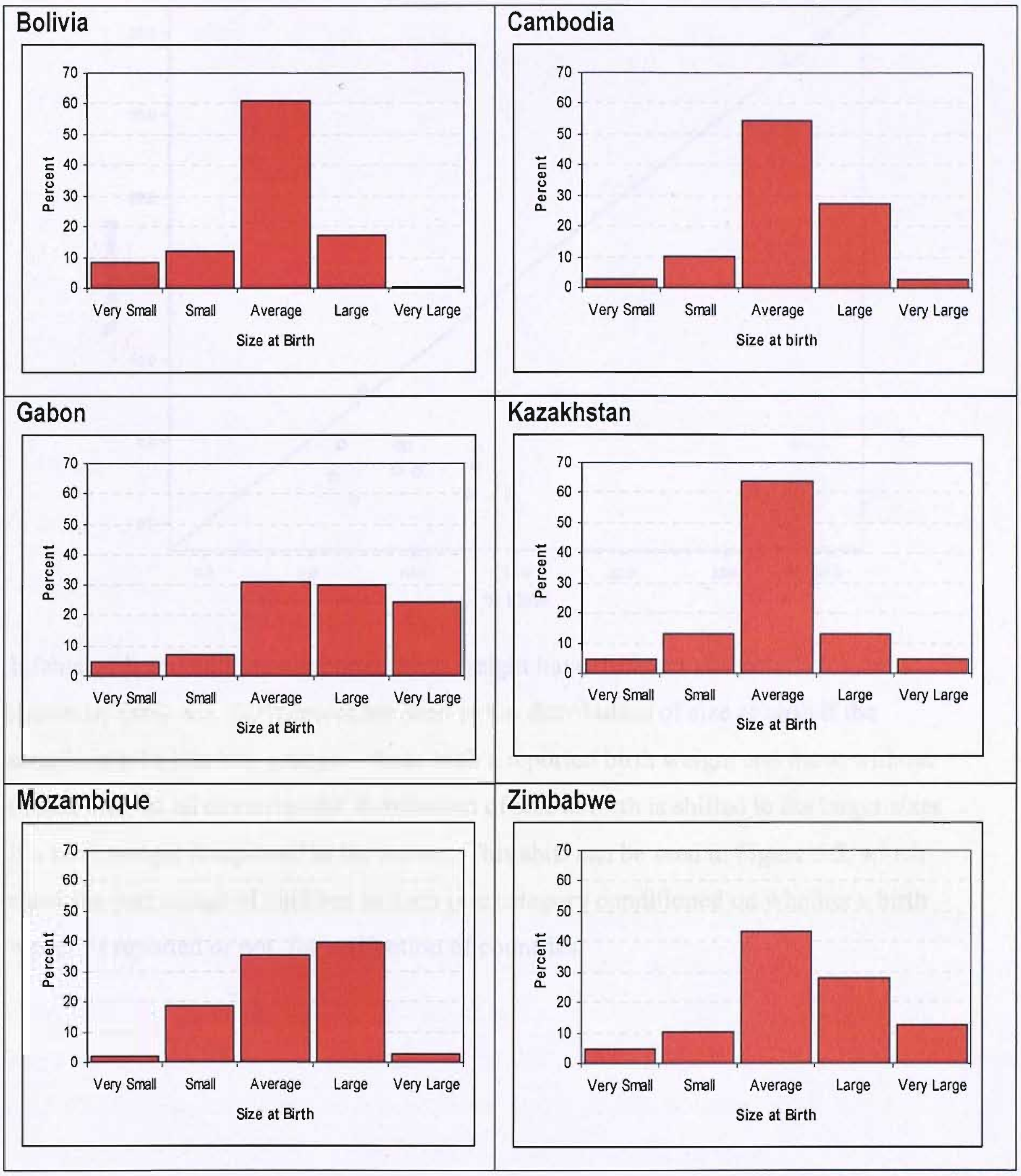
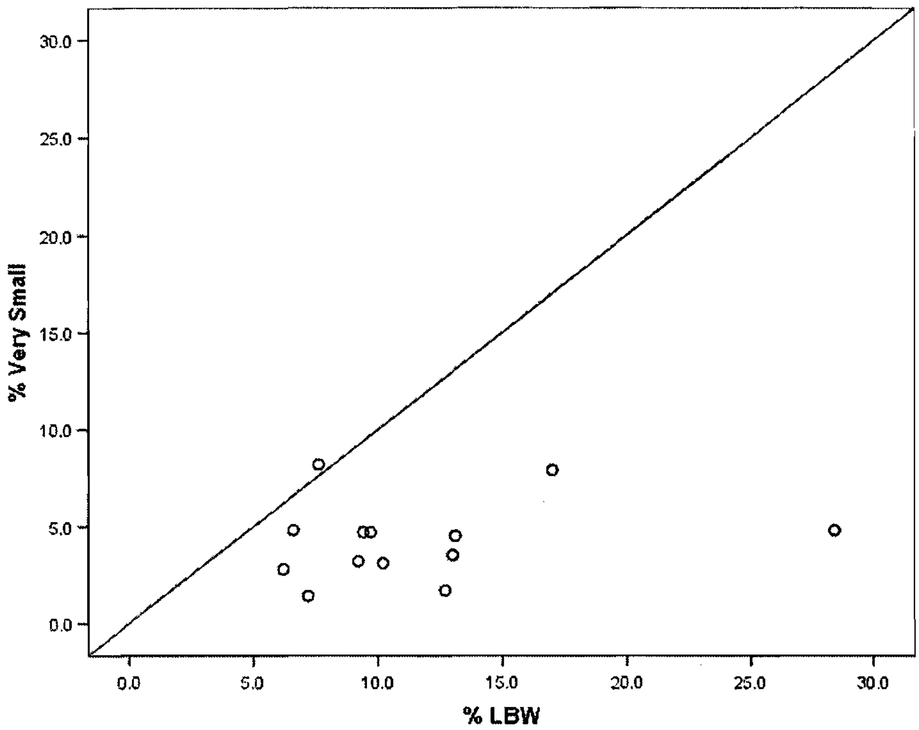


Figure 5.2: Scatterplot of the percentage of infants with LBW against the percentage of infants in the very smallest size category for 13 countries



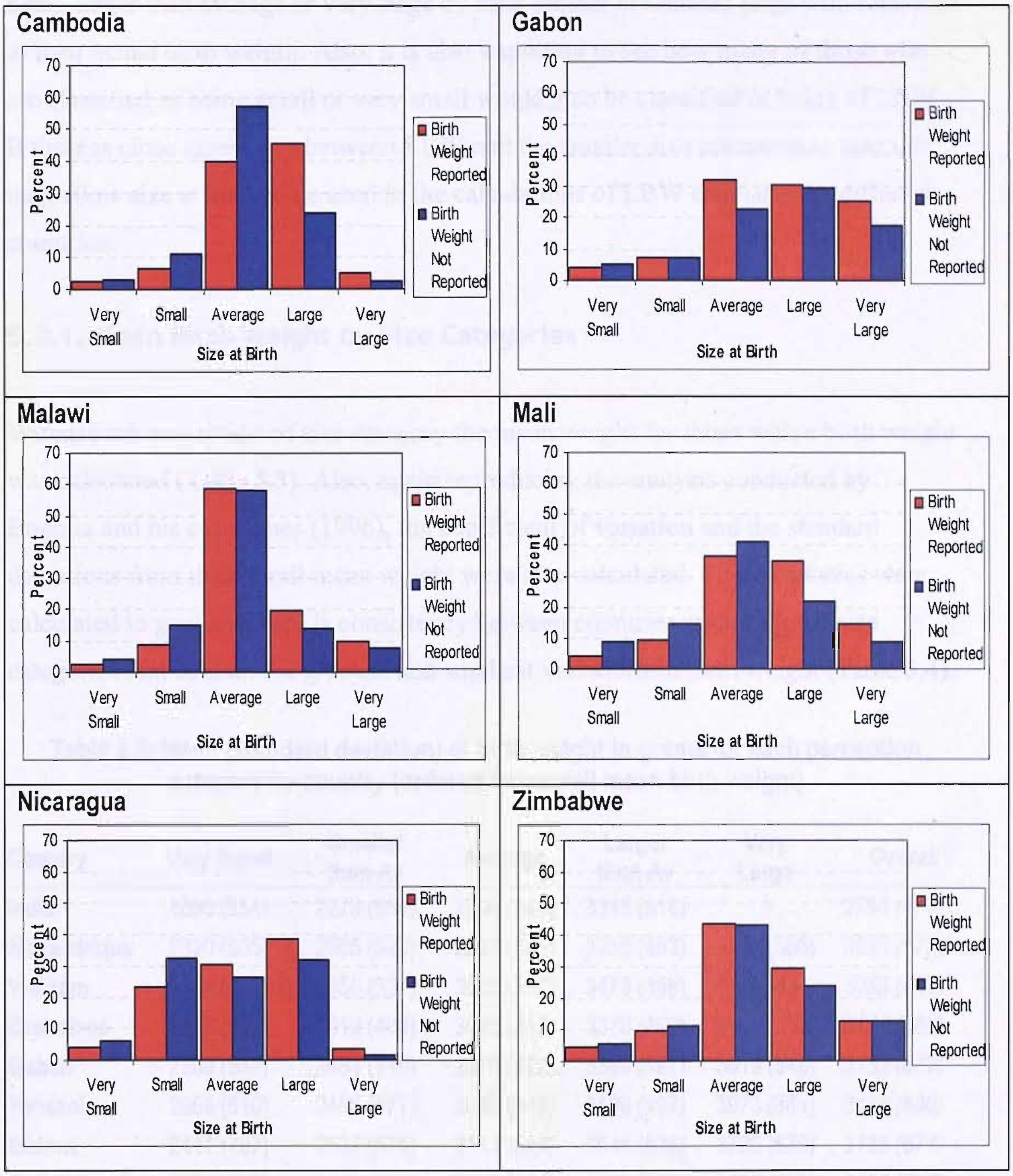
Infants with and without a reported birth weight have different characteristics, as shown in Table 4.7. Differences are seen in the distribution of size at birth if the sample is split into two groups – those with a reported birth weight and those without (Table 5.2). In all countries the distribution of size at birth is shifted to the larger sizes if a birth weight is reported in the survey. This shift can be seen in Figure 5.3, which show the percentage of children in each size category conditioned on whether a birth weight is reported or not, for a selection of countries.

Table 5.2: Distribution of mother's perception by availability of birth weight (%)

	Birth weight reported?	Very Small	Smaller than Av	Average	Larger than Av	Very Large	Missing	Count
Bolivia	Yes	7.7	10.5	62.0	19.0	0.8	0.0	4147
	No	*8.9*	*14.5*	*60.4*	*14.6*	*0.1*	*1.5*	*3063*
Cambodia	Yes	2.4	6.6	40.1	45.7	5.2	0.0	1167
	No	*2.9*	*11.0*	*57.5*	*24.0*	*2.3*	*2.2*	*7476*
Gabon	Yes	4.4	7.2	32.1	30.4	25.5	0.4	3592
	No	*5.4*	*7.5*	*22.7*	*29.5*	*17.6*	*17.3*	*629*
India	Yes	3.7	15.9	59.7	20.7	-	0.0	8496
	No	*5.2*	*20.5*	*62.1*	*11.8*	-	*0.5*	*24115*
Kazakhstan	Yes	4.6	13.0	64.0	13.5	4.8	0.1	1280
	No	*13.1*	*7.0*	*55.8*	*3.4*	*0.0*	*20.7*	*37*
Malawi	Yes	2.6	8.8	58.8	19.9	9.9	0.0	5230
	No	*4.2*	*15.0*	*58.0*	*14.1*	*7.5*	*1.2*	*6202*
Mali	Yes	4.1	9.4	36.6	34.8	14.5	0.6	2380
	No	*8.8*	*14.9*	*41.2*	*22.2*	*8.6*	*4.3*	*10293*
Mozambique	Yes	3.0	14.8	36.2	40.9	4.6	0.5	1892
	No	*0.8*	*20.8*	*35.3*	*38.7*	*1.9*	*2.5*	*2110*
Nicaragua	Yes	4.1	23.5	30.4	38.6	3.3	0.1	4513
	No	*6.2*	*32.3*	*26.4*	*31.8*	*1.6*	*1.8*	*2333*
Tanzania	Yes	1.8	5.5	67.6	13.8	11.3	0.0	1367
	No	*4.3*	*7.9*	*70.3*	*11.1*	*6.2*	*0.2*	*1734*
Vietnam	Yes	1.2	7.7	73.0	16.9	1.2	0.0	1058
	No	*2.2*	*9.8*	*80.1*	*7.4*	*0.0*	*0.5*	*245*
Zambia	Yes	3.4	9.1	59.5	22.1	5.6	0.1	2597
	No	*2.9*	*10.5*	*62.4*	*17.3*	*6.4*	*0.5*	*4061*
Zimbabwe	Yes	4.4	9.8	43.4	29.4	12.6	0.4	2645
	No	*5.7*	*11.2*	*43.2*	*23.9*	*12.6*	*3.3*	*882*

Chi-squared tests were used to assess if there was an association between size at birth and a reported birth weight. In all countries an association was observed at the 5% level, and in 11 of the countries at the 1% level. This difference in the distributions of the relative size at birth is unsurprising, given that there is a significant difference in the characteristics of those who report a birth weight and those who did not. These characteristics associated with reporting a birth weight are also related to an increase in birth weight (Kramer, 1987). This may lead to the assessment of the newborn children being larger than average because they are, indeed, larger than average. Therefore, these results are evidence that the size at birth of the infants as reported by the mother might be a good proxy of birth weight.

Figure 5.3: Bar charts showing the distribution of mother's perception by availability of birth weight (%)



5.2. Birth Weight According to Size at Birth

In order to assess the accuracy of a mother's perception of a baby's size at birth it is necessary to judge the size at birth assessment against reported birth weight. Obviously, this can only be done for infants who have a recorded birth weight, which as seen is not representative of the whole population. However, in the absence of any other data pertaining to those who did not report a birth weight, only these individuals can be used. The aim is to ascertain whether mothers of children who are stated as being larger than average or very large by their mother are indeed large with reference to their actual birth weight. Also, it is also important to see how many of those who are classified as being small or very small would also be classified as being of LBW. If there is close agreement between LBW and the smaller size assessments then this may allow size at birth to be used in the calculations of LBW estimates for different countries.

5.2.1. Mean Birth Weight by Size Categories

Within each perception of size category the mean weight for those with a birth weight was calculated (Table 5.3). Also, again reproducing the analysis conducted by Boerma and his colleagues (1996), the coefficient of variation and the standard deviations from the overall mean weight were also calculated. These statistics were calculated to gauge if there is consistency between countries regarding the size categories that contain the greatest and smallest variations in birth weight (Table 5.4).

Table 5.3: Mean (standard deviation) of birth weight in grams for each perception category by country (ordered by overall mean birth weight)

Country	Very Small	Smaller than Av	Average	Larger than Av	Very Large	*Overall*
India	1860 (654)	2278 (554)	2806 (540)	3318 (618)	-[a]	*2793 (670)*
Mozambique	2320 (555)	2665 (520)	2963 (543)	3255 (483)	3320 (566)	*3036 (573)*
Vietnam	1934 (456)	2456 (337)	3060 (337)	3473 (359)	4149 (434)	*3083 (453)*
Zimbabwe	2304 (567)	2619 (400)	3045 (412)	3379 (462)	3617 (556)	*3141 (560)*
Gabon	2209 (539)	2483 (410)	2878 (422)	3344 (467)	3619 (548)	*3152 (623)*
Tanzania	2058 (510)	2486 (577)	3060 (449)	3599 (497)	3973 (661)	*3188 (630)*
Malawi	2411 (797)	2537 (575)	3113 (544)	3544 (635)	3706 (679)	*3188 (674)*
Mali	1925 (518)	2433 (569)	2918 (474)	3456 (566)	4075 (733)	*3190 (777)*
Zambia	2051 (626)	2474 (405)	3151 (444)	3637 (525)	3894 (657)	*3201 (630)*
Cambodia	1968 (534)	2469 (461)	2988 (431)	3481 (476)	3923 (560)	*3202 (608)*
Nicaragua	2221 (619)	2852 (546)	3231 (425)	3620 (520)	4164 (684)	*3281 (649)*
Kazakhstan	2333 (575)	2772 (449)	3299 (359)	3895 (404)	4219 (414)	*3311 (567)*
Bolivia	2477 (613)	2769 (529)	3414 (462)	3919 (594)	4510 (684)	*3379 (655)*

[a] India did not collect information about a 'Very Large' group

Table 5.4: Coefficient of variation and standard deviations from the mean weight in each perception category by country (ordered by overall mean birth weight)

		Very Small	Smaller than Av	Average	Larger than Av	Very Large	Overall
India	Coef of Variation	0.35	0.24	0.19	0.19	-[a]	0.24
	SDs from Mean	*-1.39*	*-0.77*	*0.02*	*0.78*	-[a]	
Mozambique	Coef of Variation	0.24	0.19	0.18	0.15	0.17	0.19
	SDs from Mean	*-1.25*	*-0.65*	*-0.13*	*0.38*	*0.50*	
Vietnam	Coef of Variation	0.24	0.14	0.11	0.10	0.10	0.15
	SDs from Mean	*-2.54*	*-1.38*	*-0.05*	*0.86*	*2.35*	
Zimbabwe	Coef of Variation	0.25	0.15	0.14	0.14	0.15	0.18
	SDs from Mean	*-1.49*	*-0.93*	*-0.17*	*0.43*	*0.85*	
Gabon	Coef of Variation	0.24	0.17	0.15	0.14	0.15	0.2
	SDs from Mean	*-1.51*	*-1.07*	*-0.44*	*0.31*	*0.75*	
Tanzania	Coef of Variation	0.25	0.23	0.15	0.14	0.17	0.20
	SDs from Mean	*-1.79*	*-1.11*	*-0.20*	*0.65*	*1.25*	
Malawi	Coef of Variation	0.33	0.23	0.17	0.18	0.18	0.21
	SDs from Mean	*-1.15*	*-0.97*	*-0.11*	*0.53*	*0.77*	
Mali	Coef of Variation	0.27	0.23	0.16	0.16	0.18	0.24
	SDs from Mean	*-1.63*	*-0.97*	*-0.35*	*0.34*	*1.14*	
Zambia	Coef of Variation	0.31	0.16	0.14	0.14	0.17	0.20
	SDs from Mean	*-1.83*	*-1.15*	*-0.08*	*0.69*	*1.10*	
Cambodia	Coef of Variation	0.27	0.19	0.14	0.14	0.14	0.19
	SDs from Mean	*-2.03*	*-1.21*	*-0.35*	*0.46*	*1.19*	
Nicaragua	Coef of Variation	0.28	0.19	0.13	0.14	0.16	0.20
	SDs from Mean	*-1.63*	*-0.66*	*-0.08*	*0.52*	*1.36*	
Kazakhstan	Coef of Variation	0.25	0.16	0.11	0.10	0.10	0.17
	SDs from Mean	*-1.73*	*-0.95*	*-0.02*	*1.03*	*1.60*	
Bolivia	Coef of Variation	0.25	0.19	0.14	0.15	0.15	0.19
	SDs from Mean	*-1.38*	*-0.93*	*0.05*	*0.82*	*1.73*	

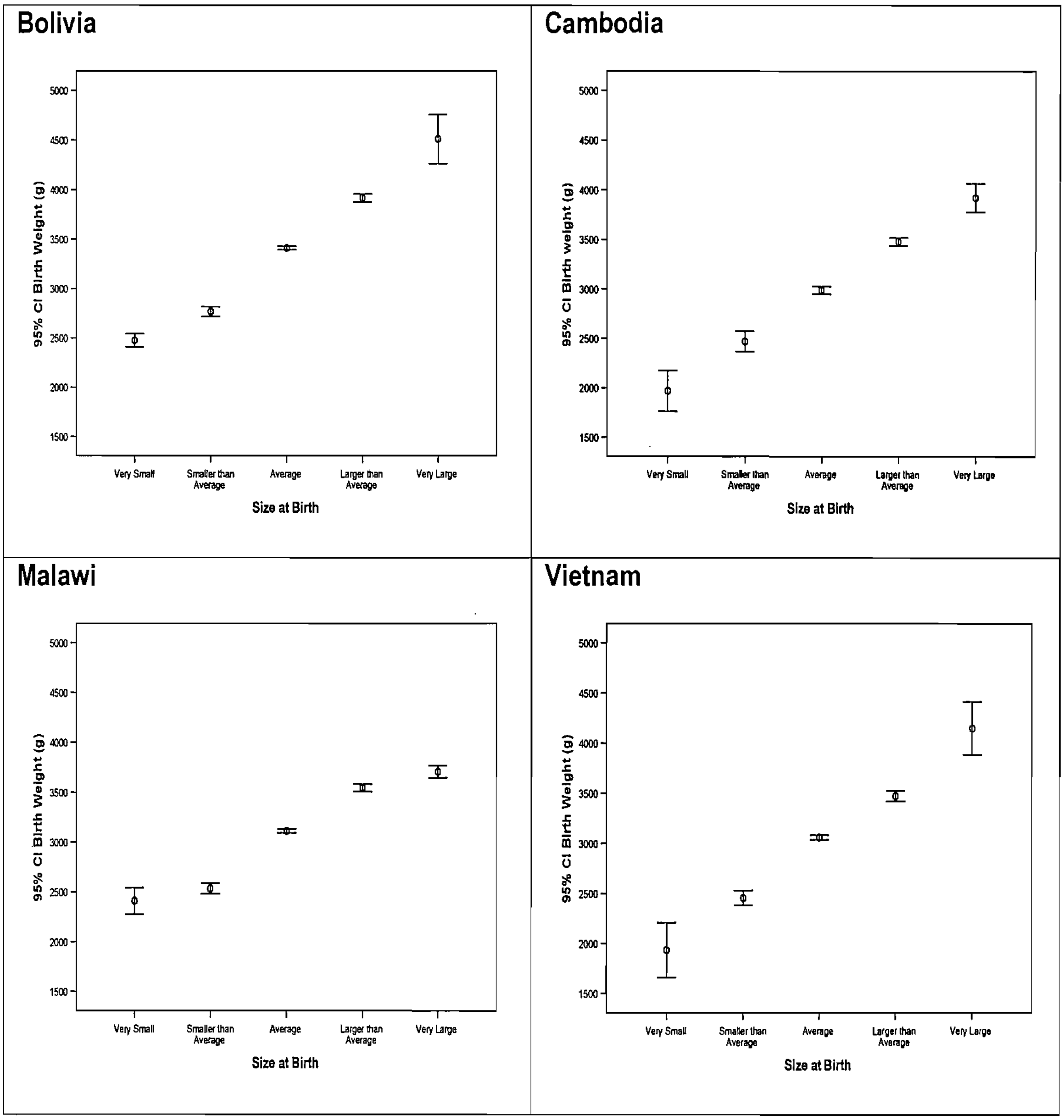
[a] India did not collect information about a 'Very Large' group

From Table 5.3 it is clear that the mean birth weight in each category of size follows the expected trend within each country. In all cases the mean weight in the very large category is the heaviest, with the mean in each subsequent category being lighter than the one before. The mean birth weight in the very small category is consistently the lowest, but also has, in all countries, the largest coefficient of variation, as seen in Table 5.4. This shows that there is the least agreement amongst mothers over what constitutes a very small baby.

A further observation that can be made is that the mean weight within the very small category for every country under analysis is under the 2500g low birth weight threshold. The amount that the mean weight is beneath this threshold ranges from only 23g in Bolivia to 640g in India. This is to be expected, as Bolivia has the highest mean weight and India has the lowest. Most of the other countries' mean weights within the very small category are over 200g beneath the cut off point for LBW. If the mean weights for the smaller than average sized category are studied, it is seen that seven of the countries have mean weights that are also beneath the 2500g cut off. Six of the countries' means in this category are only less by a small margin (under 70g less), whilst India's mean is still a large margin beneath 2500g. The mean for the very small babies lies between 1.15 (Malawi) and 2.54 (Vietnam) standard deviations below the overall mean birth weight, although the majority of countries lie between about 1.40 and 2.00 standard deviations below their overall mean. There is also great variation in the mean birth weights across countries for the very large category between the countries. Bolivia still has the highest mean weight in this category, at 4510g, and Mozambique has the lowest, at 3320g, a range of 1190g. India, as explained above, does not include this category, although the mean weight for the larger than average category is 3318g, very close to the mean weight for very large babies in Mozambique. This similarity between the mean weights for the very large infants in Mozambique and the large infants in India is mainly due to the small difference in the mean birth weights of the larger than average and very large infants in Mozambique.

In most of the surveys used here the confidence intervals for the mean weight in each size category do not overlap. This can be seen in the following figure that shows the error bar plot for the mean weights in each size category for a selection of countries (see Figure 5.4). The very large and very small categories have the largest error bars due to the smaller numbers of infants classified into these categories. However, the trend from very small to very large is obvious, and reassuring that mothers' perceptions are fairly accurate, at least on this aggregate level.

Figure 5.4: Error bar plots for selected countries showing mean birth weight in each perception category



5.2.2. Can Size Categories Be Used To Measure Low Birth Weight?

The mean birth weights in each category of mothers' perception of a baby's size follow the expected trends on an aggregate level, with the mean weight for larger categories being heavier than the mean weight in smaller categories. It may be thought, therefore, that when trying to estimate the proportion of low birth weight children in a population that the proportion that has been classified as being very small and/or smaller than average can be used to provide a reliable estimate.

However, this needs to be studied in more depth, taking account of the results at the individual level. The proportion of infants who were classified as being small or smaller than average who indeed have a LBW, and how many do not have a LBW will indicate the accuracy of the size assessments. Similarly, how many children in the other categories of size actually weighed less than 2500g, and should therefore be classified as having LBW, will also allow an assessment of accuracy.

This analysis uses the methods used by Boerma et al. (1996), who calculated the sensitivity, specificity, and the positive and negative predictive value (PPV and NPV respectively) of size at birth as an indicator of low birth weight. Sensitivity is defined as the percentage of LBW infants who would be correctly identified as LBW if the categories of very small and/or smaller than average were used to determine LBW. Specificity is the proportion of children who are of normal weight who are not included in the very small and/or small categories (this definition is different to the definition given by Boerma et al. (1996), although it is thought that the definition given in their original article is erroneous). PPV is defined as the proportion of LBW infants out of all those classified in the very small and/or small categories while NPV is the proportion of normal weight children among those who are not included in the very small and/or small categories. These definitions are shown in Table 5.5. For a size at birth category to be considered a good indicator of LBW there needs to be a high sensitivity, specificity, PPV and NPV.

Table 5.5: Definition of sensitivity, specificity, PPV and NPV

		Size Classification	
		Very Small/ Small	Not Very Small/Small
Reported Birth Weight	<2500g	n_{11}	n_{12}
	$\geq$ 2500g	n_{21}	n_{22}

$$Sensitivity = \frac{n_{11}}{n_{1+}} \qquad PPV = \frac{n_{11}}{n_{+1}}$$

$$Specificity = \frac{n_{22}}{n_{2+}} \qquad NPV = \frac{n_{22}}{n_{+2}}$$

The analysis of these measures is somewhat confused by an issue identified in the previous chapter, namely the amount of heaping of birth weights at 2500g which causes problems with the identification of those with LBW. This issue was previously resolved by classifying a certain proportion of infants that weighed 2500g as LBW, based on the ratio of infants weighing 2001-2499g to 2501g-2999g. However, in this analysis at the individual level to calculate the sensitivity, specificity etc the actual infants who were reported as weighing as 2500g, but in fact weighed less than this amount, would need to be identified. These infants obviously cannot be identified. Table 5.6 shows the sensitivity, specificity, PPV and NPV for each country using the official definition of LBW (<2500g). Appendix C presents the results if all infants who weigh 2500g are included as LBW. Using the official definition allows comparison with Boerma *et al.* (1996), as this is also the definition used in their article. Two different indicators are tested – firstly using 'very small' as the identifier for LBW, and secondly using those identified as being 'very small' or 'smaller than average' to predict LBW.

Table 5.6: Sensitivity, PPV, specificity, NPW of very small and small as predictors of LBW (ordered by sensitivity of very small)

	Very Small				Small and Very Small			
	Sensitivity %	PPV %	Specificity %	NPV %	Sensitivity %	PPV %	Specificity %	NPV %
India	14	82	99	80	52	58	90	87
Malawi	14	50	99	91	50	43	93	95
Mozambique	15	58	99	90	49	32	86	93
Vietnam	17	89	100	95	69	51	95	98
Tanzania	20	84	100	94	47	49	96	96
Gabon	23	63	98	90	52	54	94	93
Mali	25	84	99	89	55	57	93	93
Zambia	26	68	99	93	69	50	93	97
Nicaragua	27	63	98	93	82	28	78	98
Zimbabwe	30	58	98	94	67	39	91	97
Cambodia	32	73	99	96	77	47	95	99
Bolivia	45	40	95	96	82	31	87	98
Kazakhstan	45	60	98	96	86	30	87	99

If the very small category is used as the indicator of LBW it is seen that the sensitivity of this test is very low, falling to 14% in India and Malawi. This means that only 14%

of children who are actually of LBW are actually classified as being very small in these countries. Bolivia and Kazakhstan have the highest sensitivity (i.e. the largest proportion of infants who are classified as being very small who are actually of LBW), although only 45% of LBW babies in these countries are identified using this definition. As expected, if both the very small and small categories are used the sensitivity rises, although not to very high levels. Kazakhstan has the highest sensitivity, at 86%, showing that over four out of five babies who are of low birth weight are perceived as being small or very small. However, other countries still have a low sensitivity, with Tanzania and Mozambique having less than 50% of children identified. These figures are very similar to those found by Boerma *et al.* (1996). If infants weighing 2500g are also defined as having LBW then the sensitivity of the size categories to predict LBW falls further (see Appendix C).

The PPV is very variable across countries. In Bolivia, even though the sensitivity is high, the PPV is the lowest, at 40%, for the very small classification. Most other countries range from between about 60% to 90%, with Vietnam and Mali having the highest PPV. Therefore, even though most of the children who are identified as very small have LBW, the sensitivity indicates that only a low proportion of those with LBW are identified in this way. If the smaller than average and very small categories are used the PPV falls, as there are more babies of normal weight included. Nicaragua has the lowest PPV using this definition, at 28%, with Kazakhstan and Bolivia also very low. India and Mali still have a fairly high PPV, at 58% and 57% respectively, indicating that over half over of the children in the very small and smaller than average categories actually do have LBW. The specificity and NPV for both tests are high, with most of the countries' results being over 80%. This is encouraging, and indicates that most of the babies who do not have a LBW would not be identified as being LBW if the mothers' perception indicators are used. Also, a large proportion of those who are in the larger categories are indeed of normal weight. Again these results mirror those found by Boerma *et al.* (1996), showing that the accuracy of these size assessments in predicting LBW has not improved over time.

From these results it is not clear whether the use of a mother's perception of her baby's size is of use in identifying LBW babies who have not been weighed. If those who are classified as being very small are classified as being of LBW, then many children who are at risk at birth due to a low birth weight will be missed. Although more inclusive, using the smallest two categories also misses a large proportion of LBW children. However, the fall in the specificity and NPV when both categories are used indicates that a proportion of infants who are not LBW would be classified as being in this higher risk category. These errors will cancel each other out if the sensitivity and PPV are equal (as is nearly the case in Tanzania and Mali). In this situation the same number of LBW infants will have a size perception of average size or larger than non-LBW infants who are classified as smaller than average or very small. In other countries where there is a big difference between the sensitivity and PPV the LBW proportions calculated using actual birth weight and the proportion of infants in the two smallest categories will be very different.

Further to this, it is unknown what the synergy between birth weight and the mothers' perception is. This analysis could only use infants with a reported birth weight, for obvious reasons. It could be that many mothers tend to place their child in the very small category after the weight is known – because the child is measured as being of a very light weight then this changes their perception of the size of the child. Indeed, after a weight has been recorded then this gives some guidance to the mother on how to classify the child, something that mothers of babies who are not weighed do not get. Also, some mothers may not understand birth weight at all and not know if a certain weight is heavy or light. Yet it could be thought, therefore, that a mother's perception is more accurate for children who have been weighed than those who do not have a reported birth weight. This can be tested to some extent by examining only those infants with a birth weight reported from a health card. This will be conducted later.

5.3. Calculating the Proportion of Children with Low Birth Weight

As discussed in the previous chapter, the proportion of infants with LBW within a population can be used as an indicator of child and maternal health. The proportion with LBW calculated from those with a reported birth weight in surveys generally gives an underestimate of the LBW proportion. The possibility of using mothers' perception as an indicator, and classifying those who are stated as being very small or smaller than average as having low birth weight, is also likely to underestimate the percentage of LBW babies, as many of the infants with LBW are actually classified by their mothers as being of average size or larger.

A different method of calculating the percentage of infants in a country with LBW is by combining the responses to the birth weight question with that of the mothers' perception question. The proportion of infants classified as having LBW within each perception category for those with a reported birth weight can be applied to the group of infants in each size category who do not have a reported birth weight. From this, the total percentage of children born with LBW can be estimated. Also, by using the mean birth weight in each perception category the overall mean for the population can be calculated. As before, the treatment of those who weigh 2500g will have a large effect on the results of the calculation of the proportion with LBW. The three estimates will be produced as before: categorising all those who weigh 2500g as having normal birth weight, including those who weigh 2500g as having LBW, and assigning a certain proportion of those weighing 2500g as having LBW. The proportion of infants weighing 2500g who are assigned as having LBW in each country is listed in Table 4.4.

Table 5.7 shows the estimated proportion of infants with LBW in each country, using the three different definitions of LBW. Three estimates are given. Firstly, the proportion of infants with LBW for those with a reported birth weight, also shown in Table 4.5. Secondly, an estimate for the proportion with LBW for those without a birth weight using the adjustment procedure noted above, and finally an overall estimate for the whole population. Table 5.8 displays the mean birth weights for these three different groups. Standard errors for both Tables 5.7 and 5.8 are shown in Appendix D. Standard errors for the proportion of LBW infants were calculated without taking into account the error introduced through the estimation process. To obtain true standard errors the bootstrap estimation procedure is required.

Table 5.7: Estimates of the proportion of infants with LBW for those with a reported birth weight, without a reported birth weight and for all infants using three different ways of classifying LBW

	Birth Weight Recorded			*Mothers' Perception Only*			*Overall*		
	Under 2500g	Inc. % of 2500g[1]	Under 2501g	Under 2500g	Inc. % of 2500g[1]	Under 2501g	Under 2500g	Inc. % of 2500g[1]	Under 2501g
Kazakhstan	6.1	6.6	8.2	12.6	13.0	14.6	6.3	6.7	8.4
Vietnam	6.5	7.2	10.7	8.5	9.1	13.4	6.9	7.5	11.2
Bolivia	6.9	7.6	9.9	8.4	9.3	12.0	7.5	8.3	10.8
Cambodia	5.6	6.2	12.6	8.2	9.2	18.8	7.9	8.8	17.9
Zimbabwe	8.5	9.4	13.2	9.8	10.7	14.9	8.8	9.7	13.6
Zambia	9.1	10.2	13.9	9.5	10.4	14.6	9.4	10.4	14.3
Nicaragua	9.6	9.7	10.0	12.8	12.9	13.3	10.7	10.8	11.1
Tanzania	7.6	9.2	15.9	10.7	12.5	19.9	9.3	11.0	18.1
Mozambique	11.5	12.7	17.3	11.9	13.2	18.6	11.7	12.9	18.0
Gabon	12.0	13.1	15.6	13.7	14.7	17.2	12.2	13.3	15.8
Malawi	9.7	13.0	20.2	12.9	16.5	24.5	11.5	14.9	22.5
Mali	14.2	17.0	21.6	21.6	24.9	31.2	20.2	23.4	29.4
India	21.9	28.4	40.5	25.7	32.7	45.7	24.7	31.6	44.4

[1]See Table 4.4 for percentage of infants weighing exactly 2500g classified as LBW for each country

Table 5.8: Estimates of mean birth weight by country for those with a recorded birth weight, without a recorded birth weight and for all respondents

	Mean Birth Weight (g)		
	Birth weight recorded	Mother's Perception only	All Respondents
Kazakhstan	3311	3118	3306
Vietnam	3083	3007	3068
Bolivia	3379	3310	3350
Cambodia	3202	3043	3065
Zimbabwe	3141	3109	3133
Zambia	3201	3180	3188
Nicaragua	3281	3184	3249
Tanzania	3188	3088	3132
Mozambique	3036	3017	3026
Gabon	3152	3123	3148
Malawi	3188	3102	3142
Mali	3190	2980	3021
India	2793	2708	2730

In all the countries under analysis the proportion of LBW infants increases when adjustment is made for those without a recorded birth weight. Similarly, the mean birth weight is lower when all the respondents are included in the calculations as opposed to when only those with a recorded birth weight are used. These results are unsurprising if the differences between those who report a birth weight and those who do not are taken into account. Therefore, the fact that there is a rise in the LBW proportion and a fall in the mean weight lends some credence to the notion that using mother's perception alongside birth weight to calculate the proportion of infants with LBW in a country improves the accuracy of the LBW estimates.

Applying the method which uses mother's perception to calculate the LBW proportion and the mean birth weight can change the estimated proportion of LBW infants by a substantial amount when compared to the estimates produced when just using those infants with a reported birth weight. For example, in Tanzania the LBW proportion rises from 9.2% to 11.0%, an increase of 20%. In Mali there is a substantial increase of 38% in the proportion with LBW. Other countries show a minimal increase, such and Gabon and Kazakhstan. There is an obvious relationship between the change in the proportion with LBW after applying this method and the amount of missing birth weight data. Those countries with higher percentage of mothers who did not report birth weight are seen to have the highest change in the proportion with LBW when the whole sample is considered.

In comparison with the results for the proportion of infants with LBW taken from the paper by Boerma *et al.* (1996), the results from this analysis are still underestimates. Two countries which are common to both analyses are Tanzania and Zambia, and thus the results should be comparable. The data for this study was taken from subsequent surveys to those used by Boerma *et al.*, although the period between the surveys is only seven years in Tanzania and nine years in Zambia. This period of time is too short for major shifts in the birth weight distribution to occur (McCormick, 1985). In their paper, after adjustment the proportion with LBW was calculated as 18.8% in Tanzania and 14.4% in Zambia. These are obviously much higher figures than the 11.0% and 10.4% calculated in this study for the two countries respectively. Some of this difference is due to the differential treatment of those who weigh 2500g. In this study fewer infants were treated as having LBW than by Boerma *et al.*, who classified half of those with a weight of 2500g as having LBW. Yet this does not explain the entire difference in the estimates. If half of the infants weighing 2500g are taken as having LBW in this study the proportion of LBW infants in Tanzania and Zambia increases to 13.7% and 11.9% respectively, still below Boerma *et al*'s estimates.

The differences between this study and Boerma *et al.* (1996) are not just seen after the adjustment for perception. There are far higher proportions of LBW in those with a birth weight reported in the earlier surveys used by Boerma *et al.* than in the ones analysed in this study, although there is a similar proportion of data missing for both countries in the two surveys. Apart from the explanation for this difference being that the percentage of children with LBW has fallen over this period, which is unlikely, a further explanation is simple sampling variation, although again, this explanation is improbable. However, corroborating evidence for the results here for these two countries comes from Blanc and Wardlaw (2005), where using slightly different methods to calculate the percentage with LBW they obtained the results for the same surveys of 12.9% for Tanzania and 12.4% for Zambia, which are much closer to the results obtained above in Table 5.7. The differences between the study by Blanc and Wardlaw (2005) and the results obtained here can be explained by the treatment of those weighing 2500g.

5.4. Proportion with Low Birth Weight by Method of Recall

In the previous chapter it was seen that there are sometimes large differences in the proportion of infants with LBW and the mean birth weight if the reporting method of the birth weight is taken into account. In the majority of countries there are a higher proportion of babies with LBW if the weight is reported from memory than if the weight is reported from a health card, and differences between the characteristics of the mothers in the two groups were seen. It is therefore interesting to conduct the same analysis as above, looking at the accuracy of the allocation to the size categories for the different methods of recall, and also to calculate the LBW proportion taking account of these different methods of reporting.

5.4.1. Sensitivity, Specificity, PPV and NPV of LBW by Recall Method

To assess if the size at birth estimate from the mother is influenced by the method of recall of the birth weight, the sensitivity, specificity, PPV and NPV of size at birth as a predictor of LBW was estimated for the different reporting methods. This will indicate whether the method of recall leads to greater accuracy in the assessment of a baby's size at birth, or if there is an influence of knowing the birth weight accurately on the perception of the babies' size. The results for each recall method are shown in Table 5.9 for weights reported from memory and Table 5.10 those reported from a health card. The results are shown using the official definition of LBW (i.e. <2500g).

Table 5.9: Sensitivity, PPV, specificity and NPV of very small and smaller than average as predictors of LBW for weights recalled from memory

	Very Small				Small and Very Small			
	Sensitivity %	PPV %	Specificity %	NPV %	Sensitivity %	PPV %	Specificity %	NPV %
Malawi	12	45	98	90	50	45	92	94
India	15	84	99	80	56	62	90	87
Tanzania	16	81	100	93	41	57	97	95
Gabon	23	67	98	89	50	55	94	92
Zambia	24	72	99	92	71	52	93	97
Mozambique	26	94	100	87	54	46	87	91
Nicaragua	27	66	98	93	83	30	79	98
Mali	28	90	99	89	62	65	94	93
Cambodia	32	100	100	95	81	63	97	99
Vietnam	39	88	99	94	81	60	95	98
Zimbabwe	40	68	98	93	74	50	92	97
Bolivia	44	42	95	96	81	33	87	98
Kazakhstan	45	60	98	96	86	30	87	99

Table 5.10: Sensitivity, PPV, specificity and NPV of very small and smaller than average as predictors of LBW for weights reported from a health card

	Very Small				Small and Very Small			
	Sensitivity %	PPV %	Specificity %	NPV %	Sensitivity %	PPV %	Specificity %	NPV %
Vietnam	4	100	100	95	63	45	95	98
Mozambique	5	19	98	91	45	24	86	94
India	13	79	99	81	48	54	89	86
Zimbabwe	17	39	98	94	57	29	90	97
Malawi	19	70	99	95	53	36	94	97
Mali	19	70	99	89	43	44	92	91
Gabon	23	58	98	92	55	52	94	95
Tanzania	24	86	100	94	52	44	95	96
Nicaragua	28	50	97	94	73	22	76	97
Zambia	29	64	99	94	67	47	93	97
Cambodia	32	63	99	96	75	41	94	99
Bolivia	49	29	94	98	96	22	84	100
Kazakhstan	- [a]	- [a]	- [a]	- [a]	- [a]	- [a]	- [a]	- [a]

[a] N is too small to calculate accurate statistics

There is no consistent trend shown over all the countries with one of the reporting methods, either memory or card recall, showing more accurate predictions of LBW from the mothers' perception of the babies' size. The sensitivity of the tests varies widely in some countries by recall method, although generally the sensitivity is low. This indicates that the smaller than average and very small categories only contain few of the infants who actually had low birth weight as seen above when all infants were analysed together. Mozambique, Vietnam and Zimbabwe all have much higher sensitivity for those recalled from memory than they do from card recall, especially when only those who are classified as very small are used as an indicator of LBW. If the smaller than average and very small categories are studied together, then Mali also shows a much greater sensitivity for the identification of LBW for those who are recalled from memory as opposed to a card. Bolivia displays the reverse trend with those who are recalled from a card and are classified as either smaller than average or very small representing a much higher percentage of actual LBW babies than those who are recalled from memory.

Regarding PPV, in general this is better for those who are recalled from memory – more children who are classified as smaller than average or very small are indeed of low birth weight according to their mothers' report. Mozambique displays the greatest difference between reporting methods, with 94% of very small babies actually having LBW if the weight is recalled from memory, whilst only 19% of the very small babies have LBW if the weight is recalled from a card. Large differences in the same direction are also seen for Cambodia and Zimbabwe. If infants who are classified as either smaller than average or very small are analysed together then all the countries in this study display better results for memory recall than card recall.

The results for the specificity and NPV do not show much variation between the recall methods, mainly because the results are closer to 100% and therefore there is much less scope for change. However, in general the specificity is higher if the weight is recalled from memory, although the NPV is higher if card recall was used. Most of these differences are less than 3% though, and thus do not have much effect.

From the above results, it appears that the perceptions of size for mothers who recall the birth weight from memory are more accurate and are better at predicting low birth than the perceptions from mothers who report from a card. It could be that the mother who is recalling from memory subconsciously links the two questions together. In the survey the question on the size of the child at birth is asked before the actual birth weight is requested, and thus the response to the size may influence the recall of weight from memory. If a mother states that their child is small, then it is likely that the recalled weight will be subconsciously rounded down to a lighter weight. Thus there will be more very small and small babies who have been recalled as having LBW.

5.4.2. Proportion of infants with LBW by method of recall

For each method of reporting birth weight, from memory or from a health card, the proportion with LBW in each category of size was calculated. These proportions were, in turn, applied to those children without a weight to obtain two separate estimates for the proportion of infants with LBW. Therefore, there are three components to each estimate of LBW: the LBW proportion for those with a weight reported from memory, the LBW proportion for those with a weight reported from a card, and a LBW proportion estimate for those without a birth weight calculated from either the card or the memory proportions. Again, the three different definitions of LBW were used – below 2500g, 2500g and below and classifying some of those with a weight of 2500g as LBW (Table 5.11). Standard errors of these estimates are shown in Appendix E.

Table 5.11: Estimate of the proportion of infants with LBW after adjustment for method of recall and missing data

	Reported from Card				Recalled from Memory			
		% with LBW				% with LBW		
	Mean (g)	Under 2500g	Inc. % of 2500g[1]	Under 2501g	Mean (g)	Under 2500g	Inc. % of 2500g[1]	Under 2501g
Bolivia	3358	6.2	6.8	8.6	3348	7.8	8.6	11.2
Kazakhstan	3298	6.2	6.6	8.2	3307	6.3	6.7	8.4
Nicaragua	3217	9.9	10.1	10.8	3254	10.9	10.9	11.2
Zambia	3158	8.9	9.7	13.0	3211	9.7	10.8	15.4
Gabon	3143	12.1	13.0	15.4	3154	12.4	13.4	16.1
Zimbabwe	3127	8.4	9.3	12.9	3141	9.1	10.1	14.3
Malawi	3116	9.9	13.1	20.2	3151	12.1	15.6	23.4
Tanzania	3113	8.7	10.3	17.1	3148	10.2	12.0	19.5
Vietnam	3068	7.0	7.5	11.1	3062	6.9	7.6	11.7
Cambodia	3050	7.1	8.1	17.7	3094	9.7	10.5	18.5
Mozambique	3029	11.0	12.1	16.6	3024	13.0	14.6	20.5
Mali	3015	18.6	21.3	27.3	3028	21.0	24.5	30.5
India	2737	24.3	31.1	43.5	2725	24.9	32.1	45.2

[1]See Table 4.4 for percentage of infants weighing exactly 2500g classified as LBW for each country

There are some large differences in proportions with LBW depending on the method of calculation, either using the birth weights from cards or from memory. In all cases the proportion with LBW is higher if the adjustment weights are taken from memory as opposed to a card. In Bolivia, using the middle estimate (classifying some of those weighing 2500g as LBW) the memory reported estimate of LBW is 8.6% while the card recalled estimate is 6.8%. Mozambique also displays a large difference, from 14.6% for memory to 12.1% for card reported weights. Conversely, other countries do not display much change in the low birth rate depending on the method of calculation. Kazakhstan's LBW proportion rises from 6.6% to 6.7% if memory reported weights are used rather than card reported weights in the adjustment. This is mainly due to there being a small amount of children without a birth weight reported and thus, only a small amount of potential variation in the figure is possible. The proportion with LBW in Gabon, India and Vietnam also only differs by a small percentage when the different methods of adjustment are applied, which indicate that the distribution of mothers' perceptions of their baby's sizes are similar between those mothers who report birth weight from a card and from their memory.

If the original LBW estimates, using just those who reported a birth weight irrespective of reporting method (Table 4.5), are compared with the adjusted figures for LBW calculated using the weights obtained from a mother's memory, then there are very large rises in the proportion of infants with LBW in some countries. In Cambodia and Mali the increase in the LBW is extreme, with the change in the estimated proportion of infants with LBW rising by 69% and 44% respectively. In Cambodia, this means that the level of LBW in the country increases from an initial estimate of about one in sixteen (6.2%) babies to about one in ten (10.5%) weighing beneath 2500g. In Mali, the estimate of LBW using the memory recalled birth weights indicates that about a quarter of babies may be of LBW (24.5%). Most countries show an increase in the LBW proportion of over 10% from the initial estimate. Two countries which do not show this increase are Gabon and Kazakhstan, where the proportion only increases by about 2%. These two countries have the smallest amount of missing data, with a low level of heaping, and therefore there is a smaller adjustment when including those who did not report a birth weight in the calculation. The distribution of the size at birth variable is also similar for infants with a weight reported from a card as for those with a birth weight recalled from memory.

5.5. Discussion

The results from Chapter 4 indicate that by using only those birth weights which have been reported in the DHS to estimate the proportion of infants with LBW that unreliable results are obtained. This is due to the differences in characteristics between infants with and without a recorded birth weight. The focus of this chapter has been the improvement of these LBW statistics by using a mother's perception of her child's size in the estimation process. Although the true level of LBW in a country is not known, adjusting the results obtained from those with a birth weight by utilising the mothers' perception of their children's size is seen to produce more realistic estimates, as has been observed in other studies (Boerma *et al.*, 1996; Blanc and Wardlaw, 2005). The results obtained from this study cannot be directly compared to these other papers as the treatment of those reported as weighing 2500g differs. Furthermore, the method is extended to take account of differences in reporting method, which has not been studied previously.

The small amount of missing data seen in response to the question to mothers regarding the perception of the size of their child is reassuring. Furthermore, due to the question being asked in reference only to the children born in the last five years there is likely to be a good recall memory for the size of the child. The amount of missing data seen in Mali, 3.5%, is not large enough to cause great concern to further analyses, although it is strange that the amount of missing information on the size of the baby variable in Mali is so much greater than the other countries under analysis. No cogent argument can be made to explain why Mali has a much higher level of missing data on this variable than the other countries in the analysis.

Responses to the question regarding the size of the child show interesting results. The upward skew of the perceptions in most countries so that there are more infants classified as larger than average or very large than smaller than average or very small may be indicative of the general feeling amongst mothers that 'bigger is better', with mothers inflating the size of their child so that the child sounds healthy to the interviewer. This skewing may indicate that size at birth is not that accurate at reflecting actual birth weight, but in fact reflects social norms, as the distributions of birth weight that have been recorded in the respective countries' surveys are not skewed in this way.

The distribution of mothers' perception does differ for those infants with and without a reported birth weight. The results indicate that those with a reported birth weight are more likely to classify their child as larger than those who do not report a birth weight. In some countries this shift to larger sizes for those with a reported birth weight is not a large one, but in other countries, such as Cambodia, Mali and India there is a large shift to the larger sizes for those with a reported birth weight. Those with a birth weight, as has been seen in the previous chapter, have attributes that mean that they are likely to have a higher birth weight, on average, so the shift in perceptions to the larger sizes could reflect reality.

Within each size perception category the mean birth weights follow the expected trends, with the mean birth weight in the very large category being the heaviest, and in the very small category being the lightest. Given this, there is validity behind using perception of size to obtain estimates of LBW for the complete population. It is seen that simply using those infants who have been classified as small or very small is not a valid method for deciding on which infants are LBW, due to the low sensitivity when using the very small or small perception categories to predict LBW. Many children who have LBW are not classified as small or very small, although most of the children who have been classified as small or very small do actually have a LBW. So, even though the small and very small categories mainly contain LBW infants, and few infants with normal birth weights are in these categories, there are many LBW infants who are classified as being of average size or larger. Using simply the proportion of small and very small infants as an estimate of the LBW proportion is therefore not a reliable option to obtain good estimates, although this method has been used in some studies (e.g. Rodrigues and da Costa Leite, 1999; Magadi *et al.*, 2001; Ghosh, 2006).

Infants with both a reported birth weight and an assessment of size can be used to improve LBW estimates. The proportion of babies with LBW in each category of size can be applied to those without a birth weight. If this is done then the percentage

LBW becomes far more realistic in comparison to the proportions of LBW infants seen in developed countries. Also, the mean birth weight falls, which is expected due to the different attributes of the group who reported a birth weight and the group that did not. In Cambodia and Mali the fall in the mean birth weight is over 100g once all those without a birth weight are included in the estimation for the mean weight. As expected, the countries with the largest amount of missing data had the largest changes in the mean birth weight. The proportion with LBW after correction rose in all countries, although it is difficult to assess whether the new figures are accurate, due to a lack of reliable data with which to compare against. The problem with comparison against other estimates also lies in the treatment of infants with weights heaped at 2500g, and the way in which these infants are treated. However, irrespective of how those weighing 2500g are treated there is a large change in the proportion of infants with LBW after including all infants in the analysis. Referring to the goals set by the UN for the reduction in LBW (United Nations, 2002) this uncertainty makes it very difficult for an accurate assessment of the scale of any reductions in LBW in any country without full coverage of birth weight statistics.

In the same vein, if the different reporting methods of birth weight are used to calculate the percentage with LBW there is a difference in the results from those obtained when using the full sample of birth weight responses. Card reported birth weights are seen to be less likely to be LBW. As a result estimates of the percentage of infants with LBW is lower when only the card recalled weights are used when compared to results obtained using the full sample. Card recalled birth weights can be considered to be more reliable than memory recalled weights, as they should be official records of the weight, although it has been seen (Chapter 4) that even weights reported from a health card may be highly heaped. However, in general, the calculation of the estimate of the percentage with LBW in each country can be thought of as more reliable if the card birth weights are used to control for missing information rather than both the card and memory reported weights. However, as those infants who have a weight reported from a card are generally of a higher socio-economic status, it may be hypothesised that the characteristics of infants with a memory reported birth weight are closer to the characteristics of infants without a reported birth weight, and therefore those with a memory reported birth weight should be used to calculate the proportion of infants with LBW in a country. If this is done then the LBW proportion rises even further.

The method used to produce these estimates is not without error. There is an implicit assumption that the relationship between perception of size and birth weight is the same for those with a recorded birth weight and for those without. The violation of this assumption is easy to imagine – those who know the child's birth weight may judge the size on the birth weight rather than thinking about the actual size at birth. Mothers who do not know the birth weight of their child have to form a mental picture of their child before stating a size. Therefore the processes by which a size classification is chosen may differ depending on whether a birth weight has been recorded or not. Children may be long and thin, or small and heavy. Which dimension is the mother recalling when attempting to judge the size of the child? A second issue with the method is that it assumes that those with a birth weight are as likely as those without a birth weight to have LBW within each size category, which again is unlikely due to the characteristics of the two groups. LBW is likely to be less common amongst those with a reported birth weight, and therefore applying these proportions to those without a recorded birth weight is still likely to lead to underestimation of the true proportion of LBW in the country as a whole.

A further concern regarding this method is how the mothers actually decide on their response to the question regarding the size of their child. The psychological process by which this happens is outside the scope of this thesis, but it is important to understand who the mothers are judging the size of their baby against. The potential responses given to the mother, very small to very large, require judgement against other children to obtain an answer. However, it is not known whether mothers judge children against others in their family, in their village, in the hospital where the birth occurred, or against a 'generic' child seen in the media. Chapter 7 will look at the determinants of the perception of size in detail to try and clarify this point. A further point is that the method is dependent on the mother being correct in her classification of the size of her baby. It is clear that this is not the case, with many mothers classifying very light infants into large size categories, but are certain mothers better at specifying a correct size than others? This will be studied in the next chapter.

Overall, the analysis in this chapter has indicated that a mother's perception of her baby's size can be used to produce more realistic estimates of LBW within a country, although it is difficult to assess how valid these estimates actually are. Aside from the drawbacks to this method which have been highlighted above, the method is simple to use and can be applied quickly to countries where surveys have asked the question regarding size at birth. The treatment of infants whose weights are heaped at 2500g does have a large effect on the proportion with LBW, but if all analyses conducted apply the same treatment then the estimates are comparable across countries and across different surveys. It is important to account for the differences in birth weights observed between memory and card reported weights, as ignoring these differences may produce unreliable estimates.

Chapter 5: Key Points

- Mother's perception of the size of their baby is skewed towards larger sizes, and this skew is stronger for those with a reported birth weight than for those without.
- The mean birth weights in each size category follow expected trends, with infants in smaller size categories having lower mean birth weights than those in larger size categories.
- The smallest size categories only contain a low proportion of infants who are actually of LBW, with memory reported weights being more accurate than card reported weights.
- Using the mother's perception of size in the calculation of the proportion of infants with LBW produces estimates which are closer to those expected.
- By accounting for the method of reporting when calculating the percentage of infants with LBW more accurate country level estimates can be achieved.

Chapter 6

Which Mothers are Correct in Assessing the Size of their Child?

The use of mother's perception of the size of her baby at birth to aid in the calculation of low birth weight (LBW) estimates in countries where much birth weight information is missing is thought to improve estimates (e.g. Boerma *et al.*, 1996; Blanc and Wardlaw, 2005). It is seen that there is a large change in the proportion of infants estimated to have LBW when those without a reported birth weight are included in calculations. Mother's perception of her child's size is an accurate predictor of birth weight at an aggregate level, although on an individual basis there are many mothers who appear to misclassify their child into an unsuitable size category. This chapter looks in detail at which groups of mothers classify their newborns into the correct size categories, and which mothers are more likely to misclassify their child's size.

Much research into the effect of birth weight on various outcome measures focuses on LBW and ignores heavier infants, although many of these heavier infants also have a raised risk of mortality and morbidity (McCormick, 1985). Therefore the accuracy of the mother's perception of the size of the infant should be assessed for the whole range of birth weights. Studies which use the mother's perception as a proxy for birth weight in models of mortality and other outcome measures usually use the full five categories of size, from very small to very large (Magadi *et al.*, 2001; Madise *et al.*, 2003; Magadi *et al.*, 2007). It is therefore important to understand if mothers are more likely to classify smaller or larger infants into correct size categories, or if there are minimal differences between weights. For mothers' perception of size to be treated as a good proxy for birth weight it should be expected that there is little misclassification of infants into incorrect size categories when compared to their actual weight, and any misclassification observed is not related to the actual size of the infant in question.

6.1. How is Correctness Assessed?

To investigate which mothers are best at assessing the size of their infant correctly it is first necessary to classify the mothers' perceptions as correct or incorrect. Obviously this is not straightforward, as there may be different interpretations of the question asked in the survey by different mothers. Asking a mother for a child's size at birth may be taken as requiring an assessment of the weight at birth. Alternatively, other interpretations of the question may include assessments of the length of the child or the amount of subcutaneous fat on the baby. The idea of the size of an 'average' child will differ for each mother: there is not a single 'reference child'. These issues will be discussed further in the Chapter 7.

With regard to determining which mothers correctly assess the size of their baby it is clear that only those infants who have a reported birth weight in the DHS can be used in the analysis. Using only these cases gives estimates that are not applicable to the whole population, only to those who have a reported birth weight. As demonstrated in previous chapters and in other research (e.g. Blanc and Wardlaw, 2005) using this group of infants causes problems. Birth weights are hypothesised to be skewed towards larger sizes for those with a reported birth weight compared to those without. The distribution of the size at birth response is also skewed towards larger sizes for the same group of infants. However, it is not known whether the magnitude of the skew observed for size is of the same extent as the hypothesised difference in the mean birth weights. To assess whether a mother has gauged the size of her child correctly assumes that the amount of negative skew on both variables is the same, something that is difficult to verify.

Taking the above issues into account, a method needs to be devised in order to gauge whether mother's perception is consistent with the birth weight. To correspond directly to the different categories of mother's perception it is easiest to classify birth weight into five categories, and then observe the concordance of mother's perception with the birth weight groups. There are a number of possible methods to classify birth weight into five groups, one of which is to use standard deviations from the mean weight as the boundaries for the different categories. Table 6.1 displays one manner of doing this, although other boundary points could be chosen. There are a number of choices that can be made for the mean weight to use, such as the mean weight in the area or region that the child lives. Further options are to use the country mean weight, or even a global mean. For this study the country mean birth weight was used.

Table 6.1: Categorising birth weight into size classes by standard deviation from a country's mean birth weight

Category	Classification of Birth Weight
Very Small	Below -2 Std. Dev. from the mean
Small	Between -1 and -2 Std. Dev. from the mean
Average	Between -1 and +1 Std. Dev. from the mean
Large	Between +1 and +2 Std. Dev. from the mean
Very Large	Above +2 Std. Dev. from the mean

For each country, birth weight was categorised into these 5 categories. These categories were then compared with mother's perception categories for the same infants, and accurate reports of size were assigned the value of '1'. If the weight and size did not match then the case was assigned a value '0'. Analyses of the percentage of infants who had a correct size assessment were conducted, followed by multivariate analysis of the determinants of a correct perception using logistic regression. Further analyses were conducted on the factors which were associated with over- and under-estimation of the size of an infant. Infants who were classified as being smaller than their actual birth weight suggested were placed in one category; those who were given an accurate size assessment were placed in another; those who were larger than their actual birth weight classification were placed into a final category. Multilevel multinomial logistic regression was used to estimate the relationship between various potential explanatory variables and the chances of the birth weight being under or over estimated.

6.2. Exploratory Analyses of Infants with a Correct Size Assessment

The percentage of infants who were given a size assessment by their mother which is commensurate with their reported birth weight are shown in Table 6.2 for each of the 13 countries in the analysis.

Table 6.2: Percentage of mothers' perception of size responses corresponding to birth weight categories

Country	% Consistent in Determining Size
Gabon	36.0
Mozambique	40.4
Nicaragua	42.0
Cambodia	45.1
Mali	46.1
Zimbabwe	48.4
Malawi	52.3
India	60.6
Zambia	63.8
Tanzania	64.7
Bolivia	65.6
Kazakhstan	70.5
Vietnam	71.0

There is a large range in the percentage of correct responses over the countries. In Vietnam 71.0% of infants were assessed as being in the correct size category, compared with only 36.0% in Gabon. In all, there are six countries in which over half the mothers have not assessed the size of their child in line with the birth weight which has been reported. The main reason for this is due to the percentage of infants who are classified by the mothers as being larger than average or very large (refer to Table 5.2). If a sizeable proportion of infants have been classified as being larger than average or very large then the percentage of infants who are correctly assessed is low. This is the case as in Gabon, where 54.9% of infants are either larger than average or very large and Nicaragua, where 49.3% of infants are in these two categories. Conversely, where the distribution of the perception of size is more equitable above and below the central 'average' size category, there is a higher percentage of correct responses, such as in Tanzania and Vietnam.

The association between birth weight and mother's perception can easily be seen when plotted together. The percentage of infants classified into the different size categories by birth weight are shown for three countries in Figure 6.1. The countries were selected to represent countries with different levels of 'correctness', as displayed in Table 6.2 above. The graphs clearly indicate that lighter infants are, in general, classified as being of a smaller size than heavier infants. However, there are a number of infants who are classified into size categories which are not appropriate. For instance, in Malawi a number of infants weighing less than 2 S.D. below the mean weight were classified as having a very large size (see Figure 6.1). Other country graphs are shown in Appendix F.

The misclassification of a child into the incorrect size category can easily be explained for those infants who are placed into a size grouping either side of the correct category e.g. placed in the smaller than average group when they should be classified as average. This may be due to the size assessment not being based purely on birth weight, but also on other aspects of the newborn. However, misclassification by two or more categories is harder to understand, as length, weight and fat levels are all highly correlated. The percentage of infants who were placed into the size categories which were not correct or into categories either side of the correct category is listed in Table 6.3.

Figure 6.1: Stacked bar chart of the percentage of size classification by birth weight for Gabon, Malawi and Vietnam

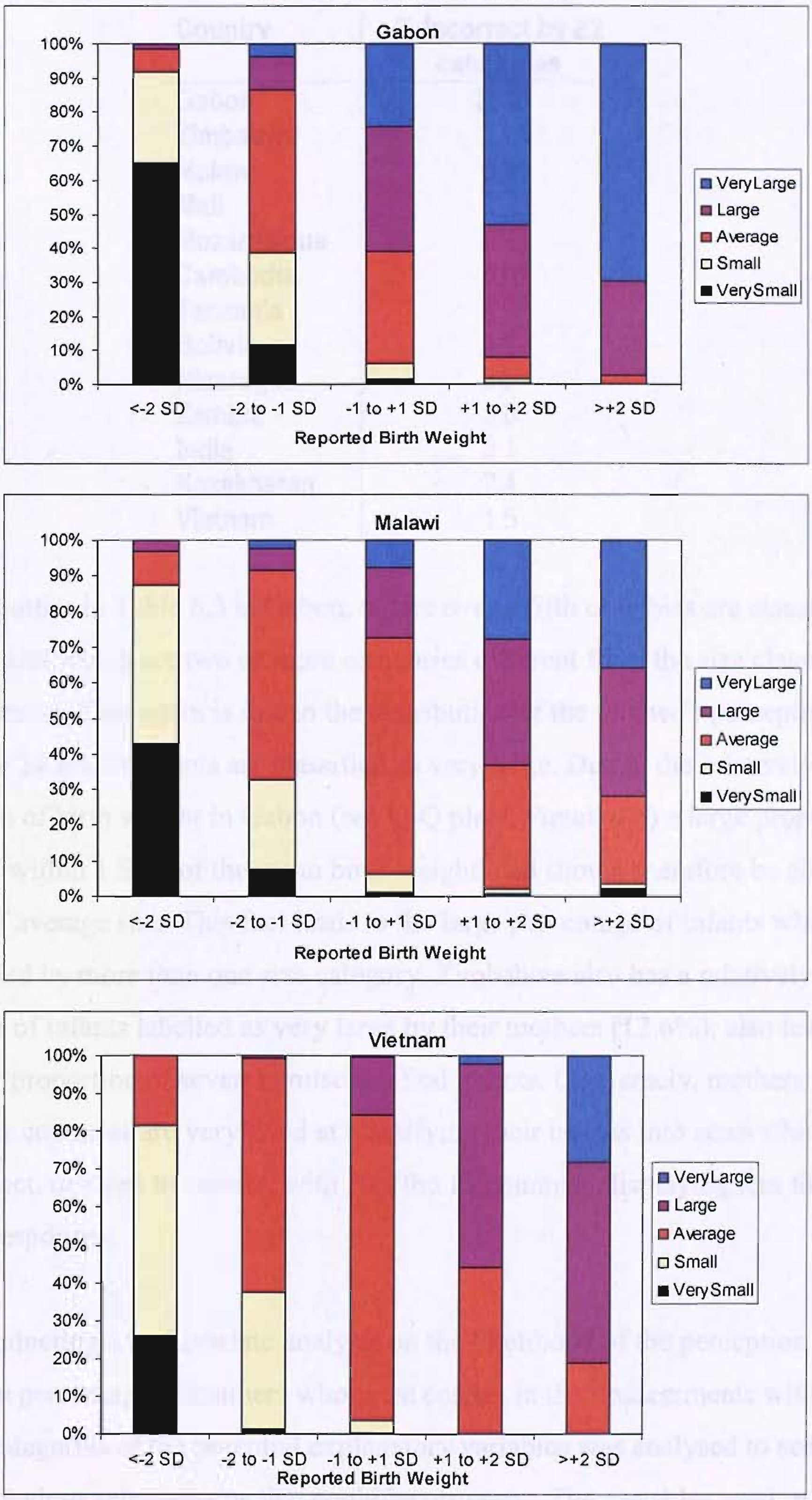


Table 6.3: Percentage of infants misclassified into size categories by more than one category

Country	% Incorrect by ≥2 categories
Gabon	20.2
Zimbabwe	10.6
Malawi	8.2
Mali	7.2
Mozambique	6.2
Cambodia	6.0
Tanzania	4.9
Bolivia	4.6
Nicaragua	3.9
Zambia	3.8
India	3.1
Kazakhstan	2.4
Vietnam	1.5

The clear outlier in Table 6.3 is Gabon, where over a fifth of babies are classified into size categories which are two or more categories different from the size classification that is expected. This again is due to the distribution of the mother's perception of size, where 24.6% of infants are classified as very large. Due to the relatively normal distribution of birth weight in Gabon (see Q-Q plots, Figure 4.6) a large proportion of infants are within 1 S.D. of the mean birth weight, and should therefore be classified as being of average size. This fact leads to the large percentage of infants who are misclassified by more than one size category. Zimbabwe also has a relatively sizeable percentage of infants labelled as very large by their mothers (12.6%), also leading to the greater proportion of severely misclassified infants. Conversely, mothers in many of the other countries are very good at classifying their infants into sizes which are either correct, or close to correct, with 7 of the 13 countries displaying less than 5% incorrect responses.

Before conducting a multivariate analysis on the likelihood of the perception being correct, the percentage of mothers who were correct in their assessments within different categories of the potential explanatory variables was analysed to see if there were any obvious relationships that could be observed. The variables used in this investigation were similar to those used in previous chapters, including maternal and paternal education, survival status and gender of the child, place of residence and delivery and the birth order of the child. Figures 6.2 and 6.3 plot the relationship between a correct assessment of size and maternal educational level and place of delivery respectively.

Figure 6.2: Line graph of percentage of infants with a consistent size assessment by highest educational level for seven selected countries

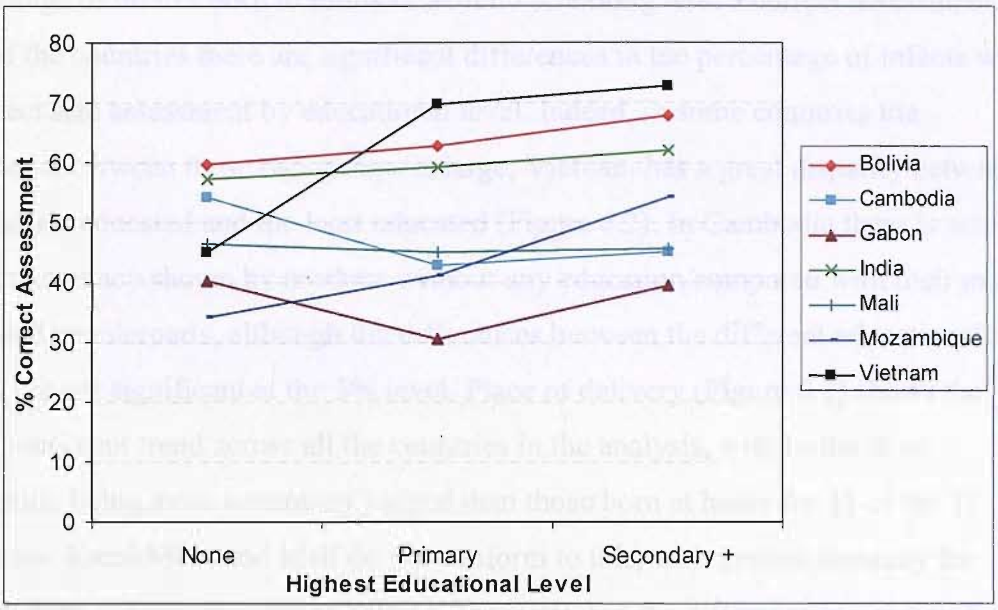
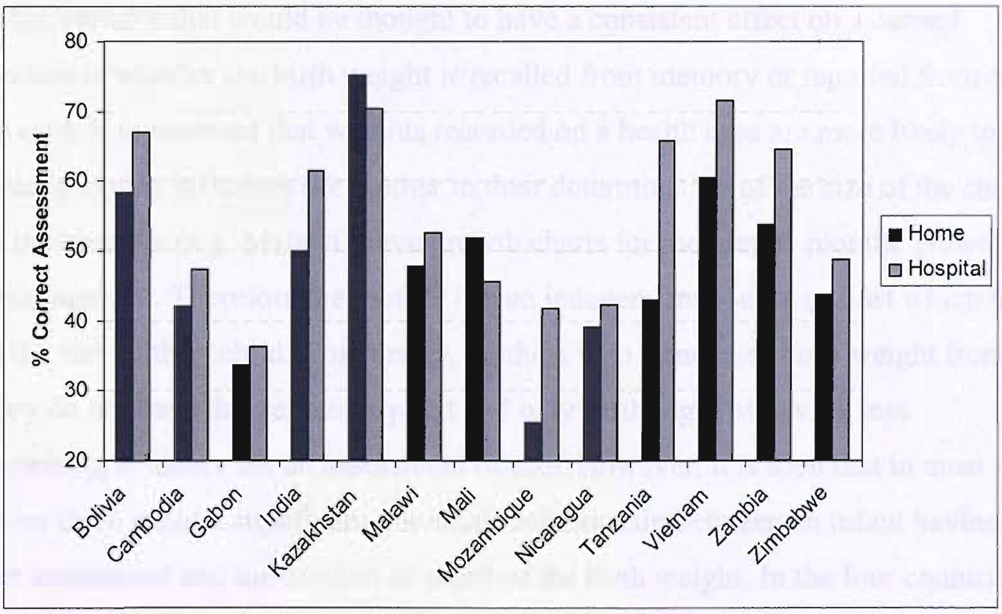


Figure 6.3: Bar chart of percentage correct size assessment by place of delivery



The univariate relationships analysed suggest that there are different variables related to a correct assessment of size in each of the countries. Figure 6.2 shows the relationship between educational level and a correct assessment for seven of the countries in the analysis. In general, the ability to assess a child's size correctly increases with greater education. In 9 of the 12 countries under analysis (Kazakhstan is excluded from the analysis of educational level as secondary level schooling was almost universal for mothers) the percentage of infants born to mothers with a secondary or higher schooling who had a correct size assessment is greater than the percentage of infants born to mothers with no schooling with a correct assessment. In five of the countries there are significant differences in the percentage of infants with a correct size assessment by educational level. Indeed, in some countries the difference between these two groups is large; Vietnam has a great disparity between the highest educated and the least educated (Figure 6.2). In Cambodia there is actually greater accuracy shown by mothers without any education compared with their more educated counterparts, although the differences between the different educational levels are not significant at the 5% level. Place of delivery (Figure 6.3) shows the most consistent trend across all the countries in the analysis, with births in an institution being more accurately judged than those born at home for 11 of the 13 countries. Kazakhstan and Mali do not conform to this, with greater accuracy for infants born at home than those born in a hospital, but the difference is not significant in these countries.

A further variable that would be thought to have a consistent effect on a correct assessment is whether the birth weight is recalled from memory or reported from a health card. It is assumed that weights recorded on a health card are more likely to be accurate, and may influence the mother in their determination of the size of the child. Some health cards (e.g. Malawi) have growth charts for mothers to plot the growth of the child against[2]. Therefore the mother has an independent source against which to judge the size of their child. Conversely, mothers who remember birth weight from memory do not have this reference point and may be thought of having less corroborating evidence for an assessment of size. However, it is seen that in most countries there is not a significant univariate relationship between an infant having a correct assessment and the method of recall of the birth weight. In the four countries where there is significant association, two have higher correctness for card recall and two for memory recall. This lack of uniformity over all the countries may be due to

[2] Personal communication with Nyovani Madise

the order by which the questions in the survey were asked – the question related to size perception was asked before the question relating to birth weight, and thus the mother had to decide on the size assessment before referring to the health card or considering the birth weight from their memory.

6.3. Multivariate Analyses of the Determinants of a Correct Size Assessment

The univariate analyses performed above indicate that there is no discernable trend over all countries in this study regarding the determinants of a correct assessment of the size of a child by a mother. Multivariate analyses will further indicate if there are any trends across all countries regarding the determinants of 'correctness'. To do this, multivariate logistic regression was conducted. Variables used in the model include maternal and paternal education, marital status, place of residence (urban/rural), place of delivery, gender, age of the mother, religion, parity and survival status of the child, although in some countries not all of the variables were collected. These were all entered into the model without selection, which results in a number of variables in the final model which are not significantly related to a correct assessment of size. This was done in order to allow comparison between different countries. The reference categories for each variable in the model were set to be the same in each country, also to aid comparison. The results for selected variables are shown in Table 6.4, with the odds ratios of being correct presented for each category in the analysis. Significance of the parameters was tested using the Wald statistic (see Section 3.4.1. for more details).

Table 6.4: Odds ratios for a correct assessment of the size of a child at birth

		Bolivia	Cambodia	Gabon	India	Kazakhstan	Malawi	Mali	Mozambique	Nicaragua	Tanzania	Vietnam	Zambia	Zimbabwe
Gender	Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female	1.04	1.11	**1.29****	0.98	1.06	1.01	1.13	**1.52***	1.07	1.02	0.95	**1.21***	**1.31****
Survival Status	Alive	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Died	0.90	1.26	0.86	0.79	0.88	1.12	1.45	1.59	1.20	1.11	2.85	1.17	1.01
Residence	Urban	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Rural	1.10	1.34	**0.82***	0.95	1.07	1.02	0.94	**1.61****	1.10	1.19	1.17	**0.79***	0.85
Place of Delivery	Hospital	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Home	**0.72****	**0.62****	0.89	**0.65*****	1.26	0.84	1.32	**0.53***	0.89	**0.53****	0.80	**0.67***	0.86
Mother's Age	15-19	0.97	0.79	1.18	1.02	1.11	0.81	1.42	0.71	0.89	0.72	0.51	0.93	1.13
	20-29	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	30-39	**1.24***	0.95	0.95	0.94	0.89	0.92	1.19	**1.80***	0.99	1.33	1.22	1.02	1.06
	40-49	0.94	1.74	0.80	0.76	1.06	**0.59****	0.94	1.06	1.29	1.13	0.90	0.97	1.02
Birth Order	First Birth	0.90	0.98	1.22	0.94	0.78	1.04	0.85	1.51	0.99	0.89	**1.43***	0.86	1.23
	2nd-3rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	4th-5th	1.07	0.78	0.92	0.98	1.21	1.00	1.01	1.05	0.90	1.11	**0.43****	1.01	**1.46***
	6th or more	0.91	1.00	1.06	0.81	0.67	1.32	0.92	0.65	1.10	0.78	0.71	1.07	1.06
Recall Method	Memory	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Card	0.96	0.81	**0.74*****	0.96	1.13	**1.20***	**0.71****	0.81	0.85	0.95	1.24	**1.35****	0.94
Educational Level	No Education	0.85	1.22	1.34	0.92		1.02	1.02	0.53	0.79	1.01	0.49	1.14	0.97
	Primary	0.89	0.76	**0.73****	0.93	N/A	1.06	0.95	0.72	0.85	0.78	0.91	1.04	0.85
	Secondary +	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Marital Status	Never Married	1.54	-	0.85	-	**0.01*****	1.22	1.21	0.90	1.14	1.47	-	0.64	0.91
	Currently Married	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Formerly Married	0.91	1.22	0.98	0.87	**1.87***	1.00	0.87	0.87	1.01	0.83	0.58	1.02	0.81
Partner's Educational Level	No Education	0.82	1.12	0.66	0.91	1.18	0.84	0.98	0.72	0.87		**0.30****	**0.57***	0.94
	Primary	0.83	**1.57***	1.00	0.99	-	0.90	0.81	0.81	0.85	N/A	1.16	0.89	1.05
	Secondary +	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00
	Missing	0.54	1.08	0.91	1.34	-	1.00	0.70	1.40	0.65		-	1.59	1.30

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01

The logistic regression results confirm the results from the bivariate analysis that the determinants of a correct assessment are not consistent between countries, even after controlling for other factors. Also noticeable is the fact that very few variables are actually related to a correct assessment. The one factor that is most consistently related to a correct response in most countries is the place of delivery, which is significant in six countries. The logistic models for these countries estimate that infants born in a hospital are more likely to be assessed correctly by their mother.

Gender of the infant is significant for four of the countries (Gabon, Mozambique, Zambia and Zimbabwe). In these countries females have higher odds than males of being assessed as a size which is consistent with their actual birth weight. In the nine other countries that do not show a significant relationship the odds ratios for females are close to unity and are not approaching significance. The educational level of the mother is not significant except in Gabon. This indicates that although there are trends seen in some countries between educational level and a correct assessment of size when the univariate relationship is analysed (see Figure 6.2) these trends are mediated by other factors in the models. Another potential explanatory variable which may be hypothesised to influence a mother's perception of size but is seen not to be related to an accurate assessment is the survival status of the infant. In some countries there are large odds ratios for the survival status, with those who have died having higher odds of a size assessment which is correct in Mali, Mozambique and Vietnam. However, the odds ratios for these countries have a large standard error and hence are not significant at the 5% level.

The fact that few variables are related to a correct size perception and the lack of consistency over the countries may be due to a number of reasons. Firstly, the estimates may be correct and there is homogeneity between groups regarding correct assessments, leading to few significant responses. Secondly, the classification of birth weight into five categories using standard deviations from the mean birth weight may be criticised, but other categorisations using alternative methods did not alter these results greatly (results not shown). A final reason is because the simple dichotomy of correct versus incorrect may hide interesting relationships within the data. This is studied in detail in the next section.

6.4. How are Infants Misclassified?

When a mother decides on the size of their child at the time of birth there are three outcomes which may occur. The size can either be underestimated, overestimated or correct (however correctness is determined). It is noted above that the determinants of a correct assessment of size versus an incorrect assessment are not regular across countries, and there are few significant variables related to an incorrect assessment. Heterogeneity in the characteristics of infants who are incorrectly assessed by their mothers may be due to only having one group of incorrectly assessed infants. By splitting up the incorrect group into those who were classified as smaller than their weight dictates and those who were classified as larger may clarify some of the relationships within the dataset.

Further differences in correctness may be observed in different areas of each country. The hierarchical nature of the DHS, with children born to mothers grouped in households, sampled within clusters which are located in regions, allows the investigation of differences between and similarities within these different areas. If there are significant variations between these different levels regarding the correct assessment of size for an infant this may indicate that mothers refer to other infants in the near vicinity to judge the size of their child. For instance, if a sampling cluster is seen to be more likely to overestimate the size of their child it may be that the actual average size (however measured) in that cluster is smaller than the national average. If, compared with the national average, an infant should be classified as small, but in comparison with those around them in the local area they are actually of average size and are classified as such by their mothers, then their size will be classified as an overestimate.

To analyse the determinants of these different assessments multilevel multinomial logistic regression was used. For a full explanation of this technique please refer to section 3.4.3. Multinomial regression was chosen for this analysis since there are three categories (correct, under- and over-estimated assessments) which are not numerically ordered. Infants who were correctly classified by their mothers were treated as the baseline group, and the results from the model give the odds of being in either the under- or over- estimated group compared with the correct group. The multilevel analysis was conducted to gauge if there are any household, cluster or regional effects. The same potential explanatory variables were chosen to be tested as in the simple logistic regression modelling procedure conducted in the previous section of this chapter. Forward selection was used to select the significant variables in the model, with variables being kept in the model if significant at the 5% level.

In order to investigate the determinants of a correct assessment in greater depth using the above method only three countries were used: Cambodia, Kazakhstan and Malawi. These were chosen due to the different characteristics in each of these countries regarding birth weight and mother's perception. Firstly, each country has a different proportion of missing birth weight. In Cambodia this proportion was very high, with 84.1% of the birth weight missing, while in Kazakhstan on 2.9% of the birth weight were not collected in the survey. In Malawi, just over half (55.9%) of the infants did not have a reported birth weight. Furthermore, in Kazakhstan a large proportion of infants had their size assessed correctly, while in Malawi and Cambodia the proportion correct was lower.

6.4.1. Exploratory Analysis of the Misclassification of an Infant's Size

Before considering the results of the multilevel multinomial logistic models for the three countries some basic statistics and relationships will be displayed in this section. Table 6.5 displays the number and percentage of infants in each of the three categories assessing correctness.

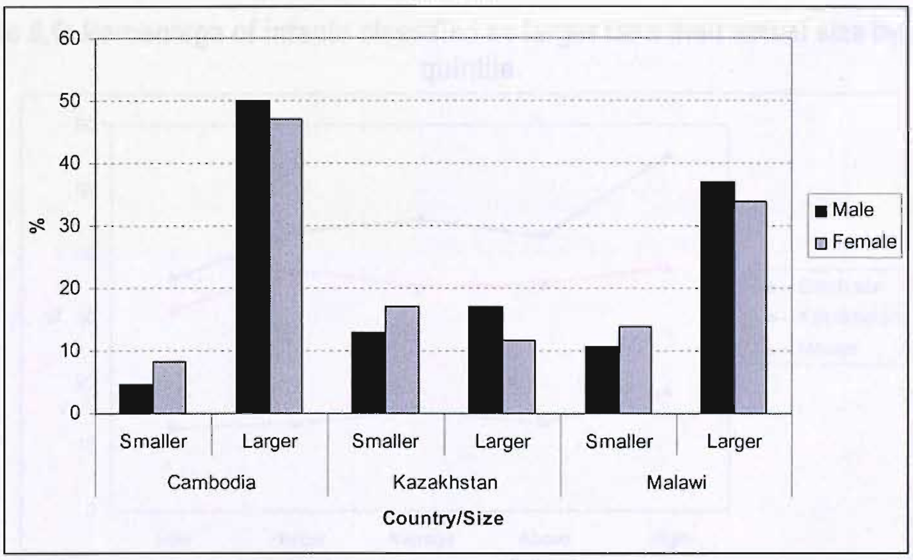
Table 6.5: Count and percentage of infants in different size assessment categories for Cambodia, Kazakhstan and Malawi

	Cambodia		Kazakhstan		Malawi	
Size Assessment	**Count**	**%**	**Count**	**%**	**Count**	**%**
Smaller than Actual Size	74	*6.4*	193	*15.1*	640	*12.2*
Correct	526	*45.1*	902	*70.5*	2732	*52.3*
Larger than Actual Size	567	*48.5*	185	*14.4*	1854	*35.5*
Total	1167	*100.0*	1270	*100.0*	5226	*100.0*

In both Cambodia and Malawi many more infants were incorrectly assessed as being larger than their actual weight suggests. In Cambodia this differential is fairly extreme, with only 6.4% of infants having their size underestimated, while nearly half of the infants were classified into a size category larger than expected. Kazakhstan displays completely different results, with roughly the same proportion of infants classified as being larger and being smaller than their birth weight suggests.

The relationship between a correct assessment and gender indicates that there are differences in assessments by gender. Figure 6.4 shows a bar chart of the proportion of infants being classified as larger or smaller than their birth weight implies. It can be seen that in each country a higher proportion of females are classified as being smaller than their actual size, while a higher proportion of males are classified as being larger than their actual size.

Figure 6.4: Percentage of infants classified as larger or smaller than their actual size by gender



Wealth is also seen to have a strong relationship with the assessment of an infant in size categories. Infants who are born into poorer households are more likely to be classified into a smaller size group than infants born to richer households. Infants who are placed into a larger category than their birth weight suggests are more likely to be in a richer household than a poorer one. This can be seen in Figures 6.5 and 6.6. Figure 6.5 displays the relationship between a smaller size classification and wealth quintile, while Figure 6.6 shows the same relationship but for those infants who have a larger size classification.

Figure 6.5: Percentage of infants classified as smaller than their actual size by wealth quintile

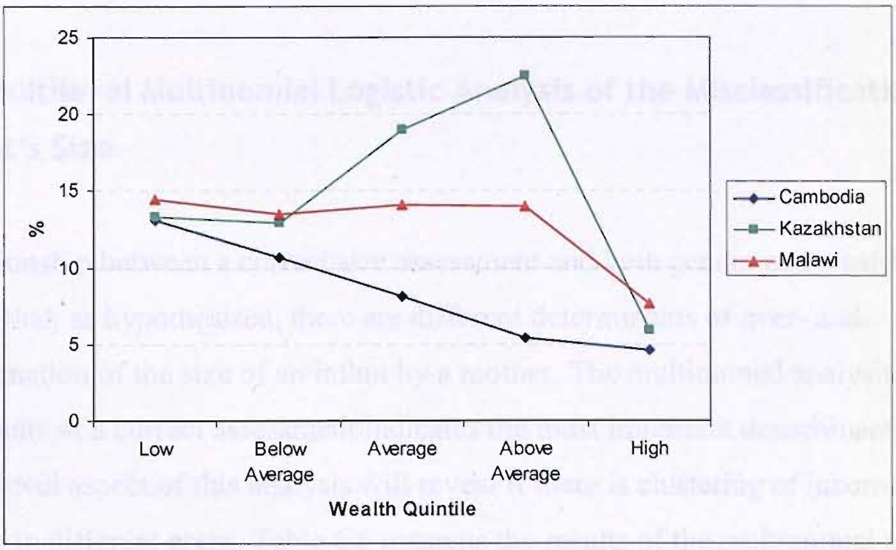
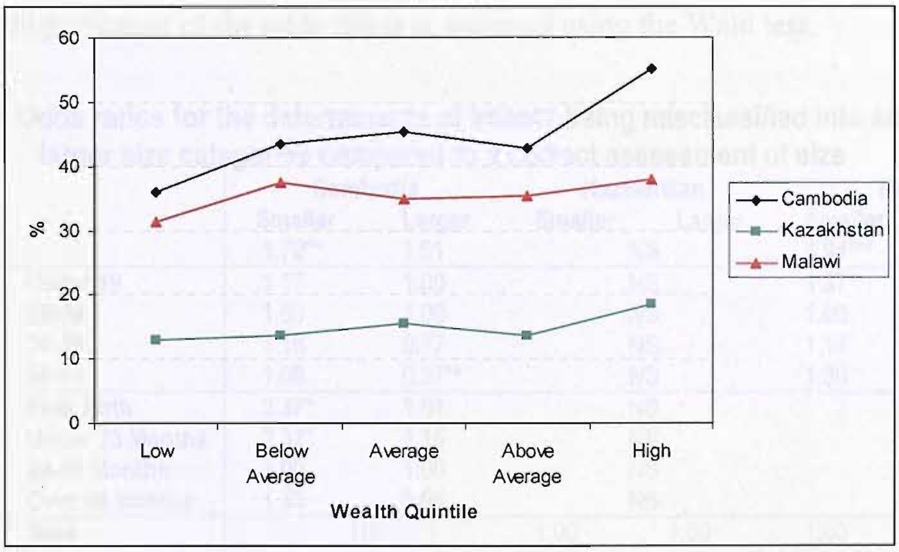


Figure 6.6: Percentage of infants classified as larger than their actual size by wealth quintile



In all three countries the wealthiest quintile has the lowest proportion of infants misclassified as being smaller than their birth weight indicates. Furthermore, this same wealth quintile group has the highest proportion of infants who are classified as being larger than their birth weight. However, for those who were classified as being smaller the three countries do not show a consistent relationship. In Cambodia there is a gradual reduction in the proportion of infants with an underestimate of size as wealth increases, while in Malawi the proportion remains very similar except for the wealthiest. Kazakhstan actually displays an increase in the proportion of infants whose size was underestimated in the average and above average wealth groups, before a dramatic decrease in the highest wealth household group.

6.4.2. Multilevel Multinomial Logistic Analysis of the Misclassification of an Infant's Size

The relationship between a correct size assessment and both gender and wealth indicates that, as hypothesised, there are different determinants of over- and underestimation of the size of an infant by a mother. The multinomial analysis of the determinants of a correct assessment indicates the most important determinants, and the multilevel aspect of this analysis will reveal if there is clustering of incorrect responses in different areas. Table 6.6 presents the results of the multinomial analysis for Cambodia, Kazakhstan and Malawi. Odds ratios are shown, comparing the odds of an infant being placed in either a smaller or larger size category than the correct size category. Significance of the odds ratios is assessed using the Wald test.

Table 6.6: Odds ratios for the determinants of infants being misclassified into smaller or larger size categories compared to a correct assessment of size

		Cambodia		Kazakhstan		Malawi	
		Smaller	Larger	Smaller	Larger	Smaller	Larger
Birth Weight		1.72**	1.01	NS		1.94***	0.79***
Maternal Age	Under 19	1.17	1.00	NS		1.37**	1.02
	20-29	1.00	1.00	NS		1.00	1.00
	30-39	1.16	0.77	NS		1.14	1.06
	40-49	1.05	0.37**	NS		1.30	1.39*
Birth Interval	First Birth	2.37*	1.01	NS		NS	
	Under 23 Months	2.37*	1.15	NS		NS	
	24-48 Months	1.00	1.00	NS		NS	
	Over 48 Months	1.40	0.95	NS		NS	
Gender	Male	NS		1.00	1.00	1.00	1.00
	Female	NS		1.47*	0.78	1.34***	0.92
Wealth Quintile	Lowest	NS		1.79	0.68	1.22	1.02
	Below Average	NS		1.98*	0.68	1.52**	1.22*
	Average	NS		3.49***	1.09	1.38*	1.24*
	Above Average	NS		2.97***	0.84	1.41*	1.09
	Highest	NS		1.00	1.00	1.00	1.00
Residence	Urban	NS		NS		1.00	1.00
	Rural	NS		NS		1.39*	1.06
Weight Recall Method	Card	NS		NS		1.00	1.00
	Memory	NS		NS		1.37**	1.01
Number of Younger Siblings		NS		NS		1.25**	0.99

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01; NS = Not Significant

None of the explanatory variables are related to the misclassification of size across all three countries, indicating that there is variation between countries in the determinants of a correct classification of size. Also noticeable is that for most explanatory variables that are significantly related to the correct size classification the variables are related to either a larger or a smaller classification of size, and not to both. This implies that simply analysing the determinants of a correct assessment against an incorrect assessment will not provide a full picture of the determinants.

Reported birth weight is seen to be significantly related to correctness in both Cambodia and Malawi. As birth weight increases the odds of a smaller assessment of size increase in both countries, while the odds of a larger assessment decrease in Malawi. These results are not surprising and make substantive sense. As birth weight increases there are a larger number of categories which, if selected, would result in the infant being assessed as being in a smaller size category, and vice versa. Therefore the surprising element is not that birth weight is related to correctness in these two countries but that it is not related to correctness in Kazakhstan. This may be due to the higher level of correct assessments in this country, but the lack of a significant relationship indicates that mothers are equally as accurate in making their assessments for all birth weights.

Maternal age is also significantly related to a correct perception in Cambodia and Malawi. In Cambodia the oldest mothers have lower odds of classifying a child as being larger than the correct size compared to mothers aged 20-29. Conversely, in Malawi the oldest mothers have higher odds. Also in Malawi mothers who were aged less than 20 at the time of the birth are more likely to classify their child as being smaller than the correct size than the actual correct size, compared with mothers in the reference category of 20-29 years. The results from Cambodia also indicate that first births and infants born after a short birth interval are more likely to have an incorrect classification on the smaller side rather than a correct classification when compared with infants born between 24 and 48 months from the previous birth.

In both Kazakhstan and Malawi females are estimated to be more likely to be classified as smaller than their birth weight suggests than their male counterparts. However, there are no differences between the sexes in the odds of being classified as larger, although this result was indicated by the univariate analyses (see Figure 6.4). In these two countries the wealth quintile was also estimated to be related to a correct assessment, with higher odds of being incorrect by stating a smaller evaluation of an infant's size for all wealth quintiles (except for the very poorest) compared to the wealthiest. In Malawi there are raised odds for both larger and smaller judgements of size in the below average and average wealth quintiles. This indicates that infants in these groups are more likely to have an incorrect perception of size than a correct perception, irrespective of whether the perception is larger or smaller than the corresponding birth weight.

A number of other variables are also related to a correct assessment of size in Malawi. A rural place of residence, the birth weight recalled from memory and the number of younger siblings were all associated with an increase in the odds of the mother assessing the child as smaller than the correct size. As the number of younger siblings of an infant increases the index infant has higher odds of being classified into a smaller category when compared with those without any younger siblings.
The multilevel multinomial models for each country also indicate that there is significant variation between clusters and districts in Cambodia and Malawi. The variation observed at each of the levels for both larger and smaller assessments in each country are displayed in Table 6.7. Covariance between the variance estimates at each of these levels was calculated but was observed not to be significant, and thus is not presented here. The model residuals are presented in Box 6.1.

Table 6.7: Variance at the household, cluster and district levels for multilevel multinomial logistic regression studying correct assessment of size

		Household	Cluster	District
Cambodia	Smaller	-	0.443 (0.310)	0.074 (0.109)
	Larger	-	0.221 (0.100)*	0.129 (0.077)*
Kazakhstan	Smaller	-	-	-
	Larger	-	-	-
Malawi	Smaller	-	0.002 (0.059)	0.126 (0.048)**
	Larger	-	0.086 (0.034)**	0.193 (0.056)***

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01

Apart from significant variation for a smaller assessment of size at the district level in Malawi, significant variation is only seen at the different levels for a larger assessment of size. In Cambodia and Malawi this variation is at the cluster and district levels, while for Kazakhstan it is estimated that there was no variation at any level. This implies that some clusters and districts significantly differ in the odds of a mother classifying their infant into a larger size category in Cambodia and Malawi. This result indicates that mothers in some clusters and districts are more likely to incorrectly assess their child as being larger than the birth weight would imply than in other clusters or districts. This may be due to cultural variations in different areas of the country. Some groups of mothers may feel that it is more culturally desirable to state that their infant was large than other mothers. Therefore the significant variation for the larger variation in some areas would be observed.

Alternatively the results may indicate that mothers use as a reference those infants in the near vicinity to assess the size of their own child. For example, take an infant who weighs the mean birth weight for the local area. This infant is likely to be classified as being of average size if those in the local area are used as the reference by the mother. If the mean area birth weight is lighter than the national mean birth weight then it could be that the infant should actually have been classified as being smaller than average when compared to the infants in the whole country. Therefore the infant, in this analysis, will be incorrectly classified into a larger size category. The regional and cluster variation observed may be as a result of this. In Malawi, the significant variation at the district level for a smaller classification may also be due to the converse process, with a specific district having a heavy mean birth weight.

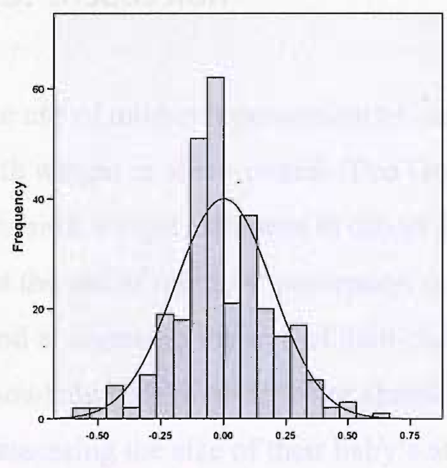
In summary, the analysis of assessments of size compared with birth weight indicates that certain groups are more likely to overestimate or underestimate the size of their infant. Simple analyses of a correct versus an incorrect response do not allow the full appreciation of the determinants of an incorrect assessment. Significant variation is observed in Malawi and Cambodia in the odds of a correct assessment at the cluster and regional levels, indicating that mothers in some areas consistently overstate the size of their infants.

Box 6.1

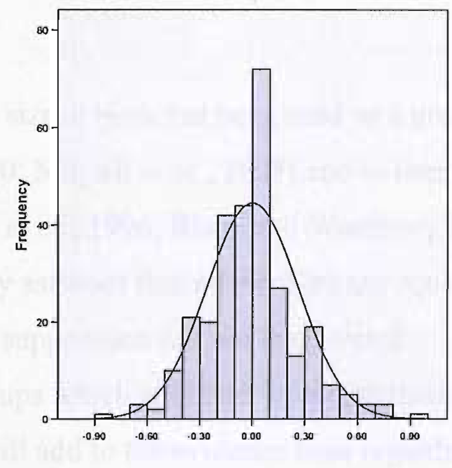
The residuals from the Cambodian and Malawian multilevel models were calculated to assess normality and constant variability of residuals at the cluster and district levels in the model. This was not assessed in Kazakhstan as no levels were significant in the model, and hence only a single level model was estimated. For a single level logistic model no distributional assumptions are made and thus the residuals do not need to be assessed. The results for the analysis of the residuals at the cluster level for Cambodia are shown here. The results for the district level in Cambodia and for Malawi are shown in Appendix G.

At each level there are two sets of residuals: one for the larger assessments and one for the smaller assessments. To assess normality a histogram of the residuals was plotted, along with a P-P plot. A normally distributed histogram and residuals which lie along the diagonal line on the P-P plot indicate normality.

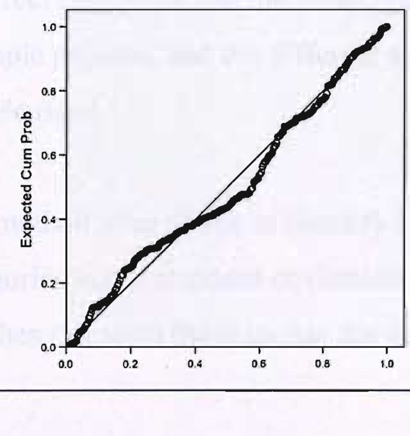
Histogram of Cluster Level Residuals
(Larger Assessment of Size)



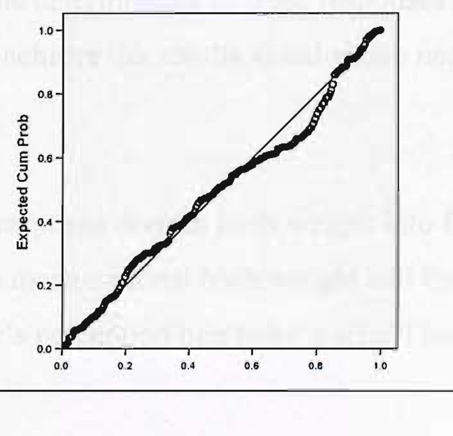
Histogram of Cluster Level Residuals
(Smaller Assessment of Size)



Normal P-P Plot of Cluster Level Residuals
(Larger Assessment of Size)

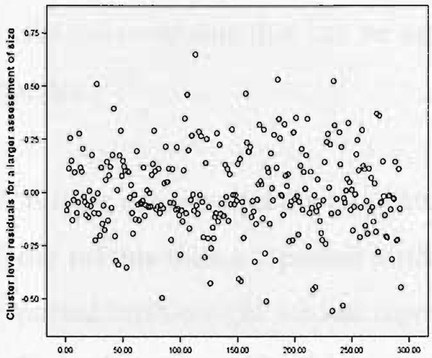


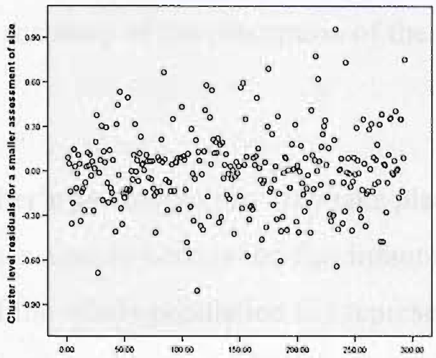
Normal P-P Plot of Cluster Level Residuals
(Smaller Assessment of Size)



Box 6.1 (continued)

Although not perfectly normal, the above graphs do indicate that the residuals are basically normally distributed and are acceptable to satisfy the assumptions. To assess constant variance scatterplots were produced of the residuals against the cluster level identifier. These plots do not show any discernable pattern. It is therefore accepted that the assumptions of the multilevel model hold.





6.5. Discussion

The use of mother's perception of her baby's size at birth has been used as a proxy for birth weight in some studies (Das Gupta, 1990; Magadi *et al.*, 2007) and to improve low birth weight estimates in others (Boerma *et al.*, 1996; Blanc and Wardlaw, 2005). Yet the use of mothers' perception in this way assumes that all mothers are equally good at assessing the size of their child. This supposition has not been tested. Knowledge of the presence or absence of groups which are better or worse than others at assessing the size of their baby's at birth will add to the evidence base regarding the utility of the mother's perception variable. However, the identification of correct or incorrect responses and the investigation of the determinants of these responses is not a simple process, and the different aspects to achieve the results noted above need to be discussed.

The method used above to identify a correct response divides birth weight into five categories using standard deviations from the mean national birth weight and then matches this with the response for the mother's perception of a baby's size. This assumes that birth weight is the only determinant of size, where in fact there are probably many other considerations. This will be discussed in greater detail in the next chapter. Yet the results obtained in this investigation need to be considered with respect to this: size is not equal to weight. There will be some mother's who classify their infants into an incorrect size category when compared with the birth weight yet they may have been correct if other aspects of the child, such as length, were taken into account. However, birth weight is the only variable which was recorded in the survey which can be hypothesised to be related to size at birth. Therefore birth weight is the only variable that can be used to assess accuracy of the perception of the mother.

A further issue is that the evaluation of a mother's perception can only take place for those infants with a reported birth weight. It has already been noted that infants with a reported birth weight are not representative of the whole population but represent a select subsection with a higher socio-economic status amongst other characteristics. The mean birth weight which is reported in the survey across the whole country is very likely to be biased upwards compared to the actual mean birth weight in the country. The method to classify whether a mother is correct in her assessment of size uses the mean birth weight for the country. This may result in the evaluation of some mothers' perceptions as being larger than the correct size if they are judging the size of their infant against all infants in the country. Furthermore the scale of the upwards bias in the reported birth weights is not known, especially for countries with a large proportion of missing birth weights. It is assumed that for the same infants the mother's perception is biased upwards by the same amount to allow birth weight to be compared with the assessment of size. The assessment of size also assumes that the reported birth weight is correct. This may obviously be an incorrect assumption and the perception of size may actually be more accurate than the reported birth weight.

A final point of discussion is regarding the scale at which the mother judges her baby to obtain an assessment of the size. Using the national average implies that this decision is done at a national level. However, it is likely that in many developing countries that mothers judge the size of their own child against those in the near vicinity due to a lack of exposure to media and national information systems. Using an average birth weight in the different clusters or districts to assess if a mother is correct may be more accurate in determining which groups of mother's are more accurate at evaluating the size of their child. However, some clusters and districts have very small samples of infants with a reported birth weight, especially in countries such as Cambodia, India and Mali, which only have a small proportion of infants with a reported birth weight. Using only a small sample to calculate the mean birth weight in a cluster or district may provide highly biased results which are not representative of that area. Therefore using these mean birth weights to categorise actual birth weight into five groups may not be reliable.

The hypothesis that mothers judge the size of their infants against other infants in the near vicinity may be supported by the variation that is seen at the different levels in Cambodia and Malawi. The logic behind this has been explained above, but the variation indicates that infants in some areas are more likely to be classified as larger than average than in other areas. This is likely to be due to the national mean birth weight being used in this analysis to assess correctness of the assessments, and thus infants in areas where the mean birth weight is below the national average will be more likely to evaluate the size of their infant as larger than the birth weight implies. A further possibility to explain the variation between different clusters and districts is that there are different customs and cultures in different areas. In some areas it may be that having a large child is more socially desirable than in others, leading to a larger size assessment.

There are large differences between the thirteen countries in this analysis regarding the proportion of mothers who make a correct assessment of the size of their infant. In some countries over 70% of mothers are correct, while in other countries under half are correct. This relates directly to the number of infants who are classified as being of larger than average size. In some countries there is a large proportion of infants in this category. Obviously most of these infants will be classified as having an incorrect size as the majority will have an average weight compared with the national mean. Due to the biased national mean birth weight noted above it may be that these infants are indeed of a larger than average size compared to others in the country, but are just of an average size compared to others with a reported birth weight. Alternatively the large proportion of infants placed in the larger than average size category may be a social construct, with mothers thinking that they should classify their infant into a larger size group. This may be to impress the interviewer, or due to local social desirability for a large child.

Even though the results of the univariate and multivariate analyses of a correct versus incorrect size assessment do not show consistent significance across countries, there is general agreement that those mothers with greater education who delivered in hospital have higher odds of providing a correct judgement of the size of their child. This is not surprising, as there may be greater awareness of the size of babies from a more educated mother, and those who gave birth in a hospital have many chances to compare their child against others. Yet the multivariate analysis is striking due to its inconsistency across countries and variables.

The relationship between method of recall of the birth weight and correctness is extremely interesting due to the different patterns seen in different countries. In some countries mothers who report the birth weight from a card are more accurate while in other it is the mothers reporting the birth weight from memory who are more precise in their perceptions. This again may be related to the way in which size is judged. The information regarding size of the child is requested prior to the birth weight question in the interview. Therefore those who recall the birth weight from memory will already have a picture of their child in their mind, and the two responses may agree, either by the mother changing the birth weight to fit in with the size perception that she has just mentioned, or by the image of the infant being affected by her memory of the birth weight. Those with health cards may report the size from memory, but the actual birth weight report cannot be affected by this perception as the weight is being read off a card. This would explain the result in some countries that mothers who recall birth weight from memory are more accurate. Conversely, mothers using a health card may be more accurate in other countries because the card may have a growth chart, where the mother can plot the progress of their child against country or international norms. This would give a good indication of the size of the child against others, and improve agreement between weight and size.

The simple dichotomy of correct versus incorrect size assessments assumes that the same processes which dictate an incorrect response occur for those classifying their infants as larger than actual size than those classifying their infants as smaller. For

Cambodia, Kazakhstan and Malawi it is seen that different variables are significantly related to over and under estimation of the size. The results are not consistent across the three countries, but some variables imply that social processes are important in the assessment of size. Females are more likely to have their size underestimated than males. This can be hypothesised to be due to mothers consciously downgrading the size of a female child due to male preference and the status of males in the society.

The assessment of a correct response is fraught with difficulty as there is no way of knowing whether an infant has been placed in the correct size category as this is dependent on how birth weight is classified into five groups. The heaping of birth weights will also affect this classification, as some infants who are correctly assessed by their mothers based on the birth weight may be marked as an incorrect assessment due to the *birth weight* being incorrect due to rounding. The results above indicate that there may be some socio-economic dimension to a correct assessment, along with a district and regional factor. However, what is not known are the determinants of mother's perception. To use mothers' perception of size as a proxy requires there to be close agreement between actual birth weight and size assessment, and also that the two variables are actually measuring the same aspect of a child. This will be investigated in the next chapter.

Chapter 6: Key Points

- The percentage of infants who have correct assessments of their size varies widely across countries, ranging from 36% in Gabon to 71% in Vietnam.
- In many countries infants with a correct assessment of size are more likely to be born in a hospital than at home.
- Most incorrect size assessments are due to the mother classifying the infant as larger than the birth weight suggests.
- Females are more likely to be incorrectly classified as smaller than suggested by their reported birth weight than males.
- Certain groups of infants are more likely to have their size overestimated or underestimated, although these groups differ between countries.
- Variation between districts and clusters indicate that in some areas mothers are more likely to overestimate the size of their child than in other areas, possibly due to cultural desirability.

Chapter 7

Determinants of the Perception of an Infant's Size

The use of birth weight which is not fully enumerated in analyses leads to biased results. Due to this some authors have used another variable as a proxy for birth weight which asks the mother to assess her child's size at birth and place it into one of five size categories, ranging from very small to very large. These assessments have improved estimates of LBW (Boerma *et al.*, 1996; Blanc and Wardlaw, 2005) and have also been used in some studies of childhood mortality (Magadi *et al.*, 2001) and teenage pregnancy outcomes (Magadi *et al.*, 2007). The use of this variable has been justified by the finding that the average birth weight in each perception of size category increases as size increases. Furthermore, the previous chapter has indicated a fair agreement between size and birth weight on an individual level. However no in-depth analysis of the determinants of mother's perception of size has been conducted. An analysis of this type will indicate the factors which influence the mother's perception and highlight any regional or community factors which may shape the size classification and indicate if mothers' perception can be used as a proxy for birth weight.

7.1. Conceptual Framework for the Determinants of Mothers' Perception of Size

Mother's perception of the size of her child at the time of the birth can be hypothesised to be related to a number of factors. Birth weight is obviously a large determinant of the size classification, but there are also many other aspects of the baby's size that will lead the mother to finally classify the infant as a certain size. After the question is posed to the mother to classify their child's size the first cognitive step that the mother must take is to decide on which aspect of the child to base the size judgement. Size may be interpreted as the birth weight of the infant, or equally the length or the amount of subcutaneous fat (i.e. did the baby 'look' fat), or a combination of a number of different dimensions which may be related to size.

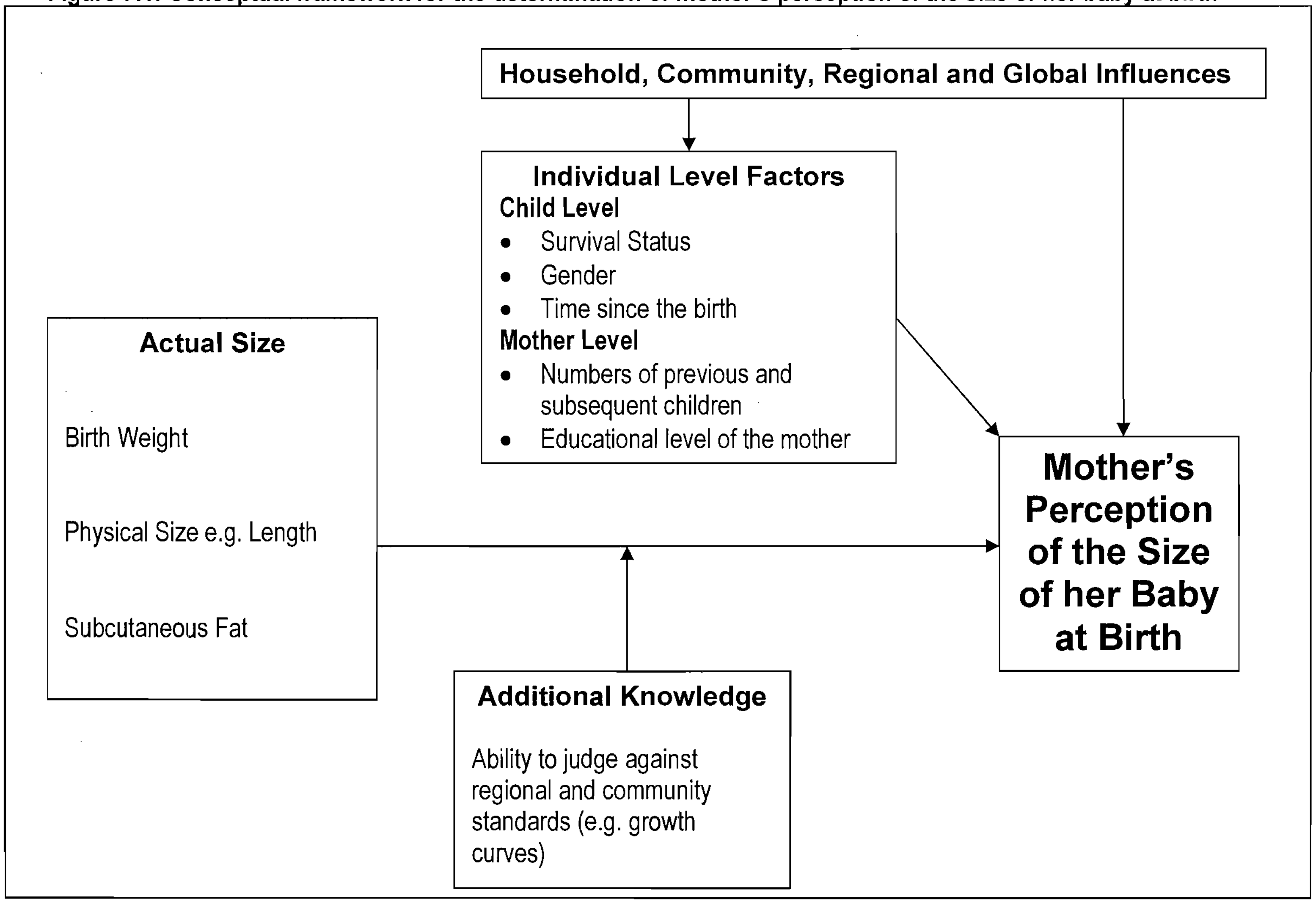
Further thought needs to be given to actual judgement of size against other children. The question asked in the DHS provides the options ranging from very small to very large and includes the size option 'average'. These classification options force the mother to think about what an average baby is. An image of an average baby must be formed in the mind of the mother against which her baby will be compared. The construction in the mother's mind of this average sized baby may be influenced by a number of factors. These may include the number of infants that the mother has come into contact with in her village or region, access to media which may have pictures of babies from different countries and ethnicities and how many children the mother has had previously. Previous and subsequent children are likely to provide good references for the mother to make their judgement. Further influences on the size assessment by the mother can be hypothesised to be gender and survival status. In cultures where the birth of a boy is cause of greater celebration than of a girl, the size perception for males may be much larger than for females. Mothers may inflate the size of boys due to their importance in the society. Infants who have died may be classified as smaller than those who have survived as a coping strategy by the mother. A mother may classify an infant who has died as small to justify their death as being outside of their control.

Figure 7.1 shows a conceptual framework for the determinants of a mother's perception of the size of her baby at birth. This takes into account the potential different aspects of the baby that may be treated as 'size' and also the determinants of the actual evaluation of the size by the mother. From the framework shown it is hypothesised that there are three determinants of perceived size. The first is the actual size. Secondly there are the household, community, regional and global factors which influence the image in the mother's mind of a baby against which their child will be judged. These regional factors also determine, to some extent, other influencing factors such as the survival status and educational status, which in turn again shapes the mother's perception. Other factors that have a direct impact on the perception of the size may include the gender of the child, the number of other infants born before and after and the time since the birth. One other factor that needs to be taken into account is additional knowledge. In some countries (e.g. Malawi), if the child has been weighed at birth and the mother is given a health card with this information on, the card contains a comparison of the infant's birth weight alongside a global standard birth weight. If the mother knows how heavy their child is against a standard population then their size judgement may be heavily affected by this information.

7.2. Methods Used to Assess the Determinants of Mothers' Perception of Size

Figure 7.1 presents a hypothesised framework for the determinants of the perception of size. In order to establish the relative contributions of the different hypothesised determinants, ordinal regression was used, as mother's perception is an ordered variable. To investigate the possible effect of the household, community and region multilevel ordinal regression was conducted. The fixed effect models were initially fitted using Stata Version 9 (StataCorp, 2005), before these were transferred to MLwiN Version 2 (Institute of Education, 2005) so that the random effects could be estimated.

Figure 7.1: Conceptual framework for the determination of mother's perception of the size of her baby at birth



Three DHS countries were selected: Cambodia, Kazakhstan and Malawi (please refer to Chapter 6 for a rationale for the choice of these countries). Each country collected information regarding mothers' perception, and there was minimal missing data for this question. Cambodia had the largest percentage of missing data on this variable, with 1.9% missing (see Box 7.1 for further analysis), whilst Kazakhstan and Malawi both had 0.7% of the mothers' perception data missing.

Box 7.1

Cambodia has a higher level of missing data than Malawi and Kazakhstan. After analysis of the DHS data it was seen that the higher level was due to the influence of three interviewers. The amount of missing data for the perception variable was listed for each interviewer and, before weighting, it was noted that only three interviewers had more than 10 people who did not answer the perception of size variable. Interviewer '43' did not obtain a response for 29 infants, representing 18.4% of all infants they tried to obtain information for, while interviewer '73' did not get a size assessment for 115 infants, 73.7% of those interviewed. The final interviewer, number '166' failed to elicit this information for 59.8% of the infants they were asked to obtain the data about (104 infants). It is possible that these interviewers did not ask the question relating to size at birth to some of their interviewees in order to speed up the questioning process or because they did not see the worth of this question. The effect of this on estimates using mothers' perception of size is thought to be minimal as the missing data is spread randomly in the dataset, and can simply be ignored.

A number of variables were tested for a significant relationship with mothers' perception. Also, contextual variables were used to assess whether the environment around the mothers is important in the decision to classify the infant into size categories. A full list of the variables used in the modelling process is listed in Appendix H. In each country in this analysis the children are clustered at four levels. Each mother may have more than one child, and there may be more than one mother within a household. Houses are grouped within the survey clusters, and each survey cluster is within a province/state/county. In the three countries used here there was insufficient clustering of mothers within households to obtain good estimates for the effect of both of these levels, and therefore this analysis looked at children within households, grouped in clusters and within the different regions.

Figure 7.1 hypothesises that actual size is the most important determinant of a mother's perception of size. But how can actual size be measured? In DHS there is only one variable that is collected that can be used: birth weight. This was used as a proxy for actual size, even though it does not include all the possible dimensions. However, birth weight, as seen, was not reported for all infants. As a result, two sets of models were constructed in order to elucidate the determination of mothers' perception.

The first set of models studying mothers' perception of size restricted the dataset to only those infants with a reported birth weight and size at birth. This was to assess the relationship between actual size (proxied by birth weight) and mothers' perception. Birth weight was entered into the ordinal model alongside other covariates to estimate if any other variables aside from actual size are related to mothers' perception. The second set of models used the full dataset, including those without a reported birth weight. The same covariates were used as for the first set of models, but an indicator for whether birth weight was reported in the survey was included in the model instead of birth weight itself. Also tested was the interaction between this indicator for a reported birth weight and the other explanatory variables in the model to assess if there are different relationships between the explanatory variables and mothers' perception for those with and without a reported birth weight.

It is hoped that as a result of these two sets of models a better understanding of the influence of different explanatory variables on the determination of a baby's size will be obtained. The first model will inform if there are any other determinants of mothers' perception aside from birth weight, while the second will establish the determinants of perception for all infants and if there are different relationships between the determinants for those with and without birth weights. Household, community and regional effects will be assessed in both sets of models by the random variation in the multilevel model. The influence of additional knowledge, such as knowledge of the comparison of their own child with a standard child (i.e. on a growth chart) is harder to assess in this study, and conclusions about this aspect of the conceptual model will not be made from this study.

Forward selection was used to construct each model, with variables being included in the model if it was seen to be significant at the 5% level. The models were tested to assess if random intercepts and slopes would improve the fit of the model, and contextual variables were also tested for significance. The results of the models were interpreted on a probability scale, assessing the changes to the probability of being in each of the five perception groups as an explanatory variable changes. Residuals were checked at the different levels in the model which showed significant variation. Estimation of the parameters was initially conducted using IGLS estimation. After the final model was obtained the estimation method was changed to RIGLS in order to acquire the final parameter estimates.

7.3. Exploratory Analysis of the Determinants of Mothers' Perception of Size

The distribution of mothers' perception has been investigated in Chapter 5, and Table 7.1 reproduces for clarity the proportions of each respondent in each of the perception categories for the three countries in this analysis, Cambodia, Kazakhstan and Malawi. It is clear that there are very similar proportions of infants in the very small and smaller than average categories across the countries, and the average sized group contains the highest proportion of infants. Kazakhstan has the highest proportion of infants classified as average size, while Cambodia has a sizeable proportion of infants in the larger than average category, and a small percentage in the very large category, compared with the other two countries.

The mean birth weights in each of the perception categories were shown in Table 5.3, and reproduced here for the three countries in question in Table 7.2. The samples used in this analysis obviously only include those who have a reported birth weight and a reported perception of size. The mean birth weights follow the expected patterns, with those in the smallest perception group having the lowest average weight, and those in the largest group having, on average, the heaviest. The mean weights in each of the size categories differ between the countries with Cambodia having the lightest mean birth weight in the very smallest category by over 300g, while Kazakhstan has the heaviest mean birth weight in the very largest category by over 200g.

Table 7.1: Distribution of mother's perception of a baby's size by country (%)

	Cambodia	Kazakhstan	Malawi
Very Small	2.8	4.8	3.5
Smaller than Average	10.3	12.9	12.2
Average	54.8	63.7	58.4
Larger than Average	27.5	13.2	16.6
Very Large	2.8	4.7	8.6
(Total)	*100.0*	*100.0*	*100.0*
Count	8643	1317	11432

Table 7.2: Average birth weights (g) by size perception categories by country

	Birth weight (g)		
Size Classification	Cambodia	Kazakhstan	Malawi
Very Small	1968	2333	2411
Smaller than Average	2469	2772	2537
Average	2988	3299	3113
Larger than Average	3481	3895	3544
Very Large	3923	4219	3706
Overall Average Weight	3202	3311	3188

Bivariate relationships between classification of size and different potential explanatory variables indicate that mother's perception is related to other explanatory variables. Table 7.3 displays the percentage of infants classified into the different perception categories by place of birth, either at home or in an institution. It can be seen that there a greater proportion of infants who have been classified as smaller than average or very small were born at home than in a hospital, as expected from previous research into the characteristics of infants born at home. However, it is unknown whether this difference in size classification by place of birth is due to actual differentials in size or is only an artefact, as mothers who give birth in hospitals think that their children should be of a larger size and increase the size classification accordingly. Using a chi-squared test to test for association all countries showed significant association between place of birth and size at the 0.1% significance level (although the result for Kazakhstan needs to be interpreted with caution due to small numbers of infants born at home).

Table 7.3: Percentage of infants in each perception category by place of delivery in Cambodia, Kazakhstan and Malawi

	Cambodia		Kazakhstan		Malawi	
Size Classification	Home/Other	Institution	Home/Other	Institution	Home/Other	Institution
Very Small	3.3	3.1	14.8	4.2	4.8	2.8
Smaller than Average	10.8	8.6	18.5	12.6	13.9	10.1
Average	57.8	45.4	59.3	64.4	58.4	59.1
Larger than Average	25.4	39.5	7.4	13.8	14.6	18.6
Very Large	2.7	3.5	0.0	5.1	8.3	9.4
(Total)	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Count	**7611**	**687**	**27**	**1282**	**4921**	**6429**

Referring to the conceptual framework in Figure 7.1, time since the birth influences the perception of size in a separate way to birth weight, physical size and fat levels. Association between time since birth and size perception will indicate that other factors aside from actual size are important in the size classification. The average time in months since the birth until the interview within each size category for each country is shown in Table 7.4. Cambodia and Malawi both show that as the average length of time since the birth grows the perception of size increases, indicating as time passes mothers' perception gets skewed towards average or larger sizes. A one-way ANOVA conducted on each of the countries separately to assess if there is a significant difference between the average time since birth in each of the size categories shows significant differences in both Cambodia and Malawi (Cambodia $p=0.001$; Malawi $p<0.001$). Conversely, in Kazakhstan the opposite is true, where the length of time falls as size categorisation increases, except for the largest category. This is not significant at the 5% level.

Table 7.4: Average time since birth in months from birth to interview for each perception of size category in Cambodia, Kazakhstan and Malawi

	Months Since Birth		
Size Classification	**Cambodia**	**Kazakhstan**	**Malawi**
Very Small	25.6	32.3	25.4
Smaller than Average	29.7	31.1	27.6
Average	30.1	30.9	27.5
Larger than Average	30.1	29.9	28.8
Very Large	31.4	33.1	29.0
Average Length of Time	29.9	30.9	27.8

7.4. Multilevel Ordinal Regression of the Determinants of Mothers' Perception of Size at Birth

The significant associations between place of delivery and time since birth with mother's perception of size, along with other variables which are significantly related to perception (not shown) indicate that multivariate analyses of the determinants of perception of size are needed. As stated previously two different models were used for each country, the first using all infants including an indicator for a reported birth weight and the second only using those with a reported birth weight and includes birth weight as a potential explanatory factor. The results below give the estimated parameter values with the associated standard errors indicating the chances of being in a smaller size category. Therefore a positive parameter indicates that the category is associated with a decrease in size perception, while a negative parameter indicates an increase in size perception for that category. The results are more easily interpreted on a probability scale, and this is done for selected variables which are seen to be significantly related to size at birth. Comparisons between different categories in the model are easy to consider after conversion to probabilities.

7.4.1. Results for Cambodia

The two models fitted to examine mothers' perception in Cambodia contain very different sample sizes. Using all the infants in the model with a reported perception of size gives a sample size of 8298, while there are only 1167 infants with a reported birth weight and who are included in the second model which utilises birth weight as an explanatory factor. The second model, therefore, has less power than the first, and also the results are only valid for those infants with a reported birth weight. The parameter values from the first model, using all infants, are displayed in Table 7.5 below.

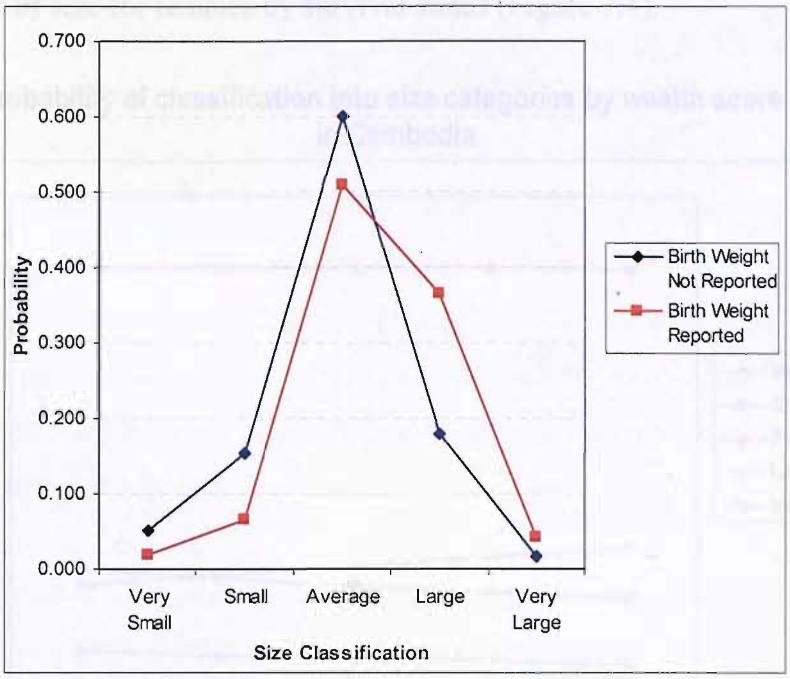
Table 7.5: Multilevel ordinal regression coefficients and standard errors for mother's perception of her baby's size in Cambodia for all infants

	Category	Coefficient (S.E.)	Sig.
Birth Weight	Not Reported	*reference*	
	Reported	-1.046 (0.093)	***
Place of Delivery	Home	*reference*	
	Institution	-0.492 (0.116)	***
Survival Status	Dead	*reference*	
	Alive	-0.570 (0.106)	***
Gender	Male	*reference*	
	Female	-0.189 (0.147)	NS
Survival Status by Gender		0.470 (0.154)	**
Partners Education	Secondary or Further	*reference*	
	None	0.283 (0.079)	***
	Primary	0.118 (0.062)	NS
	Not Applicable	0.023 (0.238)	NS
Birth Order	2-3 Birth	*reference*	
	First Birth	0.132 (0.065)	*
	4-5 Birth	-0.156 (0.062)	*
	6 or Higher Birth	-0.054 (0.064)	NS
Wealth	*(continuous)*	-0.093 (0.042)	*
Time Since Birth	*(continuous)*	-0.003 (0.001)	*

*** $p<0.001$; **$0.01>p>0.001$; * $0.05>p>0.01$; NS= Not Significant

All interactions between the birth weight indicator and the other variables in the model were not significant, indicating that the same relationships between the explanatory variables and mother's perception occur irrespective of whether the birth weight was known by the mother. Yet there is a strong effect of the knowledge of birth weight on size classification. Those infants who have a reported birth weight are likely to be said to be larger than those who do not have a reported birth weight. This can be easily seen from Figure 7.2 which shows the probability of being classified into each size category by whether birth weight was reported in the survey. Infants with a reported birth weight are much less likely to be classified as very small, smaller than average or of average size than those without a reported birth weight, and are far more likely to be assessed by their mother as larger than average or very large.

Figure 7.2: Probability of classification into size categories by reported birth weight for all infants in Cambodia



A strong relationship is also observed between wealth and classification of size. If wealth is treated as a continuous variable (the factor scores used rather than the more traditional wealth quintiles, which categorise these factor scores into five groups) this relationship is highlighted. The probability of being classified into the different size groups have been calculated for a portion of the range of the wealth score and are displayed in Figure 7.3. As the wealth score increases the probability of an infant being classified as very small, smaller than average or average is reduced, while there is a large increase in the probability of a child being classified as larger than average or very large. This is not an unexpected result, as wealthier parents do have heavier infants and, if mother's perception is a good proxy for birth weight, this should be reflected in the size classification, especially as this model does not control for actual birth weight.

The model also estimates an interaction between the gender of the infant and survival status with respect to the classification of the infant into the different size categories. Studying the influence of gender cannot be done without taking into account the survival status of the infant in question, and vice versa. Male infants who are still alive at the time of the survey are more likely to be classified into a larger size category than males who have died prior to the survey. For infants who have survived, females are classified as smaller than males. There is no difference in the classification of size for females by survival status (Figure 7.4).

Figure 7.3: Probability of classification into size categories by wealth score for all infants in Cambodia

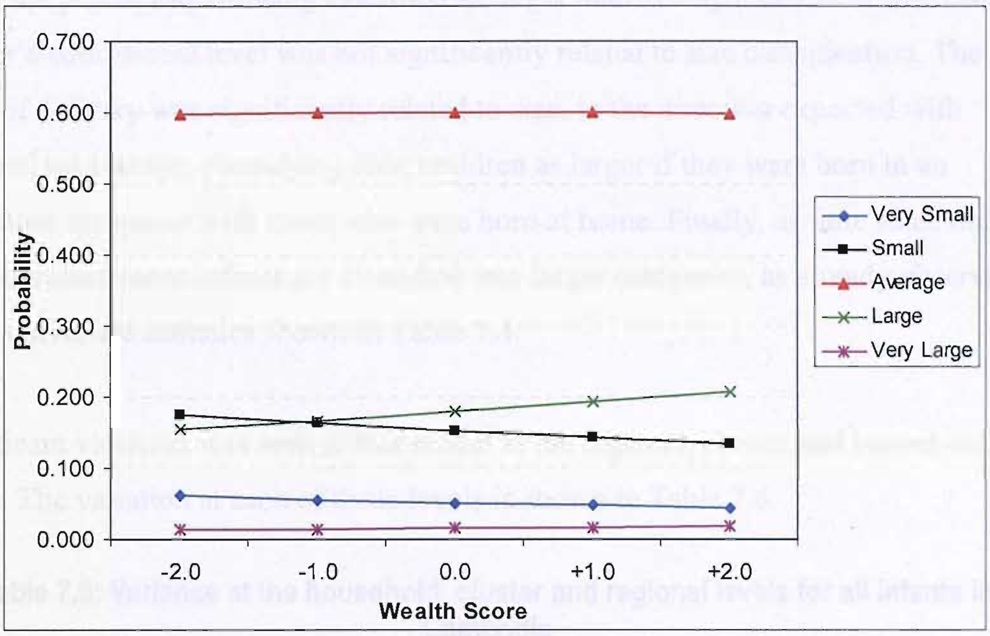
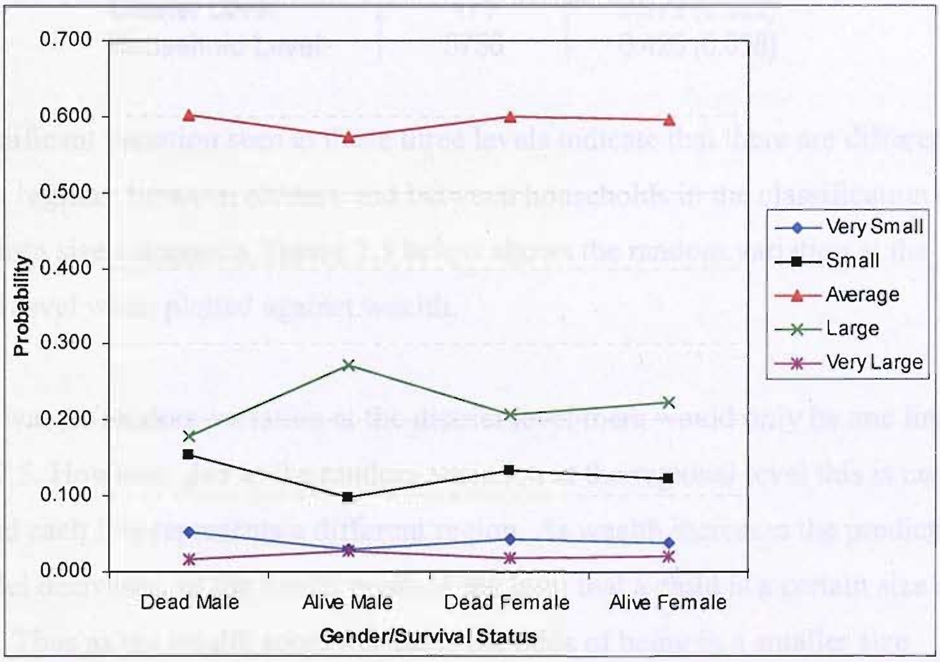


Figure 7.4: Probability of classification into size categories by gender and survival status for all infants in Cambodia



First births are seen to be classified as smaller than infants in the reference category of 2nd or 3rd order births, while 4th/5th order births are significantly larger than those in the reference category, again, as previous research predicts (Spiers and Wang, 1976; Fortney and Higgins, 1984). As education of the mother's partner increases (this may not necessarily be the father of the child but the mother's current partner) the probability that the child is classified as smaller than average or very small decreases, whilst the probability of being classified as larger than average increases. Interestingly mother's educational level was not significantly related to size classification. The place of delivery was significantly related to size, in the direction expected with mothers, on average, classifying their children as larger if they were born in an institution compared with those who were born at home. Finally, as time since the birth increases more infants are classified into larger categories, as already observed in the univariate statistics shown in Table 7.4.

Significant variation was seen in this model at the regional, cluster and household levels. The variation at each of these levels is shown in Table 7.6.

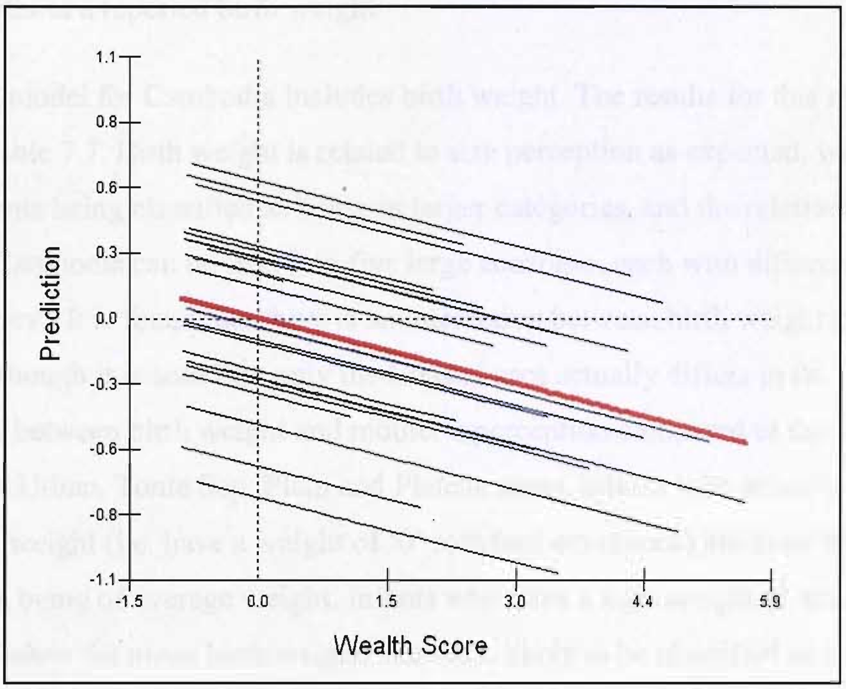
Table 7.6: Variance at the household, cluster and regional levels for all infants in Cambodia

	Count	Variance (S.E.)
Regional Level	24	0.149 (0.051)
Cluster Level	471	0.073 (0.022)
Household Level	5756	0.426 (0.058)

The significant variation seen at these three levels indicate that there are differences between regions, between clusters and between households in the classification of infants into size categories. Figure 7.5 below shows the random variation at the regional level when plotted against wealth.

If there was no random variation at the district level there would only be one line in Figure 7.5. However, due to the random variation at the regional level this is not the case, and each line represents a different region. As wealth increases the prediction of the model decreases, as the model predicts the logit that a child is a certain size or smaller. Thus as the wealth score increases the odds of being in a smaller size category decreases, shown by the lower prediction given by the model. The lower the prediction, the higher are the chances of an infant being in a larger size category. Therefore, the lines at the bottom of Figure 7.5 represent those regions where children are generally classified into larger categories, and the lines at the top are regions where the children are generally said by the mothers to be smaller.

Figure 7.5: Line graph showing the relationship between wealth and predicted score with random variation at the regional level for all infants in Cambodia



N.B. The thick red line is the average relationship between wealth score and predicted score

The random variation seen at the three levels in the model show that mothers within a household, cluster or region are more likely to classify their infants into the same categories as those around them, with differences in classification between the different areas. Different regions, clusters and households will be more alike than others in the size of their child due to genetic variation, similar nutrition and similar environmental conditions. If only the infants in the local area are used as a reference then it would be expected that there will be a similar spread of sizes within each cluster or region. The finding that, on average, some districts do show that the sizes of their infants are smaller than in other districts may be taken as evidence that mothers in those areas know that the sizes of their infants are smaller than the national average. As a result it may be posited that mothers do not use only those infants in the local area to compare the size of their own child against, but also compare the size against infants in the wider community.

In summary the ordinal logistic model for all infants in Cambodia indicates that similar factors which are known to be related to birth weight are also related to mothers' perception of size. The lack of interactions between the explanatory variables and whether birth weight was reported in the survey or not indicates that there are similar relationships between the explanatory variables and size for those with and without a reported birth weight.

The second model for Cambodia includes birth weight. The results for this model are shown in Table 7.7. Birth weight is related to size perception as expected, with heavier infants being classified as being in larger categories, and the relationship is not linear. Cambodia can be split into five large ecozones, each with different characteristics[3]. It is found that there is an interaction between birth weight and ecozone, although it is seen that only the Coastal area actually differs in its relationship between birth weight and mother's perception compared to the other four areas. In the Urban, Tonle Sap, Plain and Plateau areas, infants who actually weigh the average weight (i.e. have a weight of '0' standard deviations) are most likely to be classified as being of average weight. Infants who have a light weight (2 standard deviations below the mean birth weight) are most likely to be classified as small, while heavier infants (2 standard deviations above the mean birth weight) are most likely to be classified as large. This can be seen in Figure 7.6, shown for the Urban area.

As noted, the relationship between birth weight and perception of size differs for the Coastal region. In this instance, apart from the very lightest infants, mothers are most likely to classify their babies as being of average size, irrespective of weight. As birth weight increases the probability of being classified as smaller than average or very small does decrease, and the chances of being classified as larger than average or very large increases, although not to the extent of the increase seen in the other four areas. This is displayed in Figure 7.7. These results may be explained in a number of ways. Firstly, the results may reflect what is actually happening, with infants in the Coastal area being very similar in size. Alternatively, the different areas may have different cultures, with mothers in the Coastal area not being as worried about classifying their infants into larger size categories. Also, interviewers in the Coastal area may not have

[3] Personal communication with L. Montana from ORC Macro

stressed the importance of the size at birth question and may have influenced the mother into stating that her child was of average size.

Table 7.7: Multilevel ordinal regression coefficients and standard errors for mother's perception of her child's size in Cambodia for infants with a reported birth weight

	Category	Coefficient (S.E.)	Sig.
Birth Weight	*(continuous)*	-2.218 (0.178)	***
Birth Weight² (Squared)	*(continuous)*	0.323 (0.087)	***
Birth Weight³ (Cubed)	*(continuous)*	0.082 (0.018)	***
Birth Weight⁴ (Power of 4)	*(continuous)*	-0.017 (0.007)	*
Place of Delivery	Home	*reference*	
	Institution	-0.435 (0.144)	**
Ecozone	Urban	*reference*	
	Tonle Sap	-0.055 (0.276)	NS
	Plain	0.483 (0.308)	NS
	Plateau	0.318 (0.366)	NS
	Coastal	0.476 (0.376)	NS
Ecozone by Birth Weight	Tonle Sap	0.334 (0.182)	NS
	Plain	0.221 (0.167)	NS
	Plateau	-0.279 (0.268)	NS
	Coastal	0.934 (0.238)	***
Difference between Weight and Average Weight in Cluster	-4 to -1.5 S.D.	*reference*	
	-1.5 to -0.5 S.D.	-0.930 (0.513)	NS
	-0.5 to 0.5 S.D.	-1.063 (0.546)	NS
	0.5 to 1.5 S.D.	-1.269 (0.585)	*
	1.5 to 4 S.D.	-1.304 (0.702)	NS

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01; NS= Not Significant

Figure 7.6: Probability of classification into size categories by birth weight in the Urban areas of Cambodia for infants with a recorded birth weight

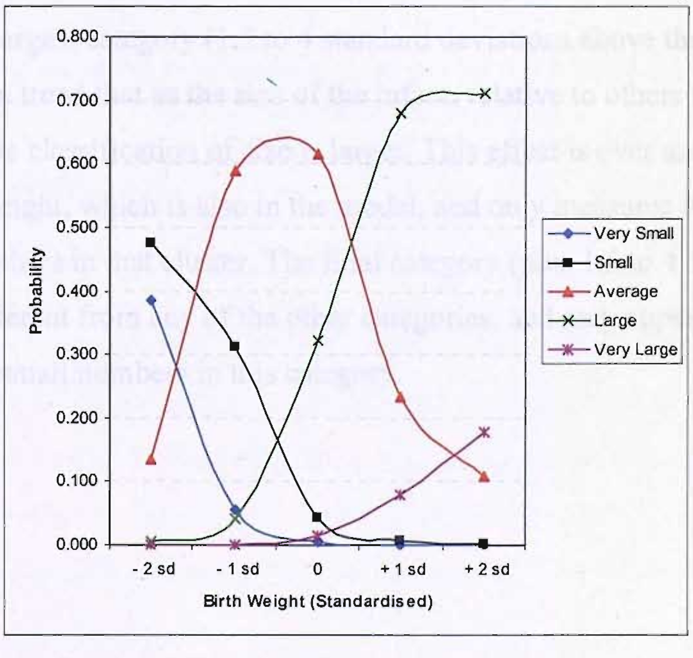
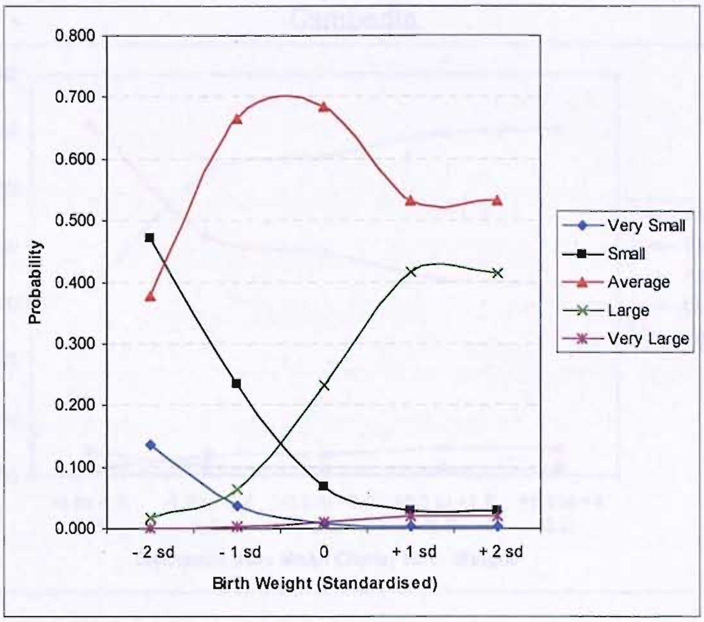
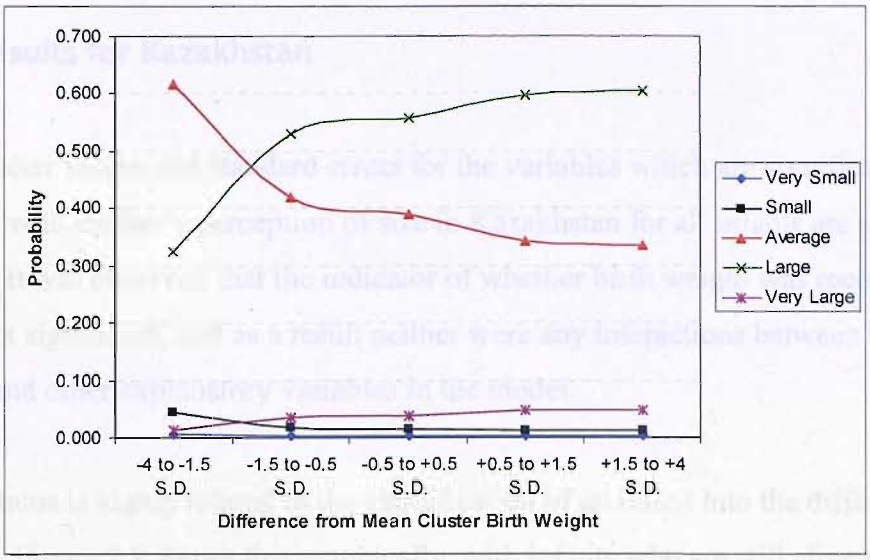


Figure 7.7: Probability of classification into size categories by birth weight in the Coastal area of Cambodia for infants with a recorded birth weight



A further result of note is observed in the difference between the individual's weight and the mean weight for the cluster. The mean z-score for birth weight in each cluster was calculated, and the difference between the weight of each infant within that cluster and the mean weight was calculated. These differences were then classified into five categories: -4 to -1.5 S.D from the mean (the smallest infants relative to the average), -1.5 to -0.5 S.D, -0.5 to +0.5 S.D., +0.5 to +1.5 S.D. and between +1.5 and +4 S.D. from the mean (representing the largest infants relative to the cluster mean). The probabilities of being placed into each size category are shown in Figure 7.8. Aside from the largest category (1.5 to 4 standard deviations above the mean cluster weight) there is a trend that as the size of the infant, relative to others in the cluster, increases, that the classification of size is larger. This effect is over and above the effect of birth weight, which is also in the model, and only measures the relative weight against others in that cluster. The final category (plus 1.5 to 4 S.D.) is not significantly different from any of the other categories, and may appear not to follow the trend due to small numbers in this category.

Figure 7.8: Probability of classification into size categories by difference between actual birth weight and mean cluster birth weight for infants with a recorded birth weight in Cambodia



Significant variation is seen at both the regional and cluster levels, as demonstrated in previous models, although not at the household level. This is probably on account of the small amount of clustering at this level due to the small numbers of infants with a recorded birth weight in the survey. The amount of variation at each of these levels is shown in Table 7.8. The random intercept at the regional and cluster levels indicates that there are significant differences between regions and between clusters in the classifications of size. No significant variation in the gradients of the slopes for the explanatory variables was seen.

Table 7.8: Variance at the household, cluster and regional levels for infants with a reported birth weight in Cambodia

	Count	Variance (S.E.)
Regional Level	23	0.251 (0.124)
Cluster Level	293	0.357 (0.120)
Household Level	964	-

The model for mother's perception of size, which includes birth weight as an explanatory variable, illustrate that the actual size of the infant is a very strong determinant of the mother's decision in the classification of the size. However, it is not the only determinant, and classification also differs by area and where the infant was actually born. Also important is the relative weight of the infant to those around them, with relatively heavier infants being classified as larger than relatively light infants.

7.4.2. Results for Kazakhstan

The parameter values and standard errors for the variables which are significantly associated with mother's perception of size in Kazakhstan for all infants are shown in Table 7.9. It was observed that the indicator of whether birth weight was recorded or not was not significant, and as a result neither were any interactions between this indicator and other explanatory variables in the model.

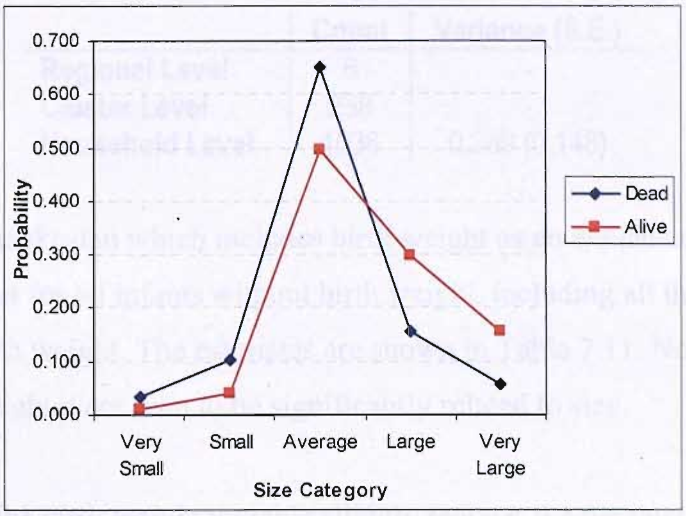
Survival status is highly related to the classification of an infant into the different size categories. Figure 7.9 shows this graphically, with infants who are still alive at the time of the survey having a higher probability of being classified in a larger size category than infants who had died. This may be due to mothers revising their size assessments after a child has died or because smaller infants are more likely to die, and thus mother's perception is reflecting the actual birth weight.

Table 7.9: Multilevel ordinal regression coefficients and standard errors for mother's perception of her child's size in Kazakhstan for all infants

	Category	Coefficient (S.E.)	Signif
Survival Status	Alive	*reference*	
	Dead	1.117 (0.266)	***
Gender	Male	*reference*	
	Female	0.474 (0.118)	***
Place of Delivery	Public Hospital	*reference*	
	Home	0.917 (0.401)	*
Partners Education	Secondary or Further	*reference*	
	None or Primary	-1.852 (0.697)	**
	Missing	0.411 (0.462)	NS
Maternal Age	20-29	*reference*	
	15-19	-0.152 (0.370)	NS
	30-39	-0.276 (0.128)	*
	40-49	0.216 (0.291)	NS

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01; NS= Not Significant

Figure 7.9: Probability of classification into size categories by survival status for all infants in Kazakhstan



Other results from the model show that those born at home are classified as smaller than those who are born in a hospital and females are also classified as smaller than their male counterparts. The education of the mother's current partner (usually the father of the infant) also has an effect, although not in the way that is expected. Infants in families where the mother's partner has little of no education are classified as larger than infants in households where the partner has a high level of education. Mothers aged between 30 and 39 are also more likely to perceive their infants as larger than mother's of other ages.

Random variation at the different levels in the model is shown in Table 7.10. Significant random variation is only seen at the household level, and is not significant at the cluster or regional level. The variation seen at the household level is surprising as there are 1309 infants nested within 1036 households, which is not a high level of clustering and in most households there is only one child. A closer look at the data reveals that out of 238 households where there is more than one infant, 134 classify all their infants as the same size. This indicates similarities within households, and as a result large differences are seen *between* households, which is the result shown in Table 7.10.

Table 7.10: Variance at the household, cluster and regional levels for all infants in Kazakhstan

	Count	Variance (S.E.)
Regional Level	6	-
Cluster Level	238	-
Household Level	1036	0.289 (0.148)

The model for Kazakhstan which includes birth weight as an explanatory variable is very similar to that for all infants without birth weight, including all the same variables plus birth weight. The estimates are shown in Table 7.11. No polynomial terms on birth weight were seen to be significantly related to size.

The inclusion of the birth weight variable slightly reduces the parameter estimates on most of the other explanatory variables in the model, although not by a great amount. Female infants, those who are not alive and were born at home are still estimated as being of a smaller size than males, those who are still alive and were not born at home. The small change in the parameters when birth weight is added to the model suggests that birth weight and the other covariates have independent effects on the perception of size.

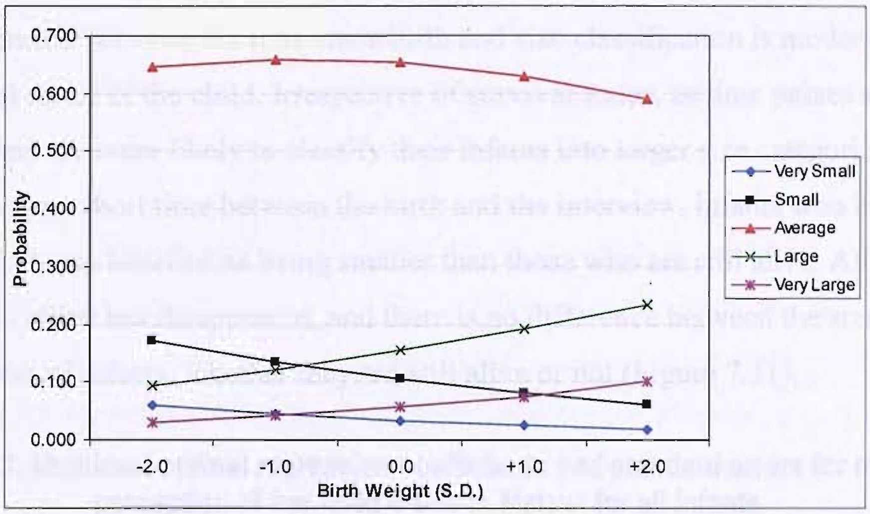
Table 7.11: Multilevel ordinal regression coefficients and standard errors for mother's perception of her child's size in Kazakhstan for infants with a reported birth weight

	Category	Coefficient (S.E.)	Sig.
Birth Weight	*(continuous)*	-0.316 (0.077)	***
Survival Status	Alive	*reference*	
	Dead	0.929 (0.278)	***
Gender	Male	*reference*	
	Female	0.424 (0.117)	***
Place of Delivery	Public Hospital	*reference*	
	Home	0.869 (0.445)	*
Partners Education	Secondary or Further	*reference*	
	None or Primary	-1.589 (0.697)	**
	Missing	0.197 (0.470)	NS
Maternal Age	20-29	*reference*	
	15-19	-0.123 (0.365)	NS
	30-39	-0.286 (0.126)	*
	40-49	0.207 (0.294)	NS

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01; NS= Not Significant

The link between birth weight and size classification is in the direction expected, although it does not have as strong a relationship as seen in Cambodia. Figure 7.10 shows the relationship between reported birth weight and perception of size. As birth weight increases there is a smaller probability of being included in the very small and smaller than average categories, while a larger probability of being classified as larger than average or very large.

Figure 7.10: Probability of classification into size categories by birth weight in Kazakhstan for infants with a recorded birth weight



A random effect is observed at the cluster level on birth weight, indicating that some clusters are significantly different from others in their relationship between size perception and birth weight. The variance of this random effect is 0.318 with a standard error of 0.098, which although significance cannot be completely established due to the penalised maximum likelihood procedure being used (Twisk, 2006) indicates that there is evidence for the need to allow the slope for birth weight to vary randomly. This means that in some clusters the relationship between birth weight and perception of size is stronger than in others, after controlling for the other variables in the model. No random intercepts were observed.

7.4.3. Results for Malawi

As in Cambodia and Kazakhstan, two models were fitted for Malawi, including and excluding birth weight. Table 7.12 shows the estimated parameters for the explanatory variables which are significantly related to mother's perception of size for all infants in Malawi. This model included an indicator stating whether birth weight was recorded/not recorded, but excluded actual birth weight. This indicator was significantly related to size perception, but did not interact with any other factors in the model. A number of other variables were significantly related to mother's perception, although one variable which has been significant in the other two countries tested, but was not in Malawi, is place of delivery, either at home or in an institution. This may be due to the close agreement in Malawi between a child having a reported birth weight and being born in an institution.

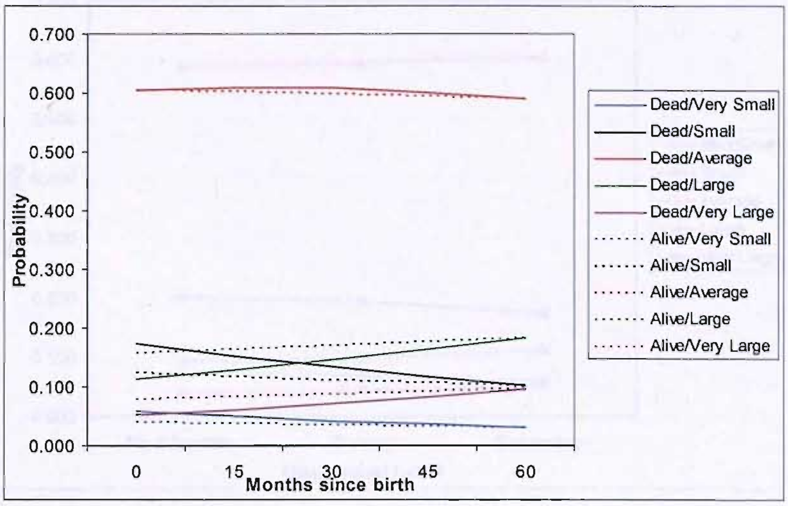
The relationship between the time since birth and size classification is moderated by the survival status of the child. Irrespective of survival status, as time passes since the birth mothers are more likely to classify their infants into larger size categories. If there has been a short time between the birth and the interview, infants who had died in this period are classified as being smaller than those who are still alive. After 60 months this effect has disappeared, and there is no difference between the size classification of infants, whether they are still alive or not (Figure 7.11).

Table 7.12: Multilevel ordinal regression coefficients and standard errors for mother's perception of her child's size in Malawi for all infants

	Category	Coefficient (S.E.)	Sig.
Birth Weight	Not Recorded	*reference*	
	Recorded	-0.443 (0.042)	***
Survival Status	Dead	*reference*	
	Alive	-0.448 (0.130)	***
Time since Birth	*(continuous)*	-0.011 (0.003)	***
Infant has survived by time since birth		0.007 (0.004)	*
Working Status	Working	*reference*	
	Not Working	0.144 (0.041)	***
Parity	2-3rd Birth	*reference*	
	First Birth	0.304 (0.050)	***
	4-5th Birth	-0.148 (0.054)	**
	6th+ Birth	-0.097 (0.055)	NS
Gender	Male	*reference*	
	Female	0.268 (0.038)	***
Maternal Education	Secondary/Higher	*reference*	
	None	0.231 (0.090)	*
	Primary	0.173 (0.081)	*
Region	North	*reference*	
	Central	-0.178 (0.165)	NS
	South	-0.325 (0.157)	*

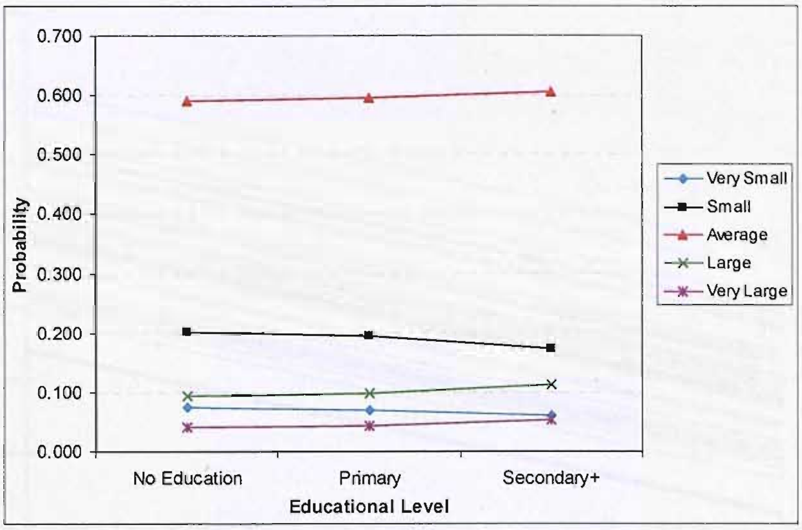
*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01; NS= Not Significant

Figure 7.11: Probability of classification into size categories by survival status and time since birth for all infants in Malawi



The other significant variables in the model are all related to mother's perception in the expected ways and in ways seen in the previous countries' models. Females and first births are all perceived as smaller than their counterparts, while those with a reported birth weight and of a higher birth order are perceived as larger. Mothers who are working at the time of the survey classify their infants as smaller than corresponding mothers who are not working at the same time. Regional variation indicates that those in the South of the country categorise their infants as larger than those who live in the North. There is no difference between the size classification between those in the Northern and Central regions. It is seen that households in the South have a higher average wealth than those in the North (analyses not shown), and this may explain this result. Mother's education is also significant, with an increase in size perception as educational level increases. This is shown in Figure 7.12, with infants having a higher probability of being classified as average or larger as educational level increases.

Figure 7.12: Probability of classification into size categories by highest educational level for all infants in Malawi



There is significant variation observed at three levels in the model: at the district level, the cluster level and the household level. This variation is shown in Table 7.13.

Table 7.13: Variance at the household, cluster and regional levels for all infants in Malawi

	Count	Variance (S.E.)
District Level	41	0.097 (0.028)
Cluster Level	559	0.068 (0.017)
Household Level	7427	0.215 (0.044)

The variation at the three levels indicates that there are differences between districts, clusters and households in the way in which infants are classified. This variation between districts is clearly seen if the relationship is studied between time since birth and size perception for infants who are alive. Figure 7.13 shows this relationship for all infants in Malawi.

There is seen to be large variation over all the districts on the perception of size of a child at birth. This is corroborated by a simple analysis of the raw data. In a region called Machinga Urban, 46.6% of infants were classified as larger than average or very large. This can be compared with Mchinji Rural, where only 10.9% of infants were placed in these categories (see Table 7.14 for a selection of districts). The variation in Figure 7.13 shows these differences between districts clearly after controlling for the other variables in the model.

Figure 7.13: Line graph showing the relationship between time since birth and predicted score with random variation at the district level for all infants in Malawi

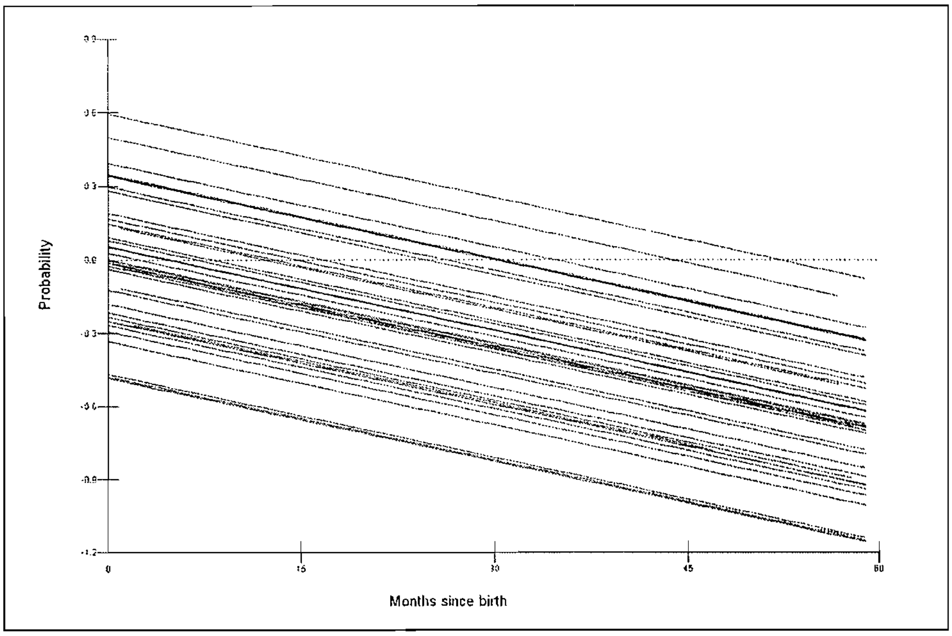


Table 7.14: Percentage of infants classified as larger than average or very large in selected districts in Malawi

District	% Larger than Average or Very Large	Number of Infants Surveyed in District
Mchinji Rural	10.9	313
Kasungu Urban	11.4	123
Lilongwe Urban	19.4	341
Mangochi Rural	21.9	443
Balaka Rural	30.8	214
Salima Rural	36.0	546
Blantyre Urban	37.0	346
Phalombe Rural	43.0	200
Machinga Urban	46.6	146

The inclusion of birth weight in the model reduces the sample size available for inclusion and alters the explanatory variables which are significantly related to mother's perception of size. The estimated parameters and standard errors are shown in Table 7.15.

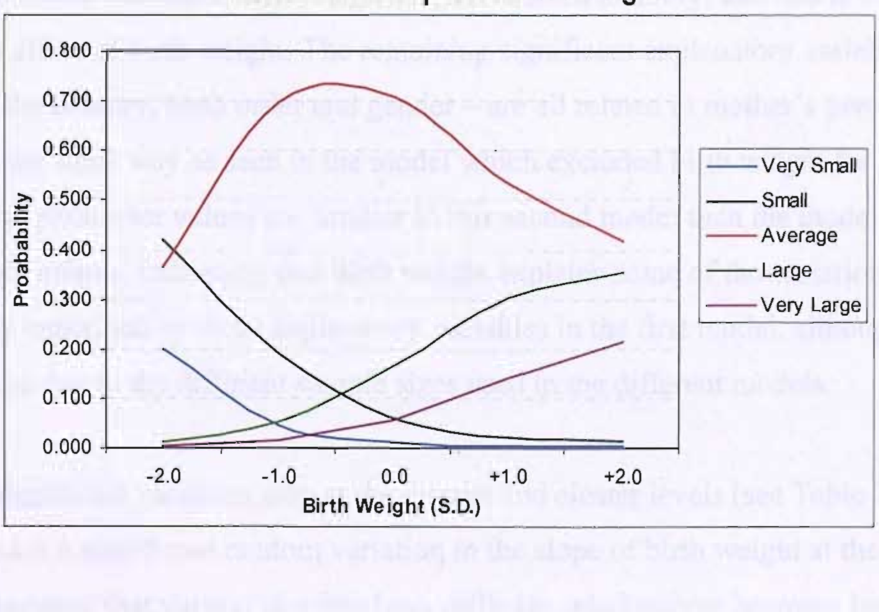
Table 7.15: Multilevel ordinal regression coefficients and standard errors for mother's perception of her child's size in Malawi using infants with a reported birth weight

	Category	Coefficient (S.E.)	Sig.
Birth Weight	*(continuous)*	-1.225 (0.097)	***
Birth Weight²	*(continuous)*	0.191 (0.021)	***
Birth Weight³	*(continuous)*	0.019 (0.008)	*
Recall of Weight	From Memory	*reference*	
	From Card	-0.180 (0.67)	**
Region	North	*reference*	
	Central	-0.290 (0.237)	NS
	South	-0.519 (0.225)	*
Gender	Male	*reference*	
	Female	0.195 (0.057)	***
Parity	2-3rd Birth	*reference*	
	First Birth	0.090 (0.073)	NS
	4-5th Birth	-0.156 (0.080)	*
	6th+ Birth	0.047 (0.082)	NS
Difference between weight and average weight in cluster		-0.234 (0.090)	**

*** p<0.001; **0.01>p>0.001; * 0.05>p>0.01; NS= Not Significant

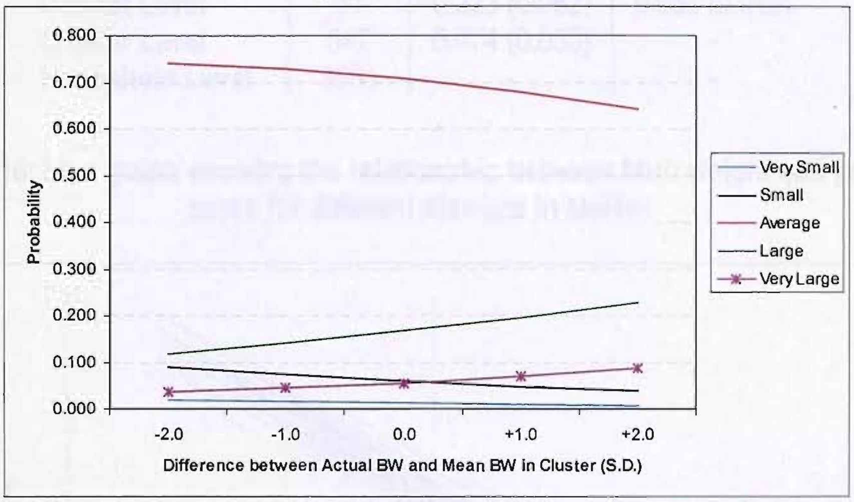
As expected, birth weight is strongly related to the perception of size. As birth weight increases, the probability of an infant being classified as larger than average or very large also increases, as shown in Figure 7.14.

Figure 7.14: Probability of classification into size categories by birth weight in Malawi for infants with a reported birth weight



The actual birth weight is not the only variable which is important in the size classification. It is seen that the weight of the infant when compared to the average weight in the cluster is related to the size classification, over and above the effect of actual birth weight, as shown in Figure 7.15. The relationship is in a similar way to that seen in Cambodia. If an infant is larger than the average for the cluster that they are resident in at the time of the survey the size classification is also likely to be larger. This implies that even if a child has a light birth weight, but other children in the area are even lighter, then the size perception will be larger.

Figure 7.15: Probability of classification into size categories by difference between actual birth weight and mean birth weight in the cluster in Malawi for infants with a reported birth weight



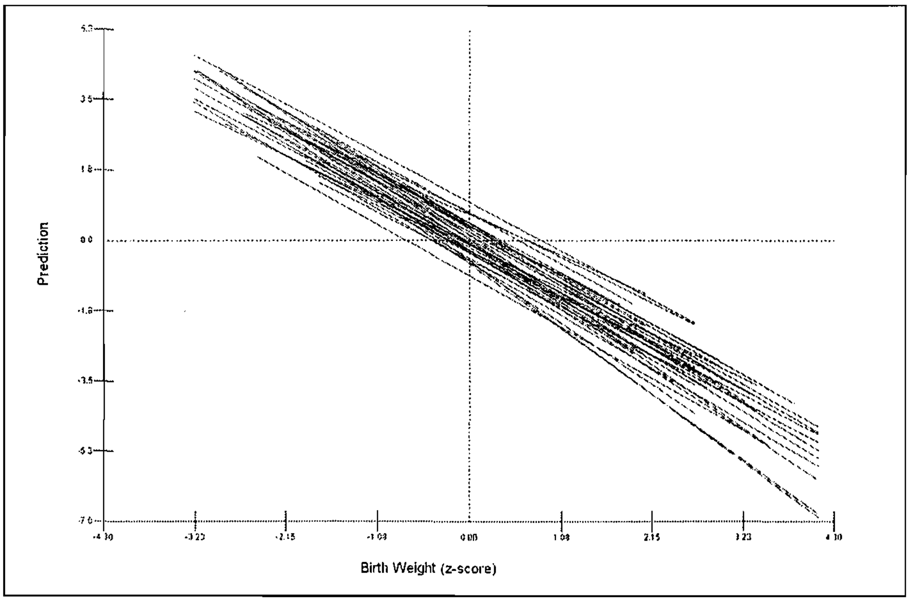
Infants who had their birth weights recalled from a health card are perceived as being larger than those who have their weights reported from memory, and this is over and above the effect of birth weight. The remaining significant explanatory variables – region of the country, birth order and gender – are all related to mother's perception of size in the same way as seen in the model which excluded birth weight for Malawi. Most of the parameter values are smaller in this second model than the model which includes all infants, indicating that birth weight explains some of the variation previously explained by these explanatory variables in the first model, although this may also be due to the different sample sizes used in the different models.

There is significant variation seen at the district and cluster levels (see Table 7.16). Also noted is a significant random variation in the slope of birth weight at the district level, suggesting that various districts have different relationships between birth weight and mother's perception of size. This can be seen in Figure 7.16. As in all other models, if the prediction from the model is low there is a higher probability of the infant being classified in a larger size category. Therefore, as birth weight increases the size classification is larger in all districts. The random variation at the district level for birth weight is not substantively very large, although it is significant. The large value for the intercept random variation indicates again the large differences between the districts in the classification of infants into the different size categories.

Table 7.16: Variance at the household, cluster and regional levels for infants with a reported birth weight in Malawi

		Variance (S.E.)	
	Count	Intercept	Birth weight
District Level	41	0.223 (0.062)	0.036 (0.015)
Cluster Level	547	0.074 (0.030)	-
Household Level	3984	-	-

Figure 7.16: Line graph showing the relationship between birth weight and predicted score for different districts in Malawi



Birth weight continues to be a very important determinant of mother's perception of size in Malawi, although there are many other factors that are related to the classification of size. The relationship between perceived size and the difference between the infants actual weight and the mean weight in the cluster implies that a mother uses infants around her to judge the size. However it must be noted that the mean birth weight in the cluster is only calculated from the sample of infants in the DHS, and thus may not represent the actual mean birth weight in that cluster, especially if there are small numbers in the survey with a reported birth weight in that cluster.

7.5. Discussion

The strong relationship seen in all three countries between birth weight and mother's perception of size indicates that actual size (proxied by birth weight) is an important determinant in the classification of infants into the different categories of size. In Cambodia and Malawi the relationship is not linear for the log-odds, as shown by the squared, cubed and higher terms in these countries. The association is in the expected direction, with larger infants being placed in larger size categories than smaller infants. In Cambodia the relationship between birth weight and size perception in all of the areas apart from the Coastal region is very clear. An infant who weighs 2 standard deviations below the mean birth weight in the country is most likely to be classified as smaller than average, while those who weight 2 standard deviations above the mean birth weight are most likely to be classified as larger than average.

The difference between the model using all infants and the model using those with a recorded birth weight shows that the influence of birth weight is independent of other factors. In Cambodia and Malawi the actual samples used for the two models are very different, and thus comparisons are difficult to make. However, in Kazakhstan, where the samples for the two models are very similar, variables that are related to mother's perception for all infants are exactly the same as those that are related to mother's perception when birth weight is included, indicating the birth weight is related to size independently to other explanatory variables. There is some slight attenuation of some parameters in the second model, with the model including birth weight having smaller parameters. This is unsurprising, as the factors that are related to mother's perception are also related to birth weight. As an example, females are known to be lighter on average than males (Kramer, 1987), and thus the relationship between gender and mother's perception is likely to be due to the actual difference in birth weights between genders. Including birth weight in the model controls for this and the remaining relationship between gender and mother's perception is the influence of gender on the perception of size over and above that of birth weight.

Other potential factors which may influence the perception of size are alternative aspects of actual size, such as physical size and amount of fat. These are not measured in the DHS and therefore cannot be included in the models for perception of size. It is possible that relationships between the explanatory variables and size perception would be further attenuated if these other actual size dimensions are included in the model.

It was initially thought that there would be a different relationship between explanatory variables and mothers' perception for those with and without a reported birth weight. This would have been seen by a significant interaction between the indicator of a reported birth weight and explanatory variables in the model which used all infants. However, although the indicator of a reported birth weight was seen to be highly significant in Cambodia and Malawi, no interactions were significant. The significance of the indicator of a recorded birth weight is expected, as those with a reported birth weight are known to have parents of a higher socio-economic class and thus are likely to be larger than infants without a reported birth weight. In effect, infants with a reported birth weight are reported to be larger than those without a reported birth weight mainly because they are, in fact, larger.

The results from all three countries indicate that there is variation at the different levels of analysis, to some extent. As a consequence we can conclude that infants in the same household, or cluster, or region, are more alike than infants in other households, clusters and regions. The similarity of infants in the same household, usually born to the same mothers, can be hypothesised to be due to similarities in size between siblings. Infants born to one mother are highly correlated in their birth weight (Bakketeig *et al.*, 1979), and thus the high similarity in reports of size is expected (if we assume that size perception is mainly based on birth weight). The variation observed between the different clusters and regions in Cambodia and Malawi shows that infants in the same area are more similar to each other in size assessment than to infants in other areas. It may be argued that this also indicates the area of reference used by mothers to assess the size of their baby. If a mother only uses infants in the local area to judge the size of their child against, the expectation is that there would be no variation observed at the regional or cluster level, as each cluster or region would have a similar distribution of sizes. This is not the case, indicating that comparisons are made across the whole country. Average birth weight varies in different regions and clusters across the whole country, and as perception of size is strongly related to birth weight then mean size in the different clusters differs too, leading to the variation observed.

Again with reference to Cambodia and Malawi, the difference between the individuals' birth weight and the mean birth weight in the sampling cluster was significantly related to perception of size. It is important to note that the mean birth weight in the cluster is calculated from the survey and therefore may not reflect the actual mean birth weight in that area. This may especially be a problem in Cambodia, where some clusters may only have minimal birth weights reported due to the small amount of birth weight information reported overall. However, with this in mind, those who weigh more than the mean amount are classified as larger than those who weigh less than the mean weight, even after controlling for birth weight. This relationship was only seen at the cluster level. One explanation for this is that mothers are using infants born in the close vicinity as a reference point to base their decision on the size of their baby.

The results from this analysis and from the determinants of a correct size assessment, studied in Chapter 6, imply that there are various regional and national influences on the determination of mothers' perception of size. The correct size assessments indicate that mothers use those around them to judge the size of their infant, while variation observed in the determinants of mothers' perception suggest that size assessments are based with reference to the national scale. It is likely that both processes are occurring to some extent. Mothers will judge the size based on those around them, in the village or region, but this process will be moderated with knowledge about children in the whole country. In different areas the effect of the local will be greater than the national and in others the effect will be reversed.

There are other factors which indicate that mother's perception is not invariant and is influenced by situational and time factors. In both Cambodia and Malawi, for the model which includes all infants, the time since the birth is significantly related to the perception of size. Expectation is that there should be no change in size classification, but it is observed that as the length of time increases, mothers are more likely to classify their babies into a larger size category. Birth weight in these countries did not decrease over the five years before the survey, as calculated from the birth weights included in the survey, and thus this result indicates that mothers do revise their size estimates upwards as time passes. It is interesting that the effect of time since the birth is not significant once birth weight is entered into the model for both countries. This may be simply due to the different samples used when birth weight is included in the model.

There are further results which indicate that there are factors aside from birth weight that affect the decision to classify infants into the different size categories. In Cambodia, the interaction between gender and survival status in the model which uses all infants in the analysis suggests that there is some revision of size classification if a son has died. Males who were still alive at the time of the survey were classified as much larger than their counterparts who had died. This may obviously be due to the fact that the infants who had died were smaller, but as there is no difference in the size perception by survival status for females, this hints that there may be some alteration in the size classification if a male dies. The loss of a male child in an environment where the birth of a male is more celebrated than that of a female may cause mothers to downgrade their size perception, in a way to justify the death. One method of coping with the death of a son is to state that they were never healthy and were likely to die irrespective of the effort input by the family for their survival, and thus the perception of size may be smaller. This theory is difficult to substantiate, but as the effect of survival status is only seen in males there is some support for this.

In Malawi the result that the method of reporting the birth weight in the survey is significantly related to mother's perception is interesting. Although infants are seen to have a higher mean birth weight if their weights are reported from a health card than recalled from memory, the result that reporting is related to size is found after controlling for the actual birth weight. In the interview process, the actual birth weight is obtained after asking the mother for the perception of size, and so size perception should not be influenced by the actual or recalled birth weight. A potential reason for this result is that mothers who do have their infants weights written on a health card inflate the size of their infant as they are of a higher socio-economic group and they believe that their child is larger than other children who are in lower socio-economic groups.

In general it is seen that birth weight is the major determinant of the mother's perception of a baby's size, although this result is obtained in the absence of other potential variables which may be considered as influencing size perception, such as the physical size or amount of fat. However, it is seen that birth weight is not the only determinant of mother's perception, and variables such as the survival status of the infants and gender are also involved in determining size. The lack of interactions between the significant variables and the whether a birth weight was recorded indicates that similar processes are conducted by all mothers regarding size assessments, irrespective of reporting a birth weight. This may be due to the mother being asked about their perception of size before being asked the birth weight. It would be interesting to assess if the determinants of perception of size change if the birth weight question is asked first. The fact that birth weight is seen to be the main determinant of birth weight lends credence to the argument that combining birth weight with size at birth to obtain LBW statistics is feasible and will provide better estimates. From these results it is also thought that the use of size as a proxy for birth weight is valid, albeit with the cautionary note that birth weight is not the only determinant of the size assessment and that there are differences between clusters and regions in this assessment.

Chapter 7: Key Points

- Birth weight is a strong determinant of size at birth.
- Regional and cluster variation is observed in Cambodia and Malawi, indicating that infants in an area are more likely to be judged as a similar size.
- Results suggest that there are local and national comparisons occurring when the mother states the size of her infant, although it is unknown which level is most important in the determination of size.
- Determinants of mother's perception are the same for those with and without a reported birth weight.
- Other variables such as gender and the place of delivery are related to perception indicating that birth weight is not the only determinant of size.

Chapter 8

Birth Weight and Mortality in the First Year of Life: Methods to Cope with Missing Birth Weight

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Birth weight is one of the best predictors of survival in the first year of life, and especially during the first few months (McCormick, 1985). However, many infants in developing countries are not weighed at birth. Biased estimates are likely to be obtained for the relationship between birth weight and mortality where the characteristics of infants with a reported birth weight differ from those without a reported birth weight. Furthermore, if birth weight is used as a control variable, parameter estimates for all variables in the models are likely to be similarly biased. As a result, if birth weight is to be used and some infants in the dataset do not have a recorded birth weight, complete case modelling procedures should not be used. Procedures to mitigate for the missing information are required.

This chapter studies the relationship between birth weight and early neonatal (ENN), neonatal (NN) and post-neonatal mortality (PNN), and how this relationship changes when different methods are applied to cope with the missing data. Cambodia, Kazakhstan and Malawi are the countries used for this study. These countries were chosen, using the same rationale as in previous chapters, due to the different proportions of missing birth weight data in each country.

For each country and for each mortality definition (ENN, NN and PNN) three different missing data approaches were used. Firstly, a complete case analysis was conducted which used only those infants with a reported birth weight. This is the approach that many researchers use when analysing datasets where not all information has been collected. The second approach used is termed inverse probability weighting (IPW), where those infants with a recorded birth weight are differentially weighted to 'represent' those without a reported birth weight. The final approach used is multiple imputation, which constructs a number of complete datasets from the relationships observed in infants with complete information. These 'complete' datasets are then used to estimate the relationship between birth weight and mortality.

One of the main aims of this thesis is to assess if a mother's perception of her baby's size at birth can be used as a proxy for birth weight. In addition to the formal statistical methods noted above to cope with the missing data, models were constructed which investigated whether a mother's perception is a good proxy for birth weight in models of mortality. Instead of using birth weight these models use mother's perception and the results obtained were then compared to the methods noted above to assess if mother's perception is a good proxy for birth weight.

The aims of this chapter are threefold:

1. To study the relationship between birth weight and ENN, NN and PNN mortality in Cambodia, Kazakhstan and Malawi.
2. To analyse and assess four different missing data techniques for coping with missing birth weight information
3. To gauge if mother's perception of her infant's size at birth is a good proxy for birth weight when modelling mortality throughout the first year of life

This chapter will firstly examine the three statistical missing data methods used in this study, followed by a brief review of the previous research on the relationship between a number of covariates used in this study and mortality throughout the first year of life. Exploratory analyses of the relationships between birth weight and the three different definitions of mortality will be conducted. The different missing data methods will then be applied to the datasets and the relationship between birth weight and mortality estimated. Closer inspection of some of the missing data techniques will be conducted followed by a discussion of the results.

8.1. Missing Data Methods

Numerous methods to deal with missing data have been designed, and this thesis will not attempt to review them all. Only the methods used in this study, namely complete case, inverse probability weighting and multiple imputation methods will be reviewed. Before studying these methods however, a brief examination of the basic concepts relating to missing data is required.

8.1.1. Basic Missing Data Concepts

In many studies which use survey data there will be some cases with missing information. Non-response in a dataset can be of two different forms. Unit non-response is where no data at all is collected from a certain individual, possibly due to an inability to contact the individual or a refusal to complete the questionnaire. Item non-response is where data are missing on certain questions but the individual has actually taken part in the survey. This may be through a refusal to answer a specific question, lack of knowledge of an answer, uncertainty about the correct response to give, a mistake by the interviewer or numerous other reasons. Different statistical methods have been designed to deal with each type of missingness. In most retrospective surveys there is usually both unit and item non-response. This study looks at item non-response, with missing birth weight for some individuals who have observed responses on other items in the survey.

If missing data exists, it is important to understand the underlying missing data mechanism, or pattern of missingness, in order to apply an appropriate statistical method. Different patterns of missing data have been identified. The terminology used here follows that defined by Rubin (1976). An indicator of non-response can be treated as a random variable and can therefore be assigned a distribution. For a dataset, denoted Y, each data point within Y can be either observed or missing:

$$Y = \begin{cases} Y_O \\ Y_M \end{cases} \tag{8.1}$$

where Y_O are data that are observed and Y_M are missing data. Some of the variables in the complete dataset, Y, may be outcome/response variables, some may be explanatory/covariates.

For each individual Y there is a corresponding response indicator, R, defined as:

$$R = \begin{cases} 1 \text{ if } Y = Y_O \\ 0 \text{ if } Y = Y_M \end{cases}. \tag{8.2}$$

By studying the probability that a value is missing given the observed and missing data i.e. $\Pr(R \mid Y_O, Y_M)$, the missing data mechanism can be determined, and an appropriate method to analyse the data devised.

There are three main patterns of missing data, termed missing data mechanisms. The first, Missing Completely at Random (MCAR), is seen when the probability of the data being missing is unrelated to the values of the observed and unobserved measurements – the missing values are missing in a random manner. More formally, this is expressed as:

$$\Pr(R \mid Y_O, Y_M) = \Pr(R). \tag{8.3}$$

If the missing data are MCAR, those with complete responses can be analysed to obtain results without bias due to the random nature of the missingness. This missing data pattern occurs, for instance, if a question is not asked to a respondent by the interviewer by pure chance, or if a questionnaire is lost in the post.

The second class of missing data is termed Missing at Random (MAR) which is denoted as:

$$\Pr(R \mid Y_O, Y_M) = \Pr(R \mid Y_O). \quad (8.4)$$

Given the observed data, the probability that an individual observation is missing is unrelated to the value of the unobserved data. Therefore, the model which expresses the missingness can be expressed solely in terms of the observations that are observed. This pattern of missingness does not conform to the usual idea of randomness. However, the data are missing at random given the observed data. For example, males may be less likely to respond to a survey question than females, but the probability of response is random within each gender. Therefore the missing data mechanism is MAR.

The final class of mechanism is where the missing value mechanism is actually related to the values of the missing data, called Missing Not at Random (MNAR). For example, questions regarding salary usually have a large amount of missing data, but it is more likely that the data is missing if the individual's wages are in the extremes of the distribution. However, we do not usually know the precise mechanism which causes the data to be missing as we do not know the missing values. This mechanism can be expressed formally as:

$$\Pr(R \mid Y_O, Y_M) = \Pr(R \mid Y). \quad (8.5)$$

The probability that R is missing is related to both the values of the observed and the missing data. Any analysis of data must take account of the missing value mechanism, although in MNAR it is often not known what this mechanism is. Once an assumption has been made regarding the mechanism behind the missing data, whether it is MCAR, MAR or MNAR, then the statistical methods to cope with the missing data can be applied. In this study it is assumed that birth weight is MAR (see below for a discussion of the reasons why this assumption is made), so the statistical missing data methods discussed will be those which relate to this missing data mechanism.

8.1.2. Complete Case Analysis

The method that many researchers use when faced with missing data is to simply ignore it and continue their analysis regardless. Many statistical programs also do this by ignoring those observations which are missing by removing the whole case from the analysis if any of the individual variables are missing. Unless the user explicitly chooses a different method to use, only those individuals with complete responses are analysed. When only those cases with complete data are used, the analysis is termed complete case analysis.

One major benefit of this type of analysis is that it is quick and easy to perform. If there is only a small amount of missing data the results from this analysis may be reasonable and similar to the results which would have been obtained if all data had been collected. Irrespective of the amount of missing data this method is also valid if the missing data mechanism is MCAR as those cases with missing data are randomly distributed across all respondents. However, if the missing data mechanism is not MCAR then using this method may lead to serious biases in the results. Furthermore, if a case is discarded if there is a missing value on any of the variables in the analysis much 'useful' information is lost to the analysis. This may lead to lower precision of estimates. As the proportion of missingness increases it is more likely that the bias in the estimates will increase if complete case analysis is used.

8.1.3. Inverse Probability Weighting

One method which modifies the complete case analysis to adjust for bias is termed inverse probability weighting (IPW). Only the complete cases in the dataset are used, but differential weights are applied to those cases with complete information in order to take account of the missing cases. This method is very similar to that used to correct for unequal sample survey selection probabilities, and in many instances the weighting methods for missing data can be combined with the sample selection weights in order to provide an overall weight to apply to each individual which accounts for both the sample selection and the missing data (Little and Rubin, 2002).

With regard to sample selection into a survey, given N units in a population, the i^{th} individual's chance of being selected into the sample is denoted π_i. If unit i is sampled it represents π_i^{-1} units in the total population. The chances of selection into the sample do not need to be the same across all N units, and indeed there are usually differential selection probabilities across different strata. If there are no missing data, and defining a variable of interest as y_i for all units in the sample, the Horvitz-Thompson estimator for the overall mean is given by:

$$\bar{y}_w = \frac{1}{n}\sum_{i=1}^{n} w_i y_i \qquad (8.6)$$

where

$$w_i = \frac{n\pi_i^{-1}}{\sum_{k=1}^{n}\pi_k^{-1}}.$$

w_i is the sampling weight of each unit in the sample, scaled to sum to the total sample size, n. It is seen that $\bar{y}_w$ is unbiased for the mean of Y when stratified random sampling has been used, and approximately unbiased if other forms of sampling has occurred (Little and Rubin, 2002).

This approach is easily extended for a variable with missing data. If there is missing data then there are two probabilities that are needed to be known: π_i, the chances of selection into the sample, and ϕ_i, the probability of a response by the unit given that selection into the sample has already occurred. Also required is knowledge of the model by which the data are missing.

To obtain this model of missingness logistic regression is conducted on the response indicator, R, which takes the value '1' for those cases where the variable of interest is not missing, and '0' for those cases if it is missing. Covariates are included in the model in order to assess if they are related to missingness. Once the modelling procedure has been conducted the covariates in the model which predict missingness can be used to divide the sample into J classes. Each of these classes will need to be differentially weighted. Predicted probabilities of observing the data within each class can be calculated from the logistic model. If continuous covariates are used, classes are difficult to construct, although predicted probabilities of observing the data from the model can be calculated nevertheless. The validity of this analysis depends on the logistic regression model on the missingness of the data being correct. If this is wrong, then the estimates produced using the method may be extremely biased (Carpenter, 2006).

After conducting the above procedure there will be J weighting classes, and it follows that within each weighting class there will be n_j sampled units and r_j respondents. From this it is simple to see that the number of units with non-missing data is $r = \sum_{j=1}^{J} r_j$. Furthermore, the response probability within class j will be r_j / n_j. Using these definitions then equation 8.6 can be used to estimate the overall mean, but the weight will be calculated using the following formula:

$$w_i = \frac{r(\pi_i \hat{\phi}_i)^{-1}}{\sum_{k=1}^{r} (\pi_k \hat{\phi}_k)^{-1}} \qquad (8.7)$$

where $\hat{\phi}_i$ is the estimated response probability calculated by r_j / n_j. This method assumes that those in each weighting class represent a random sample of those units which are in the larger sample, i.e. the missing data mechanism is MAR (Little and Rubin, 2002). Once these weights have been calculated then the usual statistical techniques can be applied to the data but with each case being weighted using these response weights.

There are a number of problems with this method, especially when there is a high proportion of missing data. In this situation the response probabilities calculated from the logistic model will be very small, simply because the probability of an individual providing a response is also very small. As the inverse of these response probabilities are used as weights this logically means that the actual weights will be very large.

Potential bias is introduced into the final results due to over-reliance on a minority of cases. When this occurs it is recommended that the weights are truncated or trimmed to a specific value (Mohadjer and Choudhry, 2002). There are various methods that can be used to decide on the truncation value to use. However, the truncation value is usually decided after consideration of the tradeoffs between bias and increased variances (Potter, 1988; Potter, 1990). A truncation value set too high may lead to problems with calculating the variance and standard errors of estimators (Potter, 1988).

This problem with extreme weights is exacerbated when there is a large n_j but a small r_j within a weighting class (i.e. an unexpected response, where most respondents with the same characteristics do not respond). Furthermore, in a survey with a high proportion of missing data there is likely to be some weighting classes with all responses missing. If this occurs then the entire weighting class is dropped from the analysis, reducing the effective sample size. A further problem occurs if multilevel models are to be used in the analysis. The weights generated are at the individual case level. In order to obtain the variances at the different levels in the multilevel model differential weights are needed at each level in the model (Pfefferman *et al.*, 1998). Procedures to calculate these weights have not yet been developed. If multilevel models are used with inverse probability weights applied, the individual parameter values will be unbiased, but the variances at the different levels will not be correct (Pfefferman, 2006).

The inverse probability weighting method calculates approximately unbiased estimators for parameters, but estimating the standard error is difficult as it is necessary to account for the variability in the weights being applied. One method to obtain standard errors when using IPW is by using the jackknife resampling technique (other methods, such as the bootstrap can also be used, but will not be discussed here). The jackknife estimate of variance initially calculates the sample statistic using the full (or in this case, the weighted complete case) dataset. Then, the same sample statistic is calculated but using a dataset where each case is removed in turn and the results noted for each calculation. These results are then combined to give an estimate of the mean and variance.

Using formal notation, if the aim is to estimate some parameter θ from a sample containing n cases (i.e. $\hat{\theta} = f(x_1, x_2, \ldots, x_n)$), the quantity $\hat{\theta}_{(i)}$ is calculated, where

$$\hat{\theta}_{(i)} = f(x_1, x_2, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n) \quad (8.8)$$

Equation 8.8 is calculated for each x_i. The jackknife estimate of θ is given by:

$$\hat{\theta}_{jacknife} = n\hat{\theta} - (n-1)\hat{\theta}_{(.)} \quad (8.9)$$

where

$$\theta_{(.)} = \frac{\sum_{i=1}^{N} \hat{\theta}_{(i)}}{n}$$

To estimate the variance of $\hat{\theta}$ the following equation is used (Efron, 1982):

$$Var_{jacknife}(\hat{\theta}) = \left(\frac{n}{n-1} \sum_{i=1}^{n} \left(\hat{\theta}_{(i)} - \hat{\theta}_{(.)} \right)^2 \right) \quad (8.10)$$

With a large dataset the calculation of the jackknifed estimate of the variance is extremely computer intensive, as each observation is required to be dropped in turn.

8.1.4. Multiple Imputation

Complete case and inverse probability weighting analyses only use those cases for which data are observed in the estimation of the parameters of interest. The technique of multiple imputation uses relationships between variables observed for the complete cases to impute likely values for the missing data, and then analyses the observed and the imputed data values together, as if they had all been collected in the first place. If a dataset is termed Y, containing two or more different variables of which at least one is not fully enumerated, the dataset can be divided into observed and missing components $Y = (Y_O, Y_M)$, as noted above. The relationship between Y_O and Y_M is estimated for those cases where both Y_O and Y_M are observed, and this information is then used to complete the dataset by drawing the missing data from the distribution of $Y_M \mid Y_O$.

In regression models, under MCAR or MAR, if only the response variable has missing data, parameter values estimated using standard modelling techniques are seen to be valid and unbiased (Carpenter and Goldstein, 2004). If explanatory variables are missing, a multivariate response regression model can be devised where the missing responses are placed on the left of the regression equations. Using maximum likelihood or Bayesian techniques (with uninformative priors) the distribution of $Y_M \mid Y_O$ can be estimated, and the imputed data for those cases with missing units can be drawn K times from this distribution to give K complete datasets. The draws are easily conducted using Markov Chain Monte Carlo (MCMC) methods, with the requirement that the draws to obtain the imputed data are independent (Schafer, 1997). The number of imputations made is usually between 3 and 10 (Durrant, 2005). The higher the proportion of missing data, the more datasets are imputed (Schafer, 2006). Each of these 'complete' datasets can then be analysed using standard modelling techniques.

These K datasets are analysed, giving parameter estimates $\tilde{\theta}_1, \tilde{\theta}_2, \ldots, \tilde{\theta}_K$ and associated standard errors $\tilde{V}_1, \tilde{V}_2, \ldots, \tilde{V}_K$. The overall mean of the distribution is calculated by simply averaging the estimates from all the imputed datasets (8.11)

$$\tilde{\theta} = \frac{1}{K}\sum_{i=1}^{K}\tilde{\theta}_i . \qquad (8.11)$$

However, the variance needs to take into account the within imputation and between imputation variance. The formula to do this is:

$$\tilde{V} = \bar{V} + \left(1 + \frac{1}{K}\right)B \qquad (8.12)$$

where $\overline{V}$ is the average within-imputation variance:

$$\overline{V} = \frac{1}{K}\sum_{i=1}^{K}\widetilde{V}_i$$

and B is the between-imputation variance of the estimates:

$$B = \frac{1}{K-1}\sum_{i=1}^{K}\left(\widetilde{\theta}_i - \widetilde{\theta}\right)^2 .$$

These methods for obtaining $\widetilde{\theta}$ and $\widetilde{V}$ are called Rubin's formulae (Little and Rubin, 2002).

The original imputation model should adhere to the structure of the data, and thus if the data are hierarchically structured then the imputation model should also be hierarchical (Carpenter and Goldstein, 2004). If the multilevel structure of the data is ignored when fitting the imputation model the correct parameters for the model may not be estimated, leading to incorrect imputations. In order to fit a multilevel model and conduct the multiple imputation, Carpenter and Goldstein (2004) have developed a macro which runs in the multilevel modelling software, MLwiN. The macro fits a multilevel multivariate imputation model using Bayesian methods with uninformative priors and using MCMC methods. This is the only known attempt to conduct multiple imputation within a multilevel framework which can cope with data with more than two levels. Schafer has developed a package which can handle structured data (Schafer, 1997), but this does not appear to be able to cope with more than two levels (Carpenter and Goldstein, 2004). Most surveys usually have more than two levels. In the DHS surveys, as noted previously, there is a hierarchical structure within the data, with children born to the same mothers, in the same households, within clusters and regions. This structure should be mirrored in the model for the imputation, with variables being mutually dependent at various levels, in order for the correct imputation model to be constructed.

In summary, the three methods mentioned above, complete case, IPW and multiple imputation each have advantages and disadvantages when coping with missing data. Complete case analysis is simple to conduct, but may lead to serious biases in the results. IPW is simple to understand and requires few modelling assumption, but the results can be very sensitive to the choice of the weighting model. Conceptually, multiple imputation is the most difficult to understand and the estimates obtained depend on the imputation model constructed. For unbiased results the imputation model needs to include all the covariates which are needed to ensure MAR. However it is thought that multiple imputation, when conducted correctly, gives more reliable and unbiased results than IPW (Carpenter *et al.*, 2005).

8.2. Mortality within the first year of life

Mortality within the first year of life is termed infant mortality. However, there are variations in the main determinants of death in different periods of this first year, so usually infant mortality is split into smaller periods of risk. An infant who dies in the period between birth and four weeks (28 days) is termed a neonatal death, and those who die after this time but before their first birthday, a post-neonatal death. However, it is possible to split neonatal mortality into even smaller periods. Early neonatal mortality is an infant who is born alive, yet dies within the first week of life (up to an including 7 days), while a late neonatal death is between 8 days and 28 days. Many studies have been conducted in both developing and developed countries which investigate the determinants of mortality in these different periods. A thorough review of the relationships between each of the determinants of mortality in each period is outside of the scope of this thesis.

The neonatal period is characterised by high risks of death from antenatal and intrapartum causes, while deaths in the post-neonatal period are caused more by environmental factors (McCormick, 1985). Thus in the first month babies are likely to die from events concerning the birth, such as prematurity, asphyxia and birth injury. Occurrences of these events are not spread randomly in the population and are seen to occur more often in the lower socio-economically advantaged groups (Puffer and Serrano, 1973). However, deaths in this neonatal period are more evenly spread across the population than post-neonatal deaths. The environmental factors which are related to post-neonatal mortality include infectious diseases, such as diarrhoea, incidence of which is heavily skewed towards the lower socio-economic groups. In countries with a high level of infant mortality most deaths in the first year are in the post-neonatal period (Puffer and Serrano, 1973). However, as the infant mortality in the country falls, usually due to better sanitation, health care and education, the majority of deaths in the first year will occur in the neonatal period (Mahy, 2003). Table 8.1 displays the relationships between selected variables and mortality in the first year of life.

Table 8.1: Summary of the relationships between selected variables and mortality in the first year of life

Variable	Relationship
Birth Interval	• Short birth intervals (both preceding and subsequent) are related with higher neonatal and post-neonatal mortality (Hobcraft *et al.*, 1983; Cleland and Sathar, 1984; De Sweemer, 1984; Lehrer, 1984; Hobcraft *et al.*, 1985; Koenig *et al.*, 1990) • Short birth interval usually defined as shorter than 2 years
Birth Order	• Clear excess mortality throughout the first year for first births (Hobcraft *et al.*, 1985) • Higher mortality for higher order births (7th or higher order birth) is also observed (Cramer, 1987; Eberstein *et al.*, 1990), although not to the same extent as for first births (Hobcraft *et al.*, 1985)
Birth Weight	• Optimal survival rate is seen for infants weighing between 3000g and 3500g (McCormick, 1985), although this differs by country. As weight decreases mortality rates increase. Also, there is a small increase in the mortality rate for very heavy infants (Wilcox and Russell, 1986) • Impact is throughout the first year of life (and onwards), but during the neonatal period the relationship between birth weight and survival is the strongest. In this period infants who have LBW are 40 times more likely to die than normal birth weight infants (McCormick, 1985)
Gender	• Females have a biological survival advantage over males throughout the first year of life and especially in the neonatal period (Hill and Upchurch, 1995; Ulizzi and Zonta, 2002). Males are more likely to die from perinatal conditions and congenital abnormalities (Waldron, 1998) • Females may have higher infant mortality levels due to discriminatory child care practices in some societies (e.g. China, India) favouring the care of males (Das Gupta, 1990; Lawn *et al.*, 2005)
Marital Status	• Infants born to currently married mothers are less likely to die than infants born to never married or formerly married mothers (Bennett, 1992; Bennett *et al.*, 1994)

Variable	Relationship
Maternal Education	• Education has an inverse relationship with infant mortality, with higher education leading to lower levels of mortality (Frenzen and Hogan, 1982; Mosley and Chen, 1984; Cramer, 1987; Arntzen *et al.*, 1996; Rutstein and Johnson, 2004) • The effect of educational level on mortality is more pronounced in the post-neonatal period than in the neonatal period (Ware, 1984)
Mother's Age at time of the Birth	• Greater risks of death in first year for infants of teenage mothers (Cramer, 1987; Reichman and Pagnini, 1997; Alam, 2000) • Much of the excess risk for younger mothers is due to the likelihood of the infant having a lower birth weight – after controlling for birth weight the risk of death is much lower (Friede *et al.*, 1987) • Infants born to older mothers have higher odds of dying in the first year of life. The risk slightly increases for mothers over 30 but is greatly elevated for mothers over 40 years (Friede *et al.*, 1988)
Place of Delivery (Hospital/Home)	• Infants born in a hospital setting are less likely to die than those born at home (Shakya and McMurray, 2001). The main reason for this is as the birth being is attended by skilled professionals (Das Gupta, 1990) • The relationship is slightly attenuated as more problem births occur in hospital (Yasmin *et al.*, 2001)
Place of Residence (Urban/Rural)	• Children born to mothers who live in urban areas are less likely to die than those who live in rural areas (Collins and David, 1992; Rutstein and Johnson, 2004)
Wealth	• As wealth increases, however measured, mortality falls (Rutstein and Johnson, 2004) • The relationship is stronger in the post-neonatal period than the neonatal period (Frenzen and Hogan, 1982)

Table 8.1 continued: Summary of the relationships between selected variables and mortality in the first year of life

To investigate the relationship between the variables listed in the table above, with an emphasis on birth weight, and mortality the missing data methods described above need to be used. This will allow the assessment of the efficacy of each of the missing data techniques. The following section explains how the missing data techniques noted above are actually applied in this investigation.

8.3. Methods Used in the Comparison of Different Methods to Mitigate for Missing Birth Weight Information

8.3.1. Mortality Analysis

This study looks at mortality in three different periods: early neonatal, neonatal and post-neonatal. These periods were chosen to highlight the different relationships between explanatory variables and mortality seen throughout the first year of life. One problem with using these three different periods is heaping of reported deaths on the boundaries between the periods (i.e. at 7 days, 28 days and one year). Another issue was that some mothers reported the time to death as 'one week', 'one month' or 'one year'. It is unclear in these situations whether the death should be included in the respective mortality periods or not. For this investigation the mother's report of the time period before the death of the child was taken as being accurate and correct. This decision meant that mothers reporting their infant's death as being 'one month' were not included in the neonatal mortality group, as the definition of the neonatal period only includes the first 28 days of life, and months usually have more than 28 days. Infants who were reported as dying after 0 days were included in the analysis. The survey asks for information about children who showed signs of life by 'crying, breathing or moving' (ORC Macro, 2002, p. 50), and not to record children who were dead at birth or to record miscarriages. Hence infants who died on the same day as the birth but showed signs of life should be treated as an early neonatal death.

The statistical method chosen to analyse mortality within these three time periods was logistic regression. This method has been described in Section 3.4.1. Logistic regression studies the probability of death within a chosen time period. This method was chosen instead of survival analysis as the precise time to death is not important in this case, only whether death has occurred within the defined period. In order that there is no problem with censored data (i.e. infants who are still alive not yet reaching the end of the time period in question) the dataset was restricted to only those infants born more than one year before the date of the interview. Thus there are only two outcomes for the children remaining in the dataset: they either died in the period in question or they survived.

For each country, Cambodia, Kazakhstan and Malawi, the three different types of mortality were analysed. Four different models were devised for each definition of mortality. The first three models used the three statistical methods to deal with missing data noted above: complete case analysis, IPW and multilevel multiple imputation (MMI). The final model constructed used the mother's perception of her infant's size at birth as a proxy for recorded birth weight. Mother's perception of size is divided into five groups, while birth weight is a continuous variable. Therefore it is difficult to compare models where these two different types of variable are used. In order that comparisons could be made between the models, birth weight was categorised into five groups. These were taken to correspond to the five categories of size used by the mothers. This categorisation was done using standard deviations from the mean birth weight with groups defined by +/- 2 and +/- 1 standard deviation(s) from the mean weight. For ease of reference these groups were termed 'Very Light', 'Lighter than Average', 'Average', 'Heavier than Average' and 'Very Heavy', and these terms will be used throughout this chapter.

8.3.2. Choice and Definition of Covariates

The main aim of this analysis is to assess the relationship between birth weight and mortality when various strategies are used to cope with missing birth weight data. Covariates which have previously been seen to be related to infant survival were also used in each model (see Table 8.1). These included birth order, birth interval, mother's age, maternal education, wealth (in quintiles), gender of the child, place of delivery (home or in a hospital), place of residence (urban or rural), marital status and whether the mother is currently working. The coding of these variables is shown in Appendix I. The relationship between each of these covariates estimated by the various models will not be described, although any interesting results observed will be mentioned.

8.3.3. Complete Case Analyses

Two different complete case analyses were conducted. Firstly, using birth weight and secondly using mother's perception of her baby's size as a proxy for birth weight. Each country has a different amount of birth weight missing in the survey. In Cambodia only 15.9% of the infants had a reported birth weight, in Kazakhstan this figure was 97.1%, and Malawi 44.1%. Mother's perception of her baby's size also was not completely enumerated in any of the countries, and thus the analyses which used this variable did not use the full sample in the models of infant survival. The amount of missing data on the mother's perception variable is considerably less than the amount seen on birth weight, as noted previously. In Cambodia 98.1% of infants had a recorded size, whilst in Kazakhstan and Malawi this figure was 99.3% (see Box 6.1 for more information regarding Cambodia).

8.3.4. Inverse Probability Weighting Analysis

In the three countries under analysis it was assumed that birth weight was missing at random (MAR). This assumption means that the reason why birth weight was not recorded in the survey for an infant is not related to the actual weight of the infant. This seems a reasonable assumption to make, although arguments could be made that the birth weight of a child is related to the chance of it being weighed (i.e. the child is too small to weigh). For the purposes of this study, however, it is assumed that this is not the case and that there is no relationship between birth weight and the probability of the child being weighed. The birth weight of the child can be hypothesised to be independent of the chances of the mother remembering the weight and reporting it to the interviewer.

To apply the inverse probability weighting method a model for the missingness of the birth weight information was required. The variables used in this model need not be the same as those chosen for inclusion in the mortality models listed above (Carpenter, 2006). However, in this study all the variables which were included when modelling mortality were also included to model missingness, as it has been seen that these variables are also related to whether birth weight was missing (see Table 4.7). Other variables which may be related to missingness were also tested for inclusion in the model of the distribution of missing data. These extra variables were the region or province that the child lived in, the mothers current age, whether the infant has a younger sibling, the number of months since the birth, ethnicity (where available) and religion. Also tested was the survival status of the infant.

The model for missingness was constructed using backwards stepwise selection with STATA version 9 (StataCorp, 2005). The variables which were seen to be significantly related to birth weight missingness (at the 5% level) were then transferred to MLwiN version 2.0 (Rasbash *et al.*, 1999) and the final modelling procedure conducted. The multilevel structure of the data was accounted for at the household, cluster and regional level. Sample selection weights were used at all times. After the final model was chosen, predicted probabilities were produced from this model, and the missing data weights obtained using the method shown in equation 8.7. The weights obtained for those children with a recorded birth weight after following this process were studied to assess the size of the weights (it is only necessary to assess the weights for those infants with a recorded birth weight as it will only be these infants who are included in the models to predict mortality). To avoid placing too much emphasis to a single response and creating instability into the model the missing data weights were truncated (Potter, 1990). The truncation level was chosen as the value '4' (a value suggested by Potter), and any missing data weights above this value were recoded as having a value of 4. The distribution of the missing data weights for each country is shown in Table 8.2.

Table 8.2: Distribution of missing data weights for each country

	% Cases with Missing Data Weight						
	1-2	**2-3**	**3-4**	**4-5**	**5-10**	**>10**	**% Over Value '4'**
Kazakhstan	100.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Malawi	92.6	2.4	1.8	1.3	1.8	0.1	**3.3**
Cambodia	17.5	12.6	8.8	6.7	13.4	40.9	**66.0**

It is clear from Table 8.2 that the missing data weights generated from the model in Cambodia needed to be highly truncated. Over 40% of individuals had a missing data weight of over 10 (indeed, 10.2% had a weight of over 100). These large weights are unsurprising as there are only 15.9% of the infants with a recorded birth weight. The crude chance of randomly picking an infant with a recorded birth weight is therefore only 1 in 6.3 (i.e. for each infant with a recorded birth weight there are 6.3 infants without), and therefore the average weight generated from the missingness model will be above the truncation value. The low levels of truncated weights in Kazakhstan and Malawi are not unexpected due to the lower levels of missing birth weight information seen in these two countries.

The missing data weights generated were then applied to the models for mortality, again using MLwiN. As the structure of the data is hierarchical, multilevel models were used. However, the missing data weights developed are only calculated at the individual level, and to obtain accurate estimates of the variance at the various levels in the model the weights are needed at each level that the variance is being estimated (Pfefferman *et al.*, 1998), as explained above. The individual parameter estimates and their associated standard errors can thus be interpreted, but the variance estimates at each of the levels in the multilevel model cannot. By using the weights in a multilevel analysis the parameter estimates are thought to be unbiased (Pfefferman *et al.*, 1998), although a recent article has indicated that this may not be the case (Rabe-Hesketh and Skrondal, 2006).

After estimating the weighted multilevel model for each measure of mortality within each country the jackknife procedure was applied to obtain unbiased estimates for the standard errors of the parameter estimates. This was also conducted in MLwiN, where a macro was written which produced a number of new datasets for each country, each dataset having one case missing. The mortality models were then applied to each of these new datasets, and the parameter estimates extracted from each of the models. Using STATA version 9 (StataCorp, 2005) these parameter estimates were combined using equations 8.9 and 8.10 noted above. Problems were encountered in Cambodia when applying the jackknife procedure. This was due to the number of missing data weights with large values and the small numbers of infants in the sample who died and had a reported birth weight. The estimation of the model parameters of some of the jackknife datasets proved difficult, and in some cases the model did not converge adequately. The implications of this will be discussed later.

8.3.5. Multilevel Multiple Imputation Analysis

The basis for the multilevel multiple imputation was the MLwiN macro written by Carpenter and Goldstein (2004). This original macro takes a model of interest, imputes the missing information for either the response or explanatory variables (or both) for a user-defined number of times before estimating the model of interest with the imputed data. It then combines the results into a final model. The macro has only been developed for use with a model of interest that has a continuous response. In this study the response variable is mortality, a binary variable. However, as birth weight is a continuous measure and is the variable that needs values to be imputed, the majority of the Carpenter and Goldstein macro can be used. A separate macro was written to ensure that the imputed birth weights were then entered into the logistic model studying mortality and the results of these models combined using Rubin's rules for multiple imputation. However, the main process to obtain the birth weight imputations utilising the hierarchical structure of the survey was the macro developed by Carpenter and Goldstein.

The variables used in the model to impute birth weight included all of the variables used in the model for mortality, as each has been seen to be related to birth weight (Kramer, 1987). A further variable also included in the imputation model which is known to be strongly related to birth weight is smoking (Butler *et al.*, 1972; Stein *et al.*, 1987). Although the DHS do not record if the mother smoked during the pregnancy it records their current smoking status, and this was included in the model for the imputation of birth weight. Mother's perception of the size of the child at birth was also included in the imputation model as it is highly related to birth weight (see Chapter 7). Backward stepwise selection for the model studying the determinants of birth weight was conducted to obtain the most parsimonious model in each country. As noted above, mother's perception of size also has a small amount of missing data and this was imputed alongside birth weight. As mother's perception is a categorical variable and the macro only imputes continuous variables, the variable was treated as continuous. Values were assigned to each variable, with 1 assigned to 'Very Small' and 5 to 'Very Large'. These imputed values were not used in any further models, but were only imputed in order to be able to impute birth weights for all infants.

A number of different options are required to be selected for the macro to be able to impute the relevant data. The number of levels in the data was set at four for Cambodia and Malawi (individual, household, cluster and province/region) while at only three levels for Kazakhstan (only five regions are defined in this country, and these were included as a fixed effect in the imputation model). The number of datasets to be imputed also varied between the countries. It is seen that the efficiency of an estimate does not increase greatly as more datasets are imputed, although with a high proportion of missing data more datasets are needed to obtain the same level of efficiency (Schafer, 2006). For Kazakhstan 5 datasets were imputed. In Malawi and Cambodia, with the greater amount of missing data, 10 datasets were imputed. A further option is the number of updates the MCMC sampler executes between drawing the different imputations. This was set as 500, which is above the value of 200 recommended by the authors of the macro (Carpenter and Goldstein, 2004) to ensure independence between the different imputed datasets. Birth weight was standardised before imputation, which also aids independence between imputation draws (Carpenter and Goldstein, 2004). After imputation, the birth weight variable was divided into five categories for each imputed dataset at +/-1 and +/-2 standard deviations from the mean. These categorised datasets were then used in the models to predict early neonatal, neonatal and post-neonatal mortality for each of the countries.

8.3.6. Model Selection and Comparison

Birth weight and all covariates were automatically entered into each mortality model and no selection process was conducted. This was to enhance comparability between methods and models. In some models the number of infants in some categories was very small. In these instances, where possible, categories were combined in order that there were larger numbers of infants in the categories. If this was required then the category grouping was replicated for all models studying that mortality definition in that country, again for comparability purposes. Reference categories were selected which were hypothesised to have the lowest odds of death.

The comparison of the results from each of the models is difficult to conduct simply by comparing the parameter values and standard errors for each variable, due to the different sample sizes in each of the models. To assess the results from each analysis, the sign and size of the estimates were studied, and although the significance of the parameter estimates was observed, this was not used as the main comparison tool. The main assessment was made with reference to the known relationship between the variables under examination and each mortality type taken from previous studies.

8.4. Initial Analyses of the Causes of Mortality within the First Year of Life

The mortality rates within each of the periods under study were easily calculated once the data for each country was restricted to only those infants who were born more than a year before the survey was conducted. The rates per 1000 infants for each country for neonatal, post-neonatal and early neonatal mortality are shown in Table 8.3. The mortality rates shown here differ slightly to those reported in the individual DHS country reports, and this is due to the different methods used to calculate the statistics and the different samples used (ORC Macro, 2005a). The method used here is simply the number of deaths in the period in question divided by the number of infants who entered into that period, excluding multiple births. Thus the rates for neonatal and post-neonatal mortality do not sum to the rate for infant mortality as they were calculated using a different denominator.

Table 8.3: Crude Early Neonatal, Neonatal and Post-neonatal Mortality Rates for Cambodia, Kazakhstan and Malawi

	Cambodia		Kazakhstan		Malawi	
	Deaths	Rate/1000	Deaths	Rate/1000	Deaths	Rate/1000
ENN Mortality	183	26.8	22	19.6	231	26.0
NN Mortality	224	32.7	26	23.3	290	32.7
PNN Mortality	394	59.7	32	29.7	593	69.1
Total Number of Infants	6830		1097		8871	

The early neonatal and neonatal mortality rates for Cambodia and Malawi are very similar, at about 26 deaths in the first week and 33 deaths in the first four weeks per thousand births. For post-neonatal mortality Malawi has a slightly higher figure than Cambodia, possibly reflecting a more adverse environment. In Kazakhstan the early neonatal and neonatal mortality rates are lower than in the other two countries, albeit by only a small margin. However, the post-neonatal rate is almost half of that seen in Malawi and Cambodia.

Exploratory analysis of the relationship between birth weight and ENN, NN and PNN mortality was conducted before the missing data methods were applied to the data. Birth weight was categorised into five different groups as explained. Association for the categorised birth weight was tested using a Chi-squared test and the results are presented for each country in Table 8.4. For the continuous measure of birth weight t-tests were used to test if there was a difference in the weights of those who had died and those who survived the period in question. The results of this are shown in Table 8.5.

Table 8.4: Number and percentage of infants who died in the ENN, NN and PNN periods for different categories of birth weight for Cambodia, Kazakhstan and Malawi

		ENN		NN		PNN	
		Deaths	%	Deaths	%	Deaths	%
Cambodia	Very Light	2	9.5	2	9.5	2	10.5
	Lighter than Average	2	2.1	2	2.1	7	7.4
	Average	10	1.5	11	1.7	16	2.5
	Heavier than Average	2	2.6	2	2.6	0	0.0
	Very Heavy	1	2.8	1	2.8	1	2.9
Kazakhstan	Very Light	6	15.8	7	18.4	1	3.3
	Lighter than Average	3	3.0	3	3.0	8	8.2
	Average	6	0.8	8	1.0	21	2.8
	Heavier than Average	0	0.0	1	0.8	0	0.0
	Very Heavy	0	0.0	0	0.0	0	0.0
Malawi	Very Light	3	6.1	5	10.2	2	4.5
	Lighter than Average	15	2.0	23	3.0	43	5.8
	Average	23	0.9	35	1.3	144	5.5
	Heavier than Average	7	1.3	7	1.3	32	5.9
	Very Heavy	1	0.8	1	0.8	11	9.0

Table 8.5: Average birth weight (grams) for infants who survived and died in the ENN, NN and PNN for Cambodia, Kazakhstan and Malawi

		Average Birth Weight (g)		
		ENN	NN	PNN
Cambodia	Survived	3203	3203	3209
	Died	3002	2996	3015
Kazakhstan	Survived	3306	3307	3315
	Died	2514***	2637***	3019**
Malawi	Survived	3206	3209	3206
	Died	3042	2921***	3262

* = P<0.05 ** = P<0.01 *** = P<0.001

In the three countries under investigation, out of the infants who were actually weighed, those who weighed more than 2 standard deviations below the mean birth weight were most likely to die in the early neonatal and neonatal periods. This was also the case for post-neonatal mortality in Cambodia, although in Kazakhstan and Malawi the lightest birth weight group did not have the highest percentage of infants dying in the PNN period. Chi-squared tests on these tables indicated that there is a significant association between birth weight and PNN mortality in Cambodia, between birth weight and all three different definitions of mortality in Kazakhstan and between birth weight and ENN and NN mortality in Malawi (all $P<0.05$). Cambodia may not show a significant relationship due to small numbers of infants who were weighed and who died in each weight category. If birth weight is taken as a continuous variable then the mean weight for those who died in each period is less than the mean weight for those who survived for all three countries. The one exception is Malawi in the PNN period, where those who died were recorded as weighing, on average, more than those who survived. The lack of significant differences in Cambodia and for ENN mortality in Malawi is likely to be due to the smaller sample sizes in these countries in this analysis due to a lack of infants with a recorded birth weight.

8.5. Results

This section will study the relationship between birth weight and ENN, NN and PNN mortality after applying the four different missing data methods: complete case (CC), inverse probability weighting (IPW), multilevel multiple imputation (MMI) and mother's perception as a proxy (MP). Only the odds ratios and significance for birth weight will be presented. The full models are presented in Appendix J. The results for each country will be presented in turn with a comparison of the results across missing data methods and mortality definitions.

8.5.1. Kazakhstan

As Kazakhstan only has a small amount of missing birth weight information it is simple to surmise that there will be little difference in the relationship between birth weight and mortality for each of the different missing data methods that use birth weight. However, this is not the case and there are some important differences seen in the odds of mortality between the three models which utilise the actual birth weight. Table 8.6 shows the odds ratios for the relationship between birth weight and mortality for each of the mortality periods. Also shown is the model using mother's perception of size as a proxy. Only three categories of birth weight/size were used due to the small sample numbers and the fact that no infants died in the large weight categories (see Table 8.4). The three largest weight and size categories were combined. The parameter estimates and associated confidence intervals for birth weight are shown graphically in Figure 8.1.

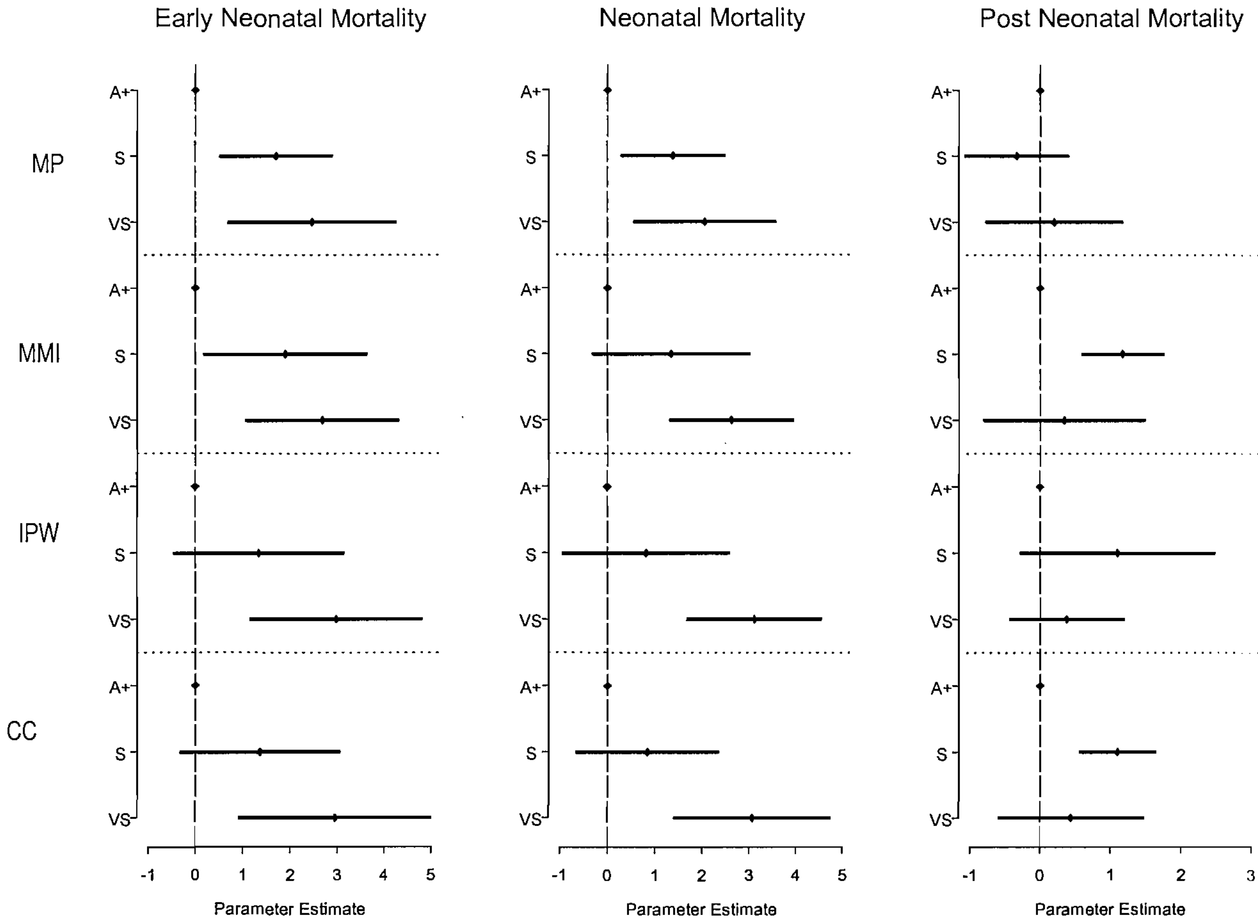
Table 8.6: Odds ratios of mortality in the ENN, NN and PNN periods for birth weight/ mothers perception for Kazakhstan

		CC	IPW	MMI	MP
ENN	Very Light	19.16*	19.71*	14.57*	11.76*
	Lighter than Average	3.91	3.82	6.69*	5.53*
	Average or Larger	1.00	1.00	1.00	1.00
NN	Very Light	21.56*	22.35*	13.71*	7.85*
	Lighter than Average	2.32	2.28	3.83	4.00*
	Average or Larger	1.00	1.00	1.00	1.00
PNN	Very Light	1.54	1.46	1.40	1.22
	Lighter than Average	2.99*	3.00	3.21*	0.72
	Average or Larger	1.00	1.00	1.00	1.00

*=P<0.05

The odds of death in the ENN and NN periods are greatly raised for infants in the lightest two birth weight groups when compared with infants who are of average weight or heavier. This is the result that would be predicted from previous research. The magnitude of this increase is very large in all models, with the CC analysis estimating that infants who are very small have odds of dying in the ENN and NN periods which are about 20 times higher than infants in the average or heavier group. In the PNN period the relationship estimated is completely different to that seen in ENN and NN mortality. In the CC model the very light infants are not significantly more likely to die in this period than those of average weight or heavier. However, infants who are recorded as being lighter than average are more likely to die in the PNN period than those categorised into the reference category. Raised risk of death is expected in both lower birth weight categories, and thus these results do not completely agree with previous research into birth weight and mortality in the post-neonatal period. However, it is clear after referring to Table 8.4 that in the PNN period 8 infants died who were of lighter than average weight, compared with only 1 infant who died who was very light. Due to the small numbers of infants who died the raised odds in the lighter than average group of infants may be due to sampling variation.

Figure 8.1: Parameter values and 95% confidence intervals of the relationship between birth weight and mortality in Kazakhstan



A comparison of the results between the different models shows that even though there is only a small amount of missing birth weight information in Kazakhstan, using different missing data methods can radically change the results. The complete case and IPW analyses are very similar in the odds ratios obtained. This is to be expected as the IPW weights used are very close to unity due to the small amount of missing data. Applying these missing data weights will therefore not make a large difference to the parameter estimates when compared with the complete case analysis.

The odds produced from the MMI model are noticeably different. The odds ratios for the very light infants for ENN and NN mortality are reduced when compared with the complete case analysis, whilst the odds for the lighter than average infants are increased. The results from the CC, IPW and MMI models for PNN are very similar. The reason for these large differences in the estimated odds ratios is that the MMI model includes all surveyed infants in the analysis, while the CC and IPW models exclude those without a birth weight. 30 infants are therefore excluded, 7 of whom died within the first year. Out of 21 early neonatal deaths, 6 do not have a reported birth weight and are therefore excluded from the complete case analysis. There are 25 neonatal deaths in total, and again 6 do not have a reported birth weight. Therefore the complete case analysis for ENN and NN mortality does not use roughly 25% of the deaths. In the post-neonatal period only one infant who died does not have a birth weight and hence the estimates obtained from each method are similar. This highlights the fact that the reporting of a birth weight is not randomly spread throughout the survey, and missing data methods are needed to obtain unbiased results even if there is only a small amount of missing data. The inclusion of the infants without a recorded birth weight in the MMI analysis, as these infants now have imputed birth weights, changes the results obtained as more information is available. The IPW analysis should have mitigated this effect by weighting infants who have died more than those who lived. However, although survival status is significantly related to the chances of a birth weight being recorded the weights produced from the model do not have much of an effect on the parameters estimated from the model.

Using mother's perception of size as a proxy for birth weight produces different estimated odds ratios from those seen in the three models using birth weight. The results for the very smallest infants in all three mortality models indicate that although there are raised odds of death compared to the reference category these are not of the scale observed in the other missing data models. However, for ENN and NN mortality the two smallest groups of infants are still both significantly more likely to die than their larger counterparts. Yet for PNN mortality the smaller than average infants are actually less likely to die than larger babies, which is not an expected result, although this odds ratio is not significantly different from one.

To assess which of the missing data methods produces results which are closest to those expected, the covariates in the model also need to be studied (see Appendix J for results). A comparison of the results from the complete case and IPW models shows only minor differences in the odds ratios obtained for the covariates, as expected due to the small missing data weights being used. The MMI models do differ in some respects from the CC and IPW models, although in many cases the differences are not large. The PNN estimates are very similar. For ENN and NN mortality the MMI model estimates, where different, could be considered to agree more with the expected results described in Table 8.1. For example, the parameter values from the MMI model for the combined birth order and birth interval variable indicate increased odds for short birth intervals but not for higher order births when compared to infants with a long birth interval and a birth order of 2 or 3. For the CC and IPW models there is increased risk for short birth intervals and higher order births. Where further differences in the model estimates are seen it could be argued that the MMI models follow the expected trends more closely than the CC and IPW estimates. The mother's perception proxy model also gives similar covariate responses for the PNN model as seen in the models using the other missing data methods. For NN and ENN mortality the parameter estimates for some variables do differ from those seen in the other models, and in some cases match the expected results better than the other methods.

In summary, the results from the CC and IPW models for birth weight can be viewed as biased due to the large proportion of infants who have died not being included in the analyses. The MMI and mother's perception models appear to estimate a feasible relationship between weight/size and mortality, at least in the ENN and NN periods. The covariate parameters do not change by a large amount between the different methods, although where there is a difference it could be argued that the MMI and mother's perception models give results closer to those expected.

8.5.2. Malawi

The large amount of missing data in Malawi indicates that the complete case analysis is likely to be highly biased as it is only using 44.1% of the available data. It is therefore expected that the missing data methods applied will change the parameter estimates. Table 8.7 shows the odds ratios for the three different mortality definitions for each of the missing data methods being used for birth weight and size of the child. Categories of birth weight/size were combined into four categories for ENN and PNN, but the five original categories were used for NN mortality due to the larger number of deaths in this period. Again, the estimated parameters for birth weight are shown graphically in Figure 8.2.

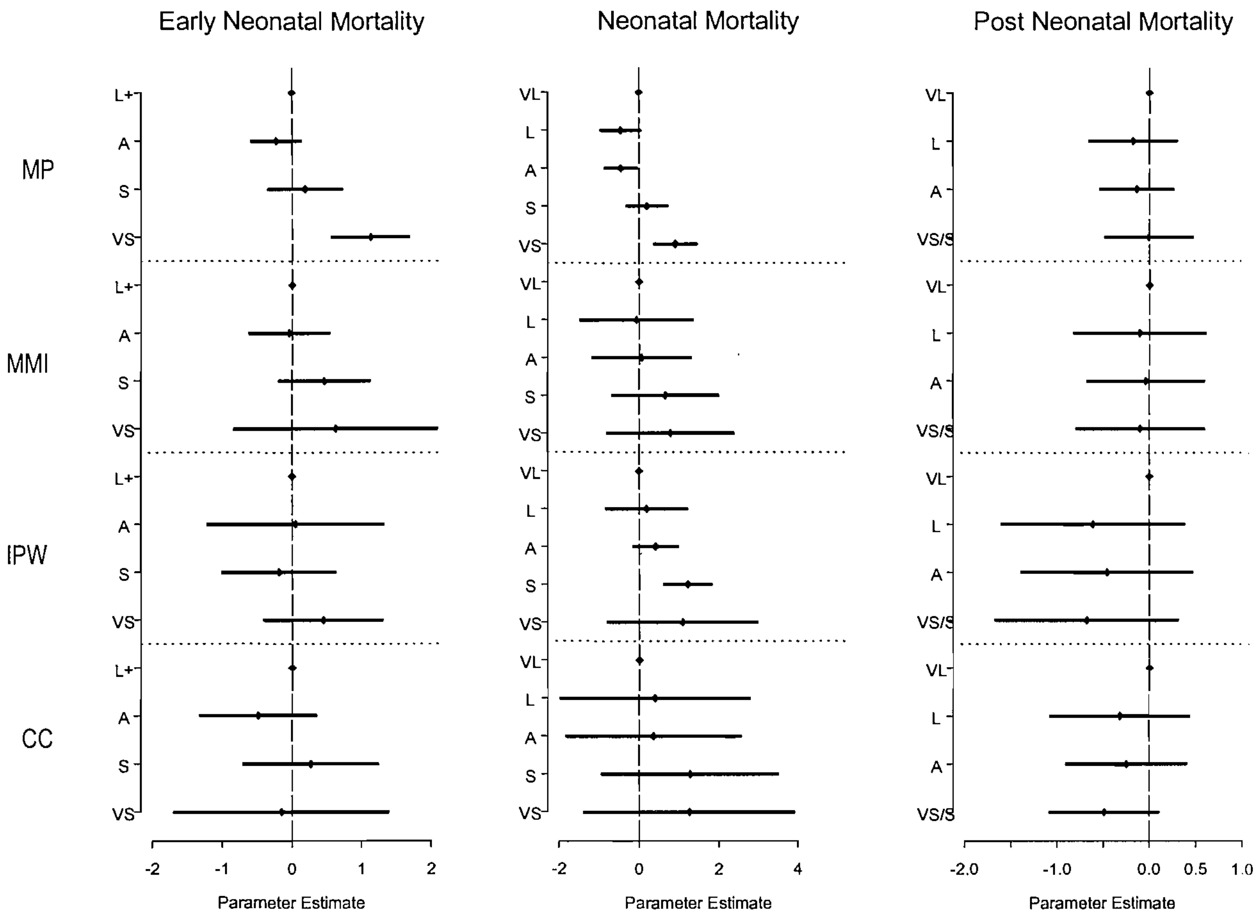
Table 8.7: Ratios of the odds of mortality in the ENN, NN and PNN periods for birth weight/mothers perception for Malawi

		CC	IPW	MMI	MP
ENN	**Very Light**	0.86	1.56	1.87	3.09*
	Lighter than Average	1.31	0.83	1.61	1.20
	Average	0.62	1.05	0.96	0.79
	Heavier than Av/Very Heavy	1.00	1.00	1.00	1.00
NN	**Very Light**	3.56	2.96	2.20	2.49*
	Lighter than Average	3.60	3.40*	1.93	1.22
	Average	1.44	1.51	1.06	0.64*
	Heavier than Average	1.50	1.21	0.93	0.63
	Very Heavy	1.00	1.00	1.00	1.00
PNN	**Very Light/Lighter than Av**	0.61	0.51	0.91	1.00
	Average	0.78	0.63	0.96	0.87
	Heavier than Average	0.73	0.54	0.89	0.83
	Very Heavy	1.00	1.00	1.00	1.00

*=P<0.05

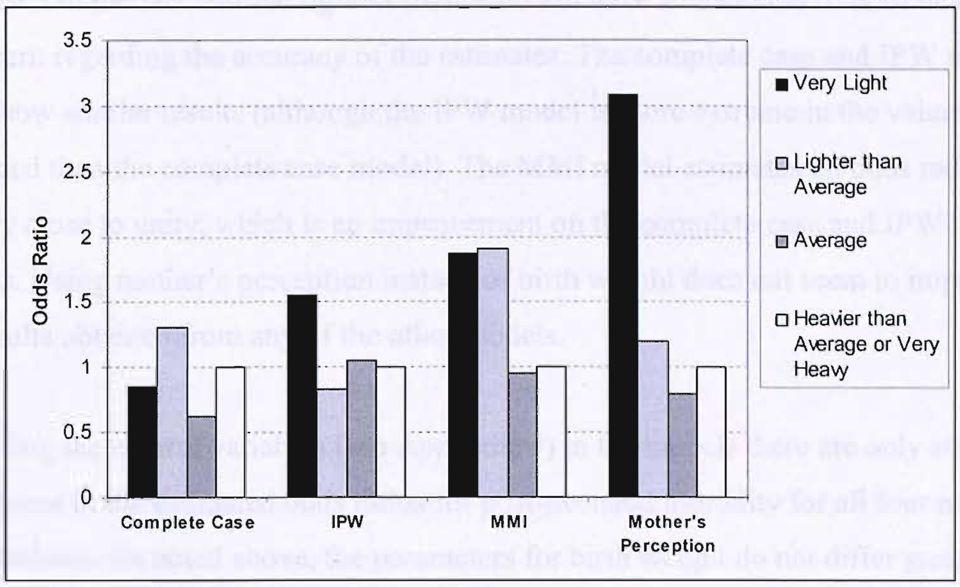
The results from each of the missing data methods indicate larger differences between the four missing data methods than seen in Kazakhstan. There are also differences in the relationship relating birth weight/size to mortality between the different mortality periods. The estimates for neonatal mortality are the closest to those expected, with higher odds for the lightest two birth weight categories when compared with the heaviest group for all models. The average and heavier than average groups do not show much difference in risk of death in this period compared to the heaviest category. For ENN and PNN there are differences between results from the missing data models, and these will be discussed below.

Figure 8.2: Parameter values and 95% confidence intervals of the relationship between birth weight and mortality in Malawi



There are no significant parameters (at the 5% significance level) for any of the models using birth weight relating to ENN or PNN. For ENN the complete case and IPW methods produce a confused picture of the relationship between birth weight and mortality, even though the odds ratios produced are not significantly different from the reference category. The differences between the models are easily seen in Figure 8.3 for ENN death. The reference category is infants who are heavier than average or very heavy.

Figure 8.3: Bar chart showing the odds ratios of early neonatal death in Malawi for different birth weight/size categories and for different missing data analyses



There are no clear trends that can be discerned in the complete case or IPW models. Indeed it is estimated that the very light babies have lower odds of death in the early neonatal period than the heaviest in the complete case analysis, which is known from previous studies to be unlikely. The profile shown by the bars estimated from the MMI model in Figure 8.3 follow the expected shape, with the very smallest having the high odds of ENN mortality, the smaller than average infants also having increased odds and minimal difference between the average and heavier infants in their odds of ENN death. However, the differences between the weight groups are not as large as expected. The mother's perception model does show a large differential in the odds between the smallest and largest infants, and the odds are significantly increased for the smallest infants, which is as expected. The three other categories are very similar for the mother's perception model, and there are not the increased odds of ENN death expected in the smaller than average infant category.

The results for post-neonatal mortality are surprising in that in all models there are reduced odds of death for all birth weight/size categories when compared with the heaviest birth weight category. Although the relationship between birth weight and mortality is attenuated somewhat in the PNN period there is still an increased risk of death for the lightest infants (McCormick, 1985), so the results obtained here do not agree with previous research. None of the results are significant, and thus there is no evidence to suggest that the lightest and smallest infants are less likely to die than the heaviest, but the fact that the lightest infants do not have an increased risk of death is a concern regarding the accuracy of the estimates. The complete case and IPW models both show similar results (although the IPW model is more extreme in the values produced than the complete case model). The MMI model estimates all odds ratios to be very close to unity, which is an improvement on the complete case and IPW models. Using mother's perception instead of birth weight does not seem to improve the results obtained from any of the other models.

Regarding the control variables (see Appendix J) in the models there are only small differences in the estimated odds ratios for post-neonatal mortality for all four missing data methods. As noted above, the parameters for birth weight do not differ greatly, although they do not follow the expected trends for the relationship between birth weight and PNN mortality. It may therefore be thought that the different missing data methods applied in this case do not improve the estimates obtained from the complete case analysis.

For ENN and NN mortality the covariates do differ between the different missing data methods. It is noticeable that the results from the MMI and mother's perception proxy models estimate similar odds ratios and the same variables are significant (except for first births for ENN mortality). Significance can be compared when using the MMI and mother's perception models as a similar sample size is used in both models. The results obtained from these two models, for both ENN and NN mortality are feasible and mostly agree with previous research. The results from the complete case and IPW models do not agree in totality, although in general the trends observed for these two methods for the different variables are similar. For some covariates in the complete case and IPW models, the estimates obtained are closer to those expected than the estimates obtained from the MMI and mother's perception models (e.g. wealth and birth interval/birth order in the NN period). However, where there are noticeable differences in the estimates between the complete case/IPW models and the MMI/mother's perception models it can be argued that the latter pair of models produces more coherent results.

The results obtained here from Malawi indicate some of the problems with comparing missing data methods when the 'correct' result is not known. As a result the assessment of the efficacy of the different methods is subjective. Saying that, it is fairly clear that the MMI and mother's perception models, at least for ENN and NN mortality, do give results closer to those expected from previous research. The results for PNN mortality, with very few differences between each of the methods results is confusing, especially as none of the estimates are close to those expected.

8.5.3. Cambodia

Applying the various methods to mitigate for the missing data in Cambodia is an interesting exercise due to the large amount of missing birth weight information. 86.1% of infants noted in the DHS do not have a recorded birth weight. Therefore the complete case analysis is only based on 13.9% of the infants, and these infants are not representative of all infants in the survey. Most missing data methods are not designed to deal with so much missing data (usually variables with so much missing data are simply discarded).

Before discussing the results of the mortality models an examination of the IPW analysis needs to be conducted. Two-thirds of the weights generated by the model studying the missingness of the data were over the designated threshold value of 4 (Table 8.2). The presence of so many large weights with only a small sample of infants with a recorded birth weight meant that the estimated standard errors of the parameters were very unstable when applying the jackknife procedure. In some instances the dropping of a single case from the analysis during the jackknife procedure led to large changes in the parameter estimates and the associated standard errors. The actual estimation of the parameters and standard errors also proved difficult when certain cases were dropped. For some of the variables in the model, in certain categories there is only one child who died. During the jackknife procedure this individual will be removed from the analysis for one of the models (as each case is removed in turn), and thus there will be a category where all infants survived. This produces infinite maximum likelihood estimates for this iteration of the jackknife. Obviously the parameters estimated in these instances are of no use in estimating the jackknife standard errors. For Cambodia there are categories with only a single death for all three definitions of mortality, and hence the jackknife standard errors are unable to be calculated for all Cambodia. The solution for this is to combine categories to ensure that during the jackknife procedure infinite parameter estimates are not estimated. This was not done so that models can be compared across all missing data methods. The problems encountered highlight the issues commensurate with conducting IPW analysis on a dataset with an extreme amount of missing data.

The estimated odds ratios for each of the missing data methods are displayed in Table 8.8. and the parameters and associated 95% confidence intervals in Figure 8.4. The estimates for the IPW analysis do not have the confidence intervals, for the reasons noted above.

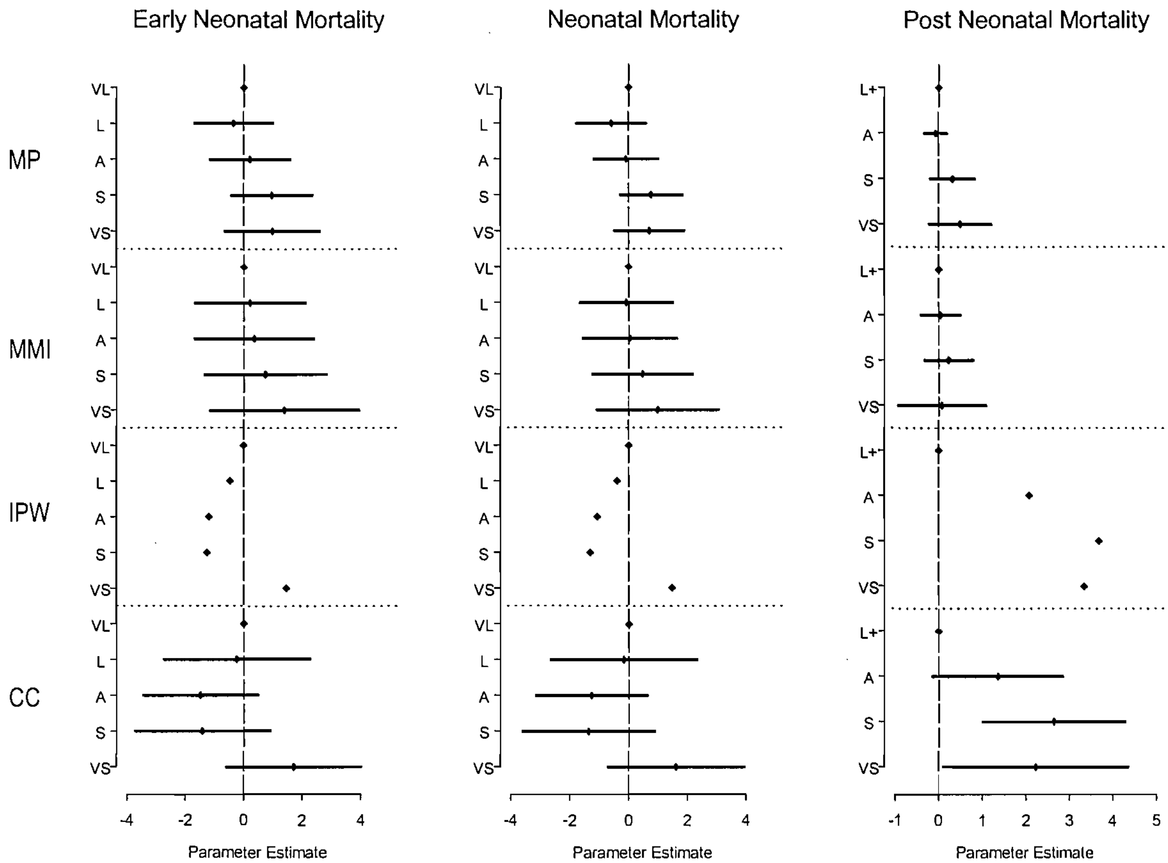
Table 8.8: Ratios of the odds of mortality in the ENN, NN and PNN periods for birth weight/mothers perception for Cambodia

		CC	IPW	MMI	MP
ENN	Very Light	5.58	4.31	3.99	2.65
	Lighter than Average	0.24	0.28	2.10	2.62
	Average	0.23	0.30	1.44	1.25
	Heavier than Average	0.79	0.64	1.24	0.71
	Very Heavy	1.00	1.00	1.00	1.00
NN	Very Light	5.03	4.37	2.66	2.02
	Lighter than Average	0.25	0.27	1.60	2.17
	Average	0.28	0.35	1.04	0.92
	Heavier than Average	0.84	0.68	0.92	0.56
	Very Heavy	1.00	1.00	1.00	1.00
PNN	Very Light	9.30	28.05	1.07	1.64
	Lighter than Average	14.06*	39.21	1.25	1.37
	Average	3.87	7.95	1.04	0.94
	Heavier than Av/Very Heavy	1.00	1.00	1.00	1.00

*=P<0.05

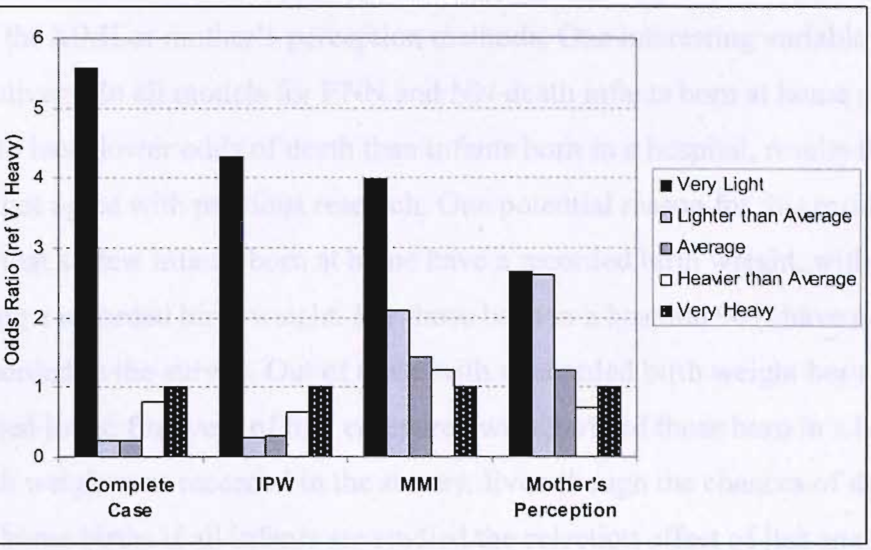
It is clear in Table 8.8 and Figure 8.4 that there is a paucity of categories of birth weight/size that are significantly related to mortality in the first year of life. Indeed, the only significant category observed is in the complete case analysis for PNN mortality, which, as noted before, has a weaker relationship with birth weight than ENN and NN mortality.

Figure 8.4: Parameter values and 95% confidence intervals of the relationship between birth weight and mortality in Cambodia



The comparison of the results from the different methods offers some interesting insights into the efficacy of the different methods. It is known that in general the lightest infants are most likely to die in all of mortality periods with decreasing odds of death as weight increases. However, for Cambodia both the complete case and IPW methods produce results which do not follow this trend for both ENN and NN mortality. The very lightest infants do have increased odds of death in these two periods, but there are substantially reduced odds for the other categories when compared to the heaviest infants. This can be seen in Figure 8.5 which displays the odds ratios for different categories of birth weight for ENN mortality. The results from the MMI analysis are encouraging as there is the steady reduction in odds expected as birth weight increases, although as mentioned earlier the odds ratios are not significantly different from unity. The model using mother's perception as a proxy is also an improvement on the complete case and IPW models, with increased odds in the two smallest categories, and small differences between the average, larger than average and very large categories in the odds of ENN death.

Figure 8.5: Bar chart showing the odds ratios of early neonatal death in Cambodia for different birth weight/size categories and for different missing data analyses



The relationship between birth weight and NN mortality for the four different missing data methods follows the same trends as for ENN mortality. The results from the complete case and IPW models do not show the trends expected, while the MMI and mother's perception models, although not exactly as expected, produce some encouraging results. For PNN mortality there are no real differences between the odds of death estimated in the MMI and mother's perception models (although there is some evidence of increased odds for the very smallest infants in the mother's perception model). The complete case and IPW models do show odds which are greatly increased for infants who are not in the heaviest two categories. Indeed, the magnitude of this increase in odds, especially for the IPW model, throws doubt on the results. Further doubt is caused by the increase in odds for the average weight infants compared to the heaviest infants. Although the chances of death do decrease slightly as weight increases across all birth weights (except when birth weight is extremely heavy) the chances of death are usually fairly similar for average weight and above infants, which is not seen in these two models.

Regarding the covariates in each of the models it is clear that the results from the MMI and mother's perception methods conform closest to the previous research in this area. There are very few differences between the parameters values for MMI and mother's perception. The IPW model produces some estimates which are extreme compared to the other models, although they are usually in the direction expected. The complete case method gives estimates which are close to those anticipated for some variables, but not for others, and therefore overall the method does not seem as reliable as the MMI or mother's perception methods. One interesting variable is the place of delivery. In all models for ENN and NN death infants born at home are estimated to have lower odds of death than infants born in a hospital, results that clearly do not agree with previous research. One potential reason for this result is due to the fact that so few infants born at home have a recorded birth weight, with only 6.7% having a recorded birth weight. For those born in a hospital 90% have a birth weight recorded in the survey. Out of those with a recorded birth weight born at home only 4% died in the first year of life, compared with 5.6% of those born in a hospital whose birth weight was recorded in the survey. Even though the chances of dying are higher for home births if all infants are studied the selection effect of just analysing those with a recorded birth weight gives the result that hospital births have higher odds of death. This result may also be obtained due to hospitals dealing with critically ill mothers and infants, thereby inflating the numbers of deaths of those born in a hospital.

Assessing the results for Cambodia, with such a high level of missing birth weight information, is difficult. The subjective analysis of the results conducted above indicate that the MMI and mother's perception proxy methods give results that would be expected if all birth weight was collected, or at least gives 'less bad' results compared with the complete case analysis. The IPW method seems to give results for some categories that are extreme, although the direction of these estimates is usually in the expected direction. This is likely to be due to the large missing data weights generated and applied in this method which places a large emphasis on few observations.

8.5.4. Summary

Noted throughout the above discussions of the results from the different countries using the different missing data methods is the difficulty in judging the method which gives results which are closest to those that would be obtained if no birth weight was missing. The true relationships between birth weight and mortality in the ENN, NN and PNN periods are almost impossible to ascertain in each country and thus the judgement of the most accurate results needs to be done subjectively. This is not ideal, but highlights the problems caused by missing data. However, it is clear that when the amount of missing data is extreme, such as in Cambodia, that the results for complete case analysis will be biased, and that the IPW method is not applicable due to the large magnitude of many of the missing data weights and small amount of cases in some categories of the covariates.

Over all three countries the two models which seem to give estimates which are closest to those that are expected are the MMI and mother's perception proxy methods. The odds ratios for birth weight/size at birth and many covariates are not exactly as predicted, but in many cases the results are better than those produced by the other two missing data methods. The IPW model did not cope with the missing data as well as expected. This may be due to misspecification of the original model which generates the missing data weights, although this is difficult to assess. The relative success of the MMI and mother's perception methods therefore calls for further investigation. The next two sections of this chapter study these two methods in more detail.

8.6. Multilevel Multiple Imputation Simulation

A simple technique to assess the performance of a missing data method is to use a dataset which is fully enumerated and to artificially simulate missing data within this dataset following a specified method. The missing data method in question is then applied to this reduced dataset, analyses performed and the results compared back to the results obtained when using the full dataset. In this study this cannot be done, as there are no DHS datasets used in this study with birth weight collected for all surveyed infants. The country with the lowest proportion of missing birth weight information, Kazakhstan, cannot be treated as a full dataset as it has already been noted that there are differences in characteristics between those with a recorded birth weight and those without. Therefore, to apply the MMI method to the datasets being used in this study the definition of a full dataset needs to be changed. In the following section a full dataset is defined as all infants with a recorded birth weight in a country.

Analyses can then be performed on these data to allow an assessment of the efficacy of the MMI method to be made in relation to the imputation of birth weight.

8.6.1. Methods for the Analysis of Multilevel Multiple Imputation

The analysis of the efficacy of the MMI method was conducted for all three countries. For each country different proportions of cases in the full dataset had their birth weights removed and the values set to 'missing'. The multilevel multiple imputation method was then applied to each of the reduced datasets. The imputations made by the method were assessed for accuracy by comparing to the 'true' results obtained before some data were set to missing. Further assessments of the efficacy of the MMI method were done by comparing the results for the multilevel logistic model studying mortality using the full dataset and the imputed data.

In all the countries studied birth weights are highly heaped (as reported in Chapter 4), although for the purposes of this investigation this heaping was ignored and the reported weights were taken as correct. The selection procedure for the cases to have their birth weight removed was not conducted using simple random selection, and was designed to mirror in some respects the pattern by which birth weight is missing in the full survey dataset. Thus variables that are related to the chance that an infant has a missing birth weight in the full survey dataset, as shown in Table 4.7, were used in the selection of infants to have their weights simulated as missing. Survival status, place of residence and birth and prenatal care are all highly related to the probability of a response to the birth weight question. Wealth is also strongly related to the probability of birth weight being collected in the survey. To select the cases to be set as missing, firstly a score was generated for each infant, with higher scores being given to infants who had a higher probability of not reporting a birth weight. This score was generated using the following expression:

$$Score = 1/(1+\exp\{\text{Wealth} + 1[\text{prenatal care obtained}] + 1[\text{hospital birth}] - 1[\text{rural dweller}] - 1[\text{infant had died}]\})$$

In the expression above wealth is defined as the continuous score obtained when calculating DHS wealth quintiles using principal component analysis, with poorer families obtaining a lower wealth score. The above score variable therefore gives a higher score to infants of poorer families, those born at home, whose mother's did not obtain prenatal care, lived in rural areas and who had died. These factors are all related to the chance of birth weight being obtained in the full dataset (see Table 4.7).

After obtaining the score for each individual with a recorded birth weight, different sized samples were selected with probability of selection proportional to this score. Therefore those with higher scores were more likely to be selected. This was conducted using Stata version 9 (StataCorp, 2005). The proportion of infants selected was set to be either 5%, 10% or 25%, and those who were selected had their birth weight deleted. The MMI method was then applied to impute birth weights for those who now had a missing birth weight following the method explained in Section 8.3.5. Five imputations were made for each country. The neonatal mortality model was then estimated using these imputed values.

To assess the estimates the results were compared to the complete case analysis already conducted for neonatal mortality (reported in Tables 8.6, 8.7 and 8.8 for Kazakhstan, Malawi and Cambodia respectively and also in Appendix J). Comparisons were made by simply contrasting the parameter values for both birth weight and covariates. Further assessments of the accuracy of the imputation procedure were conducted by comparing the imputed birth weights to the actual birth weights. The absolute difference between the imputed and actual standardised birth weights were assessed by calculating the mean difference for each imputation for the different levels of missing data in each country.

8.6.2. Results of the Analysis of Multilevel Multiple Imputation

Tables 8.9, 8.10 and 8.11 display the parameter values obtained from the complete case analysis and after applying the MMI method to different proportions of missing birth weight for Kazakhstan, Malawi and Cambodia respectively. The results for birth weight with a selection of covariates are displayed. The difference in parameter values between the complete case and the imputed analyses is also shown.

Table 8.9: Parameter estimates and differences to the complete case analysis after applying the multilevel multiple imputation method to datasets with different proportions of missing birth weight information in Kazakhstan

		Complete	5%		10%		25%	
		Case	Estimate	Diff[1]	Estimate	Diff[1]	Estimate	Diff[1]
Birth weight	Very Light	3.07	2.93	-0.14	3.24	0.17	3.35	0.28
	Lighter than Av	0.84	1.19	0.35	0.85	0.01	0.55	-0.29
	Average or Larger (Ref)	-	-	-	-	-	-	-
Birth Order /Birth Interval	First Birth	-0.43	-0.38	0.05	-0.41	0.02	-0.55	-0.12
	2-3rd/<24months	1.54	1.53	-0.01	1.49	-0.05	1.46	-0.08
	2-3rd/>24months (Ref)	-	-	-	-	-	-	-
	4th+/<24months	0.90	0.66	-0.24	0.85	-0.05	1.16	0.26
	4th+/>24months	1.13	1.04	-0.10	1.24	0.11	1.17	0.04
Wealth Quintile	Lowest	-1.53	-1.51	0.02	-1.41	0.12	-1.47	0.06
	Below Average	-1.91	-1.95	-0.03	-1.91	0.01	-1.77	0.14
	Average	-1.60	-1.71	-0.11	-1.56	0.05	-1.59	0.02
	Above Average	-2.12	-2.15	-0.03	-2.13	-0.01	-2.18	-0.06
	Highest (Ref)	-	-	-	-	-	-	-
Gender	Male	0.75	0.76	0.00	0.79	0.04	0.71	-0.04
	Female (Ref)	-	-	-	-	-	-	-
Place of Delivery	Home	-0.82	-0.82	0.00	-0.92	-0.10	-1.07	-0.25
	Institution (Ref)	-	-	-	-	-	-	-
Residence	Rural	1.30	1.36	0.05	1.29	-0.01	1.22	-0.08
	Urban (Ref)	-	-	-	-	-	-	-

[1] Difference in parameter values between the complete case and reduced datasets after applying the multilevel multiple imputation technique

Table 8.10: Parameter estimates and differences to the complete case analysis after applying the multilevel multiple imputation method to datasets with different proportions of missing birth weight information in Malawi

		Complete Case	5% Estimate	5% Diff[1]	10% Estimate	10% Diff[1]	25% Estimate	25% Diff[1]
Birth weight	Very Light	1.27	1.23	*-0.04*	1.37	*0.10*	0.20	*-1.07*
	Lighter than Av	1.28	1.32	*0.03*	1.07	*-0.21*	0.83	*-0.46*
	Average	0.37	0.42	*0.05*	0.47	*0.11*	0.21	*-0.16*
	Heavier than Av	0.41	0.52	*0.12*	0.36	*-0.04*	-0.01	*-0.42*
	Very Heavy (Ref)	-	-	-	-	-	-	-
Birth Order /Birth Interval	First Birth	0.60	0.64	*0.04*	0.67	*0.07*	0.71	*0.11*
	2-3rd/<24months	1.60	1.61	*0.01*	1.68	*0.08*	1.68	*0.08*
	2-3rd/>24months (Ref)	-	-	-	-	-	-	-
	4th+/<24months	1.17	1.20	*0.03*	1.21	*0.04*	1.21	*0.04*
	4th+/>24months	0.01	0.01	*0.00*	0.03	*0.02*	0.03	*0.02*
Wealth Quintile	Lowest	0.69	0.72	*0.03*	0.70	*0.01*	0.72	*0.03*
	Below Average	0.49	0.52	*0.02*	0.51	*0.01*	0.50	*0.01*
	Average	0.14	0.13	*-0.01*	0.12	*-0.02*	0.12	*-0.02*
	Above Average	-0.53	-0.55	*-0.02*	-0.57	*-0.03*	-0.58	*-0.05*
	Highest (Ref)	-	-	-	-	-	-	-
Gender	Male	0.08	0.08	*0.00*	0.08	*0.01*	0.09	*0.01*
	Female (Ref)	-	-	-	-	-	-	-
Place of Delivery	Home	-0.24	-0.27	*-0.03*	-0.23	*0.01*	-0.20	*0.05*
	Institution (Ref)	-	-	-	-	-	-	-
Residence	Rural	-0.19	-0.21	*-0.02*	-0.20	*-0.01*	-0.20	*-0.01*
	Urban (Ref)	-	-	-	-	-	-	-

[1] Difference in parameter values between the complete case and reduced datasets after applying the multilevel multiple imputation technique

Table 8.11: Parameter estimates and differences to the complete case analysis after applying the multilevel multiple imputation method to datasets with different proportions of missing birth weight information in Cambodia

		Complete	5%		10%		Complete	25%	
		Case	Estimate	Diff[1]	Estimate	Diff[1]	Case*	Estimate	Diff[1]
Birth weight*	Very Light	1.62	1.54	*0.07*	1.31	*-0.31*	1.74	1.82	*-0.08*
	Lighter than Av	-1.37	-1.44	*0.06*	-2.09	*-0.72*	-1.25	-1.56	*0.31*
	Average	-1.26	-1.27	*0.01*	-1.61	*-0.34*	-1.14	-1.05	*-0.09*
	Heavier than Av	-0.17	-0.27	*0.10*	-0.70	*-0.53*	-	-	-
	Very Heavy (Ref)	-	-	-	-	-	-	-	-
Birth Order /Birth Interval	First Birth	0.26	0.25	*0.01*	0.27	*0.01*	0.25	0.39	*-0.14*
	2-3rd/<24months	1.02	1.02	*0.00*	0.88	*-0.14*	1.04	1.11	*-0.07*
	2-3rd/>24months (Ref)	-	-	-	-	-	-	-	-
	4th+/<24months	0.00	-0.04	*0.03*	-0.17	*-0.17*	-0.01	-0.02	*0.02*
	4th+/>24months	-0.36	-0.37	*0.01*	-0.45	*-0.09*	-0.36	-0.19	*-0.17*
Wealth Quintile	Lowest	-0.74	-0.76	*0.02*	-0.56	*0.18*	-0.74	-0.56	*-0.17*
	Below Average	0.18	0.18	*0.00*	0.10	*-0.08*	0.20	0.19	*0.00*
	Average	0.18	0.22	*-0.04*	0.18	*0.00*	0.17	0.03	*0.14*
	Above Average	-1.41	-1.44	*0.03*	-1.39	*0.02*	-1.41	-1.49	*0.08*
	Highest (Ref)	-	-	-	-	-	-	-	-
Gender	Male	0.57	0.87	*-0.29*	0.73	*0.15*	0.87	0.83	*0.04*
	Female (Ref)	-	-	-	-	-	-	-	-
Place of Delivery	Home	-2.84	-2.88	*0.04*	-2.95	*-0.11*	-2.83	-2.82	*-0.01*
	Institution (Ref)	-	-	-	-	-	-	-	-
Residence	Rural	0.52	0.55	*-0.02*	0.62	*0.09*	0.53	0.42	*0.11*
	Urban (Ref)	-	-	-	-	-	-	-	-

[1] Difference in parameter values between the complete case and reduced datasets after applying the multilevel multiple imputation technique

* Not enough data to use five birth weight categories when 25% missing birth weight therefore only four categories used. CC is complete case analysis only using four categories of birth weight

It is clear from Tables 8.9, 8.10 and 8.11 that the results for birth weight need to be considered separately from the other covariates. When estimating the parameters for the relationship between birth weight and neonatal mortality the MMI method does not give results which are very close to the results obtained from the complete case analysis in each country. When there is only 5% missing birth weight information the results are similar to the complete case analysis for Cambodia and Malawi. Yet in Kazakhstan the estimated parameters when only 5% of the data are missing are different from the actual parameters observed in the full dataset. As the amount of missing data increases to 10% and 25% the parameter results for all countries diverge from the correct results in all countries indicating that there is still bias even after applying the MMI method. Indeed if neonatal mortality is only estimated using the reduced datasets (i.e. with 5%, 10% or 25% missing birth weight with no missing data method applied) the parameter values for some models are closer to the correct values than the values obtained after applying the MMI method.

However, the results for the covariates do not mirror those obtained for birth weight. Irrespective of the amount of missing birth weight information the parameter estimates for the covariates after imputation are close to those observed in the complete case analysis. This occurs even if the amount of missing birth weight data is 25% and holds for the covariates used in the models but not shown in Tables 8.9 to 8.11. The success of the MMI method to reduce the bias in the parameter estimates for the covariates in the neonatal mortality model, while not improving the bias related to birth weight, is interesting. One possible explanation for the covariate parameter estimates being close to the correct estimates is that models based on the reduced datasets are not actually biased and do not differ from models obtained when using the full dataset. To test this hypothesis the covariate parameter results obtained when using the reduced datasets were compared with the results obtained when using the full dataset results. The differences between the parameter estimates when using the complete and reduced datasets can be compared with the differences in the parameter estimates between the complete dataset and using the MMI method. The results of this analysis when there is 10% missing data are shown in Table 8.12. The results for 5% and 25% missing data are shown in Appendix K.

Table 8.12 and Appendix K indicate that when applying the MMI method to the datasets with the different proportions of missing birth weight information the estimates are improved in comparison to the estimates obtained when not applying any method. In Kazakhstan and Cambodia, in general, the MMI estimates are closer to the estimates obtained using the full dataset than those obtained using the reduced datasets. In Malawi the results obtained from the reduced dataset are actually better than those obtained from the MMI method. However the difference in the parameters between all models (full and reduced dataset and MMI method) is minimal. Again, the birth weight variable does not conform to the trend shown by the covariates. In each country the estimated parameters for the different birth weight categories obtained using the reduced dataset is closer to the actual parameters than the parameters obtained when using the MMI method.

A different way to assess the MMI method is to consider the accuracy of the actual imputations for the individual infants. This can be done for each of the five imputations and for the different levels of missing data (5%, 10% and 25%) to gauge if the imputed birth weights become less accurate as the proportion of missing data increases. This can be calculated in two different ways: the average absolute difference or the average actual difference between the actual and imputed birth weight. The average absolute difference will indicate the variability of the imputations, while the average actual difference will indicate how accurate the imputations are over all the imputations. These are shown for the three countries in Table 8.13. The units in all cases units are standardised birth weight.

Table 8.12: Differences in parameter estimates obtained between a) MMI method and full dataset and b) reduced and full dataset studying neonatal mortality in Kazakhstan, Malawi and Cambodia with 10% missing data

		Kazakhstan		Malawi		Cambodia	
		Difference MMI method to complete case	Difference no method to complete case	Difference MMI method to complete case	Difference no method to complete case	Difference MMI method to complete case	Difference no method to complete case
Birth weight	Very Light	0.17	0.10	0.10	0.13	-0.31	0.03
	Lighter than Av	0.01	0.02	-0.21	-0.18	-0.72	-0.54
	Average	-	-	0.11	0.02	-0.34	-0.13
	Heavier than Av	-	-	-0.04	0.04	-0.53	-0.26
	Very Heavy (Ref)	-	-	-	-	-	-
Birth Order /Birth Interval	First Birth	0.02	0.08	0.07	-0.09	0.01	-0.01
	2-3rd/<24months	-0.05	-0.10	0.08	-0.15	-0.14	-0.08
	2-3rd/>24months (Ref)	-	-	-	-	-	-
	4th+/<24months	-0.05	-0.17	0.04	-0.20	-0.17	0.16
	4th+/>24months	0.11	0.10	0.02	-0.31	-0.09	0.03
Wealth Quintile	Lowest	0.12	0.21	0.01	-0.06	0.18	0.48
	Below Average	0.01	0.03	0.01	-0.05	-0.08	0.35
	Average	0.05	0.00	-0.02	-0.07	0.00	0.23
	Above Average	-0.01	0.03	-0.03	0.02	0.02	0.16
	Highest (Ref)	-	-	-	-	-	-
Gender	Male	0.04	0.06	0.01	-0.04	0.15	0.15
	Female (Ref)	-	-	-	-	-	-
Place of Delivery	Home	-0.10	0.53	0.01	-0.19	-0.11	-0.16
	Institution (Ref)	-	-	-	-	-	-
Residence	Rural	-0.01	0.04	-0.01	0.08	0.09	0.07
	Urban (Ref)	-	-	-	-	-	-

Table 8.13: Average difference between imputed and actual birth weight for different proportions of missing data (unit of standardised birth weight)

	Kazakhstan		Malawi		Cambodia	
	Absolute	Actual	Absolute	Actual	Absolute	Actual
5% Missing	0.75	0.09	0.95	-0.02	0.80	-0.10
10% Missing	0.79	-0.10	0.96	-0.05	0.92	0.12
25% Missing	0.76	-0.07	0.95	0.02	0.83	0.01

The absolute differences between each of the imputations and the actual birth weight are quite large when averaged over all of the imputations. However, if the actual differences between the imputations and birth weight are averaged there are only small differences. This is encouraging. The variation of imputations over the different imputations is a feature of the multiple imputation technique and contributes to the estimation of accurate standard errors for model parameters. The fact that there are only small differences between the average birth weight over all imputations and the actual birth weight which has been set to missing indicates that the multilevel multiple imputation method is accurate at imputing birth weight.

One interesting point is that the accuracy of the imputations does not decrease as the proportion of missing data increases. Indeed, the actual difference between the imputations and birth weight is smallest in each country when 25% of the birth weight has been set to be missing. The absolute differences do not differ, irrespective of the proportion of missing data. This indicates that irrespective of the amount of missing data the MMI method imputes a similar range of birth weight values.

The standard errors of the estimates of the mortality models (for 5%, 10% and 25% missing data) were also compared to the standard errors of the model with fully enumerated birth weight. It was seen that the standard errors for birth weight and the covariate parameter estimates were similar, with the imputed models standard errors only deviating from the full model standard errors by a small amount (results not shown). These results lend weight to the argument that the multilevel multiple imputation method developed by Carpenter and Goldstein (2004) is a good way of reducing bias in models developed from datasets where there is missing data.

8.6.3. Summary of the Investigation into Multilevel Multiple Imputation

The results obtained from the simulation of missingness for the three countries in this study are encouraging. The method reduces the bias observed when analysing the determinants of neonatal mortality using a dataset with missing data. Yet the bias is not reduced for all variables. The estimated parameters for birth weight, the variable actually being imputed, is no better, and in many cases is actually worse, than if no method was applied to mitigate for the missing data. However, it appears that irrespective of this the parameter values for the covariates are dramatically improved. Thus applying the MMI method gives good results for covariates in the model but poor estimates for the main variable of interest. Studying the actual imputations closer it is observed that there is no drop off in accuracy of the imputed birth weights as the amount of missing data increases, and that the average value of the imputations are close to the actual birth weight. The variation of imputed values over each imputation dataset allows accurate estimates of the standard errors for parameter estimates to be calculated.

8.7. Mother's Perception as a Proxy for Birth Weight: Further Analyses

The results from Section 8.5 indicate that using mother's perception as a proxy for birth weight gives odds ratios which are close to those expected when analysing mortality in the first year of life. Bias was thought to be reduced when using this proxy variable when compared with the results when using only those infants with a recorded birth weight. However, this is difficult to assess as different sample sizes are used in the different analyses. Therefore to fully assess the accuracy when using mother's perception as a proxy for birth weight compared with simply using birth weight the same sample needs to be used.

The datasets for Cambodia, Kazakhstan and Malawi were restricted to infants with both a recorded birth weight and mother's perception of size at birth. The determinants of ENN, NN and PNN mortality were estimated on this dataset using either birth weight or mother's perception as an explanatory variable, alongside other covariates. The comparison of the results of these analyses can be easily conducted by comparing the odds ratios obtained from each model. The results are shown for neonatal mortality in the three countries in Table 8.14. The results for early neonatal and post-neonatal mortality are displayed in Appendix L. The substantive results in these models are not of interest in this analysis as the aim is to compare the models using birth weight and mother's perception using the same dataset, and thus will not be discussed.

Table 8.14 indicates that the parameter estimates obtained from models using the same infants and using either birth weight or mother's perception are similar for many of the covariates in Cambodia and Malawi. There is little agreement in Kazakhstan. However, there are large differences in the parameter estimates obtained for birth weight when compared with the parameter estimates estimated for mother's perception. In all three countries the estimated relationship between weight and NN mortality is different from the estimated relationship between size and NN mortality. Yet aside from a minority of covariate categories there is agreement in the estimates obtained irrespective of whether birth weight or size at birth is used in Cambodia and Malawi.

The general agreement between the parameter estimates for the covariates in two of the three countries, irrespective of if birth weight or mother's perception is used in the logistic model, lends weight to the argument that mother's perception can be used as a proxy for birth weight when birth weight is included as a control variable when modelling. The results from Kazakhstan are not so encouraging, although some covariate parameter estimates do show agreement. If the variable of interest is birth weight itself the results indicate that the estimates for the odds ratios between different size categories are not that accurate, and should be used with caution.

Table 8.14: Comparison of parameter estimates obtained from models studying neonatal mortality using birth weight and mother's perception for Cambodia, Kazakhstan and Malawi

		Cambodia			Kazakhstan			Malawi		
		Birth Weight	Mother's Perception	Diff	Birth Weight	Mother's Perception	Diff	Birth Weight	Mother's Perception	Diff
Birth weight	Very Light	1.62	1.17	*0.45*	3.07	1.96	*1.11*	1.27	0.65	*0.62*
	Lighter than Av	-1.37	-1.71	*0.34*	0.84	1.25	*-0.41*	1.28	0.06	*1.22*
	Average	-1.26	-1.61	*0.35*				0.37	-0.38	*0.75*
	Heavier than Av	-0.17	-1.59	*1.42*	0.00	0.00	-	0.41	-1.29	*1.69*
	Very Heavy (Ref)	0.00	0.00	-				0.00	0.00	-
Birth Order /Birth Interval	First Birth	0.26	0.12	*0.13*	-0.43	-0.23	*-0.20*	0.60	0.72	*-0.12*
	2-3rd/<24months	1.02	1.11	*-0.09*	1.54	1.83	*-0.29*	**1.60**	1.64	*-0.04*
	2-3rd/>24months (Ref)	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
	4th+/<24months	0.00	-0.20	*0.20*	0.90	0.69	*0.21*	**1.17**	1.14	*0.03*
	4th+/>24months	-0.36	-0.44	*0.09*	1.13	1.06	*0.07*	0.01	0.08	*-0.07*
Wealth Quintile	Lowest	-0.74	-0.41	*-0.33*	-1.53	-2.31	*0.78*	0.69	0.70	*-0.01*
	Below Average	0.18	0.31	*-0.13*	-1.91	-2.75	*0.84*	0.49	0.48	*0.01*
	Average	0.18	0.39	*-0.21*	-1.60	-2.71	*1.11*	0.14	0.12	*0.02*
	Above Average	-1.41	-1.34	*-0.06*	-2.12	-2.60	*0.48*	-0.53	-0.58	*0.05*
	Highest (Ref)	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
Gender	Male	0.57	1.08	*-0.51*	0.75	0.80	*-0.05*	0.08	0.11	*-0.03*
	Female (Ref)	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
Place of Delivery	Home	-2.84	-2.70	*-0.14*	-0.82	-0.42	*-0.40*	-0.24	-0.20	*-0.05*
	Institution (Ref)	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
Residence	Rural	0.52	0.53	*-0.01*	1.30	2.13	*-0.83*	-0.19	-0.23	*0.04*
	Urban (Ref)	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-

8.8. Discussion

In many surveys conducted in developing countries there are substantial amounts of birth weight not collected. This causes large problems when birth weight is used in demographic and epidemiological analyses as there are differences observed in the characteristics of infants with and without recorded birth weights. As a result it is necessary when using birth weight in analyses to use methods which take into account that the sample being used is biased in order to ensure that the estimates obtained are robust and accurate. These potential methods include applying statistical techniques to try and obtain reliable estimates when there is missing data. An alternative method is to use a proxy variable in the modelling procedure which is fully (or almost fully) enumerated. Both of these methods have been used in this study, and thus comparisons of results can be made between the various statistical methods used and also between the statistical methods and the proxy variable. Also important are the actual substantive results from the different models, although the purpose of this study is mainly to compare the missing data methods and assess if mother's perception of her baby's size can be used as a proxy for birth weight.

8.8.1. Comparison of Statistical Missing Data Methods

The three statistical missing data methods used, complete case, IPW and MMI, all gave different estimates of the relationship between birth weight and mortality in the early neonatal, neonatal and post-neonatal periods. Many studies investigating missing data methods use a complete case data set and artificially generate missing data within this dataset in order to assess the efficacy of methods. This process allows the comparison of the results obtained after applying missing data methods with the estimates obtained from analysing the complete dataset. However, in this study this option is not available. Birth weights are not routinely collected at the time of birth and as a result the true relationships between birth weight and other variables will never be known. Consequently, it is almost impossible to state with complete certainty which of the statistical methods used in this study is the best in determining the true relationship between the different explanatory variables and mortality. The estimates obtained from the logistic regression models for each definition of mortality can only be assessed against each other and previous studies. This assessment is subjective and it is always possible that the countries analysed do not actually follow established knowledge regarding these relationships. Nevertheless, for the purposes of this study it is assumed that Kazakhstan, Malawi and Cambodia do have the expected relationships between birth weight and mortality.

Complete case analysis can be described as a missing data method as the results from using such a method can be valid, and the use of the procedure in a study (hopefully) indicates a conscious choice by the researcher. Analysing only the complete cases is valid if the missing data mechanism is MCAR. It has been noted that for birth weight in these countries that the mechanism is not MCAR, but it is assumed to be MAR. Any analyses conducted on the restricted dataset will therefore produce biased estimates. This can be seen clearly for Kazakhstan. Although almost all birth weights are recorded, infants where this information is missing are more likely to have died, especially in the neonatal and early neonatal period. In general, the results from the complete case logistic regressions for Kazakhstan are feasible, although there are certain categories which do not display the expected relationship with mortality. As the proportion of missing data increases, in Malawi and then Cambodia, the estimates from the complete case analysis are observed to be more dissimilar from expectations. In Malawi the relationship between birth weight and early neonatal mortality and post-neonatal mortality does not conform to expectation, with the lightest infants being less likely to die than the heaviest. Unpredicted results are also obtained from Cambodia with regards to birth weight, although it is the lighter than average category that has much lower odds of dying than the heaviest infants in the early neonatal and neonatal periods. Other results obtained for the covariates from the complete case analyses in all three countries also indicate that this method estimates severely biased parameters.

Inverse probability weighting is a common method used when there is missing data, although the method is more commonly used when there is only a small amount of missing information. The successful implementation of the IPW method is reliant on the accurate modelling of the missingness mechanism which is then used to calculate the probability weights. One problem with this is that to model the missing data distribution accurately a complicated model may need to be constructed, and thus there will be many weighting classes generated. Cases in these weighting classes may have a small chance of having a recorded birth weight, especially when there is a large amount of missing data, and thus there will be large weights to be applied in the final model.

If it is assumed that the missing data mechanism model is correctly specified, the results of the analyses can be compared. The inverse probability weights generated for Kazakhstan do not show great variation and are close to unity due to the small proportion of missing data in this country. This means that the results for the IPW analysis are very similar to those seen for the complete case analysis. When the proportion of missing birth weight data increases, as in Malawi and Cambodia, there are more differences between the outcomes of the IPW and complete case analyses. For many covariates the parameter estimates for the IPW analysis are larger than in the complete case analysis.

It could be argued that the IPW procedure produces more extreme estimates than those seen when using only complete cases. If the complete case analysis indicates parameter values in an unexpected direction (when compared with previous research), the IPW method appears to increase these erroneous estimates in absolute value. This could indicate that the models used to model the missingness of the birth weight information are misspecified. However, it could also be due to the fact that a number of the weighting classes generated in Cambodia and Malawi do not actually have an individual within the class that has a recorded birth weight. Thus the effective sample size for the IPW analysis is not the same as the number of infants in the survey. Many infants will not be represented when conducting the modelling of mortality. The estimates produced from the IPW analyses will therefore still not be representative of all infants in the survey, just the infants who are contained within a weighting class with at least one infant with a recorded birth weight. This is further compounded by the number of inverse probability weights that are of a large magnitude and have to be truncated in Cambodia, further reducing the effective sample size.

A final problem seen when applying the IPW method occurs when attempting to calculate the standard errors of the parameters using the jackknife procedure. In Cambodia, when certain observations are dropped when conducting the jackknife procedure, infinite maximum likelihood estimates are observed for some parameters and the standard errors are highly variable for each different iteration of the jackknife. This obviously causes the jackknife standard errors to be of high magnitude. One way around this is to combine categories so there are adequate numbers of cases in each category even during the jackknife procedure. This was not done in this study to enable comparability between models. All these issues noted imply that the use of IPW is unreliable when there is a large proportion of missing data.

The final statistical method used to mitigate for the effect of the missing birth weight data was a technique that has been developed relatively recently, namely multilevel multiple imputation. The imputation of a number of different birth weights for those infants with missing information and then these birth weights being used in the investigation of mortality makes substantive sense. Rubin's rules for combining the estimates obtained from the modelling of each of the imputed dataset means that this process is relatively straightforward to conduct. Another benefit of this method is that a variable that is seen to be highly related to birth weight, mother's perception of size at birth, can be used in the model to impute the birth weight. Obviously mothers are not always accurate when categorising their child into the different size groupings, as has been seen in the previous chapter, but their judgement is the closest variable to birth weight that is available. Other covariates are also used in the imputation model to ensure that the imputed values take into account differences in mother's perception between different groups of mothers. The MMI method also copes with the small amount of missing data on the mother's perception variable by imputing this at the same time as imputing birth weight. Thus all infants have birth weight imputed and can be used in the analyses.

The results from the MMI analysis are encouraging. For Kazakhstan the parameter estimates are different from the estimates obtained from the complete case and IPW methods for early neonatal and neonatal mortality. This is likely to be due to the MMI analysis using all deaths in the dataset, whereas the complete case and IPW analyses do not use a large proportion of these deaths. The missing birth weights in Kazakhstan are concentrated in the group of infants who have died, heavily biasing the results. For post-neonatal mortality these differences are not seen, as only 2 deaths do not have a recorded birth weight and are thus excluded from the complete case and IPW models yet are included in the MMI model. For Malawi and Cambodia there is much less agreement between the MMI analysis and the other two methods, with few parameter estimates being of similar size, and this is likely to be due to the larger proportion of missing birth weights in these countries.

Regarding the actual estimates of the odds of death it is clear that the MMI estimates are close to those expected for birth weight and many of the covariates. The relationship between birth weight and mortality is as expected, with lighter infants having higher odds of death in all three periods than heavier ones. The difference between infants of average size and heavy infants is small. The post-neonatal mortality models in both Malawi and Cambodia do not show this trend, and there is no evidence that any weight categories have higher odds of death in this period. It would be expected that the strong mortality gradient observed as birth weight increases in the early neonatal and neonatal period is attenuated in the post-neonatal period, but the results obtained for these two countries indicate no such relationship. However, in Malawi the results from the MMI model are still closer to those expected than those seen in the complete case and IPW models.

By simulating missing data in the three countries a better understanding of how the multilevel multiple imputation method copes with missing data can be achieved. It is seen that although the individual imputations of birth weight are not that accurate and are highly varied, there is no noticeable degradation of this accuracy as the amount of missing data increases. The parameter estimates for birth weight indicate that the method does not give accurate estimates for this variable and may even give estimates which are further away from the correct results than doing nothing at all. Yet it appears that the method allows the accurate estimation of covariate parameters and, in many instances, dramatically improves on the estimates obtained if no method at all is applied. This occurs when the proportion of missing data is as high as 25%. Thus it could be thought that if birth weight is to be used as a covariate or a control variable in an investigation, that by performing multilevel multiple imputation the accurate estimation of the parameters of variables of interest in models can be achieved. If a method such as multilevel multiple imputation is not applied in these situations then biased estimates for the other variables in the model are likely to be obtained. However, this conclusion has only been reached for the relationship between birth weight and mortality in the first year of life and cannot be assumed to hold when there is a different outcome variable under study.

In summary, the MMI analysis appears to be the best of the three models in recreating the results that would be expected from similar countries if birth weight had been fully collected. The complete case and IPW models are very similar in certain respects, and some of the results that are obtained after using these techniques are incompatible with our expectations. This is not to say that these results are not correct, but just that in comparison to previous studies the results are unlikely. The problems with obtaining robust standard errors for Cambodia indicate further problems with using IPW with a dataset with a large proportion of missing data and a small sample size of complete observations. The MMI method does not produce estimates which completely reflect expectations, but it appears to proffer increased accuracy with respect to these expectations. Further studies indicate that the method is not accurate at estimating the parameters for birth weight itself but reduces the bias found for the covariate parameter estimates, even when a quarter of the birth weights are missing in the dataset.

8.8.2. Discussion of Mother's Perception as a Proxy

An alternative method to cope with the missing data on the birth weight variable is to use mother's perception of her child's size as a proxy for birth weight. Yet again there is the problem of judging how accurate the results are when using this proxy. As before, the results can be assessed against results from previous studies which use birth weight. Another method is to compare the results when using the mother's perception proxy against the results after using the other missing data methods as the same data is being used. Following the above discussion it is useful to compare the results with the MMI model. One problem with doing this is that when imputing birth weight in the MMI analysis the main variable which is used in the imputation model is mother's perception, and thus the results obtained are not truly independent. However, since the results from the MMI analysis do mirror established research for many categories it can still be considered valid to compare the mother's perception estimates with those obtained using the MMI method. A further benefit of comparing the results from these two methods is that there are similar sample sizes used, and therefore the significance of the parameters can also be compared between the two methods.

The main pattern that emerges when looking at the parameter estimates for the models using mother's perception is that no consistent patterns can be discerned. For some countries, and specific mortality definitions within those countries, the results are very similar to those obtained in the MMI analysis. Yet the estimates for other parameters are very different. When comparing the results for the actual mother's perception variable with the corresponding birth weight variable estimates for each country the findings are not encouraging. The lack of agreement between the MMI and mother's perception models for many of the models indicates that the two variables do not appear to be measuring the same phenomenon. Even more pertinently there are a number of models where the results do not mirror the results from previous studies. For example, the estimates relating to ENN in Cambodia indicate that infants who are smaller than average in size are much less likely to die than very large infants, when it is expected that they are more likely to die. However, in all of the models using mother's perception the very small infants do have odds of death which are comparable to the MMI model. This indicates that for the very smallest infants mother's perception may be a good proxy for infants with a very light weight at birth. Considering that the MMI method is likely to give good estimates for the covariates in the model, a comparison of the parameter estimates obtained from the mother's perception proxy model with the MMI model shows close agreement for Malawi and Cambodia. The results from Kazakhstan indicate large differences for early neonatal and neonatal mortality, but closer agreement for post-neonatal mortality.

The agreement between the MMI and mother's perception proxy models for the covariate parameter estimates may signal that the use of mother's perception instead of birth weight when studying mortality is feasible. The disagreement between the parameter estimates for the birth weight and mother's perception variables may be due to the relationship between birth weight and mortality. A continuous measurement of birth weight is likely to fit the data better than the categorised variable used in this study (used to ensure comparability between models). Splines and/or fractional polynomials of birth weight can be included in order that the relationship is not linear between birth weight and mortality. After using the multilevel multiple imputation technique it is possible to use the imputed birth weights as a continuous measure, although this was not done in this analysis in order to be able to compare the results to models using mother's perception. Mother's perception of the size cannot easily be converted into a meaningful continuous measurement and the simplicity of the variable may mean that it does not mirror the relationship between weight and mortality exactly, although its inclusion in a model is a good control and allows the accurate estimation of covariates.

8.9. Conclusion

The substantive results from this analysis are as expected, with the very light infants having a higher chance of death in the early neonatal, neonatal and post-neonatal periods than heavier infants after controlling for a number of potential confounding variables. This is not surprising, although some of the other differentials between birth weight categories for some models do not mirror expectations. Although the relationship between birth weight and mortality is extremely interesting the main purpose of this chapter is to assess if there are methods by which the estimation of the relationship can be improved if there is missing birth weight information. The results indicate that calculating improvements to the estimates for birth weight is difficult, with all methods assessed producing results which do not conform to results found in other countries with fully enumerated birth weights. However, two methods do seem to allow the accurate estimation of the relationship between covariates and mortality when controlling for birth weight. These methods are multilevel multiple imputation and using mother's perception of her baby's size at birth as a proxy for birth weight.

The development of the multilevel multiple imputation procedure is necessary for many situations where there is missing data in a clustered dataset, and the imputation of the missing data needs to take into account this clustering. However the method devised by Carpenter and Goldstein (2004) is not simple to implement, especially when the outcome variable is not continuous. Using the mother's perception of her infant's size is a far easier procedure as it is a direct substitution for birth weight and requires no manipulation. Yet it is clear that the results obtained when using both MMI and mother's perception as a proxy are not reliable for obtaining accurate parameter estimates for birth weight, but only for the covariates. This allows mother's perception to be used in models as a control when there are other variables under consideration, in order to obtain estimation of parameters for the variables of interest.

The exclusion of infants with missing birth weights from analyses biases estimates substantially, even where there is only a small amount of missing data such as in Kazakhstan. The use of mother's perception of her infant's size allows the inclusion of all infants in the analysis. Mother's perception also facilitates the use of multilevel multiple imputation as it is seen to be the best predictor of birth weight in the three countries in this analysis. Collecting information such as the infant's size at birth in surveys can be viewed as important when there is not full enumeration of infant weight as it allows it to be used either as a proxy variable or to impute birth weight. The results from this study should allow the inclusion of mother's perception as a proxy for birth weight as a control variable with a certain degree of confidence in future studies.

Chapter 8: Key Points

- Ignoring missing birth weight data when analysing the determinants of mortality yields severely biased estimates.
- Using inverse probability weighting to cope with missing birth weight information does not improve the estimates.
- Multilevel multiple imputation gives parameter estimates which are closer to the estimates expected when studying the relationship between birth weight and mortality.
- Covariate parameter estimates are accurate after applying the multiple imputation method when there is up to 25% of birth weights missing. Estimates for the parameters for birth weight itself are not accurate.
- Using mother's perception of size as a proxy of birth weight produces covariate estimates close to those produced after using multilevel multiple imputation.
- No method studied gives accurate estimates for birth weight parameters, but covariate estimates are improved using multilevel multiple imputation and mother's perception of size at birth.

Chapter 9

Discussion and Conclusions

This thesis addressed various methodological and substantive facets of birth weight data collected in 15 recent Demographic and Health Surveys. It has found that although the quality of birth weight data is generally poor that there are methods which can be applied in order to reduce the bias in the parameter estimates in models of child health. This chapter will further discuss the results obtained in the preceding chapters with reference to the research questions presented in Chapter 1. The overall conclusions from the thesis will be stated and some policy goals presented. Limitations of the study will also be discussed, and future work which may elucidate some of the findings in the thesis further will be presented.

9.1. Discussion

In Chapter 1 seven research questions were presented. Each of these will be briefly discussed, followed by a general discussion of the findings from this study.

Research Question 1: How accurate and representative are mothers at reporting their infant's birth weights?

Birth weights show a great amount of heaping. This, coupled with the large amount of missing data, calls into question the reliability of birth weight in these 15 Demographic and Health Surveys. Using the reported birth weights only represents a distinct subsection of the population: the wealthier, more educated urban dwellers who are alive at the time of the interview. These results agree with those of other authors (Da Vanzo *et al.*, 1984; Moreno and Goldman, 1990; Eggleston *et al.*, 2000). The estimated percentage of infants with LBW in most of the countries is below the level expected, and should not be assumed to be representative of the whole population of that country.

The distribution of the reported birth weights is as expected, being relatively normally distributed. There are more extreme weights than expected in some countries, indicating that some birth weights are incorrect or the infant was not weighed at the time of birth, but some time afterwards. Haiti is a country where the birth weights presented in the DHS are highly likely to be incorrect, and the data from this country are unusable. Birth weights in all countries need to be used with caution and the interpretation of any result which utilises birth weight needs to be conducted with the knowledge that the results will not be representative of the full population.

Research Question 2: Are there any differences in the distributions of birth weight by reporting method, either from a health card or from a mother's memory?

Infants whose weights were reported from their mother's memory had different characteristics to those whose weights were reported from a health card. Infants with memory recalled weights were more likely to be born at home, have died by the time of the interview and had mothers who were less educated. The percentage of infants with LBW is higher for infants with memory recalled weights. This is likely to be due to the differential characteristics of the infants by the method that birth weight is reported. The determinants of LBW do not differ by recall method.

Heaping of weights is a larger problem in memory recalled weights, although in some countries, such as India, there is also severe heaping on card recalled weights. More extremes in birth weights are observed in memory recalled birth weights. Weights officially recorded onto health cards are not as accurate as hypothesised, possibly due to poor measurement equipment, carelessness by the doctor or midwife, or rounding when transcribing the weight onto the health cards. Due to the extremes observed in memory recalled weights it may be that some infants are weighed some time after the birth or are actually never weighed at all and are given an estimate by a health worker who visits after the birth, as proposed by Robles and Goldman (1999).

Research Question 3: To what extent can mothers' reports of their babies' sizes improve the estimation of mean birth weight and the percentage of infants with LBW in a population?

Size at birth is skewed towards the larger sizes. This skew is more pronounced for those with a reported birth weight, as would be predicted due to the differences in the characteristics of infants with and without a reported birth weight. By applying the method devised by Boerma *et al.* (1996) and updated by Blanc and Wardlaw (2005) the proportion of infants with LBW increases in all countries. The proportions obtained are more realistic. Simply using the proportion of very small or and/or smaller than average infants to calculate the proportion of LBW will lead to incorrect estimates due to low sensitivity and positive predicted value (PPV) of using these size categories. No improved estimates could be obtained for Peru as the question regarding size was not asked. It is vital that in future DHS's that mothers are asked for an estimate of size of their children to allow improvements to the LBW estimates to be conducted.

Calculating the percentage of infants with LBW using size is dependent on many assumptions. The treatment of those weighing 2500g can be debated, but the proportion of infants weighing 2500g who are classified as LBW should differ between countries due to the different birth weight distributions in each country. By not classifying some of the infants who have weights heaped at 2500g as having LBW, estimates for the proportion of infants with LBW will be much lower than the actual figure in the population.

Research Question 4: Does the method by which birth weight is recorded in a survey influence the proportion of infants with LBW?

In general the sensitivity and PPV of a very small and/or smaller than average size to predict LBW is higher for memory recalled weights than card recalled weights. This indicates that there is greater agreement between size and actual birth weight for the lightest infants. Using memory recalled weights in the calculation of the percentage of infants with LBW and combining these weights with size at birth increases the percentage of LBW infants in each country compared with previous estimates.

Research Question 5: What are the maternal characteristics which are associated with an accurate assessment of the size of a baby at birth?

Many mothers do not assess the size of their infant correctly, if correctness is determined by birth weight. Infants who are born in hospitals are most likely to have a correct assessment made. Most infants' sizes are overestimated, although the reasons for this are not consistent across countries. These results may be explained by the fact that birth weight is not the only determinant of size, and other dimensions may be used (e.g. length, amount of fat). Also it may be known that 'bigger is better' in terms of an infant's size, and therefore the mother may overstate the size of their infant to the interviewer.

Research Question 6: What are the determinants of a mother's perception of the size of her baby at birth?

Birth weight is the strongest predictor of size, although there are other variables related to size perception. The determinants of size are similar for those with and without a reported birth weight. Size should not be viewed as invariant over time in the same way as birth weight can be treated as such, as classification of size increases over time in Cambodia and Malawi. Regional and cluster variation indicate that mothers differ in their size assessments in different areas of the country, potentially reflecting the actual size differentials across the country. This suggests that mothers do not only use the infants in the near vicinity to compare their child against, but may use babies from across the country as a comparison. There is a small local effect as well, with infants being compared to others in the local area.

Research Question 7: Are there any statistical missing data methods that can be applied to datasets which will reduce bias in the parameter estimates of the relationship between birth weight and early neonatal, neonatal and post-neonatal mortality?

Estimates are biased if only the infants with complete birth weight information are used in the analysis. Using the missing data method of inverse probability weighting does not improve these estimates. The multilevel multiple imputation procedure obtains estimates which are closer to those expected from previous research. This method uses the size assessments as an integral part of attaining the imputations, and this method is seen to be good at obtaining accurate estimates, even with 25% of the birth weights missing. Using mother's perception on its own also provides better estimates than using complete case analysis, although the estimates are not as close to those expected as seen when using multiple imputation.

The above results can be combined to answer three questions:

1. What is the data quality of the birth weight data in DHS?
2. Can mother's perception of size be used as a proxy for missing birth weight?
3. Can reliable and unbiased estimates of parameter coefficients be produced when there is missing birth weight information?

The birth weight data that are available are highly heaped and in some countries only a minority of children have a reported birth weight. It is difficult to decipher whether the birth weights that are recorded are useable as there is nothing to corroborate the birth weights with. Health cards were thought to be the 'gold standard', but even these are seen to be highly heaped in some countries. The differences in the distributions of weights by reporting method may be due to the different characteristics of the infants in each reporting method category. Clearly however, if only infants with reported birth weight are used then results and conclusions need to state clearly that the estimates are not representative of the full population. Comparisons between countries of birth weight distributions and the percentage of infants with LBW are difficult due to the different percentages of infants with missing data in each country, and the fact that different strata of infants in each country do not have a reported birth weight.

Overall, it is impossible to state definitively how good retrospective reports of birth weight are in DHS due to a lack of official corroborating records. Although retrospective surveys have been seen to be good in developed countries at collecting birth weight information (Gayle *et al.*, 1988; Tomeo *et al.*, 1999; O'Sullivan *et al.*, 2000), the culture of remembering these statistics is not as important in developing countries. As a result retrospective surveys in less developed countries do not obtain as reliable birth weight reports as obtained in more developed countries.

To obtain representative statistics it is important to combine birth weight with other variables, such as mother's perception of size. Size should not be used as a direct proxy due to the large proportion of infants who are misclassified into an incorrect size category, even though many studies have used the classification of very small or smaller than average as a response variable (Rodrigues and da Costa Leite, 1999; Magadi *et al.*, 2001; Ghosh, 2006; Magadi *et al.*, 2007). Size at birth does not only represent birth weight but includes many other dimensions of the child. In effect the variable could be more useful than birth weight in indicating health at birth as it is related to many variables rather than simply birth weight. The misclassification of size may not be as severe as presented in the analysis conducted in Chapter 6, as it is not birth weight being measured but overall size. However, the skewed distribution of size perception towards the larger sizes intimates that there may be a cultural component to this variable, with mothers overstating the size of their babies. To obtain more accurate estimates the interviewer could show the mother a picture of a child in each category of size, and the mother picks out the infant which is closest to her own.

Size assessment is only reported in five categories (four in India). Therefore it is not as good as actual birth weight measured on a continuous scale when conducting modelling procedures due to nonlinear relationships between birth weight and outcome variables being common. The combination of birth weight and size perception allows the benefits of both variables to be gained, especially in the imputation of birth weights for those infants without a reported weight in the survey.

The size assessment allows (almost) the full sample to be used, which is a huge benefit when attempting to obtain unbiased estimates from regression models.

The missing data methods used in the modelling of mortality in different periods of the first year of life indicate that the fact that even though there is missing data on the birth weight variable that this does not preclude more accurate estimates of the relationship between covariates and mortality. One issue with this is that there is nothing to compare the results with, and thus we can only us estimates from developed countries on which to base the comparisons. The multilevel multiple imputation method mirrors the method by which the sample was obtained, as the survey is hierarchical. This method also obtains imputed continuous birth weights which can be used in many other investigations. It is seen that this method reduces the bias in the covariate parameter estimates, but not for birth weight itself. The use of mother's perception of size to obtain these imputations is important for accuracy. However, in a country such as Cambodia with such a large proportion of missing birth weight information, any missing data method will struggle to produce unbiased estimates of parameter coefficients. When there is so much missing data in the dataset it may be better to accept that little can be done to reduce bias.

9.2. Study Limitations

As with all studies there are a number of limitations of the thesis that need to be highlighted, and results and conclusions of the thesis need to be interpreted with these limitations in mind. It is felt that these limitations do not undermine the conclusions that can be drawn from the thesis.

The countries selected for this study were chosen to represent different areas of the developing world. Many other countries could also be chosen either to complement or to replace any of the 15 countries which were included. The extrapolation of the results obtained here to other countries which conduct Demographic and Health Surveys must be done with caution, as each country has a different health system and the birth weight data may be of different quality (either better or worse) than the countries chosen. Furthermore, in some countries mothers may be better at judging the size of their child due to the information contained on the health cards, and thus this information will be more reliable (although this will only affect those infants with a recorded birth weight).

The samples within each of the countries are selected to be nationally representative, after weighting, for the sample selection methods. Obviously the results are affected by the sample taken, simply through natural sampling variation. This is intrinsic to all sample surveys, and little can be done about this. Taking larger samples would reduce this variation, although not eradicate it. Of more concern is if there are specific groups of infants that are not be included in the samples, possibly biasing the results. The procedures followed to select the sample are presented in the individual country reports of the results (ORC Macro, 2005a). In general, these procedures included stratifying the country into regions/provinces and again into urban and rural areas, and selecting a sample of villages from these areas through random selection from the most recent Census frame. This method assumes that the Census frame is correct, and little has changed between the previous census and the time of the survey. Also, little is stated about the sample selection methodology in cities, some of which may have large areas of land filled with temporary housing (i.e. shanty towns). The census frame may not be accurate in these areas as these areas may not be legal, and may therefore be excluded from the sampling process. Infants in these areas are in the poorest stratum of the population, and the exclusion of them from the survey may bias such statistics as the proportion of infants with LBW.

The information regarding the infant's birth weights are obtained from mothers. Between the date of the childbirth and the potential time of the survey the mothers may have died or they are still alive. If the mother has died, and their infant has also died, then the infant will be missing from the survey. If a child dies after the birth but the mother survives then their weight or size at birth should still be reported by the mother. However, if a mother dies in childbirth or soon afterwards all her infants will not be included in the analyses, as the information regarding birth weight and size at birth are obtained from the women's questionnaire. If both mother and her child died during childbirth (or soon after) then it could be argued that the child's information should not be included anyway, as only live births are supposed to be included. Deaths are not spread randomly through the population, and mothers who have died are likely to be poorer, and have infants who have a lighter birth weight. This is an issue, although the numbers involved are likely to be small, and have minimal effect on the results.

For the mothers who are still alive at the time of the survey, it is observed that if their infant has died before the interview that the infant's details are more likely to be missing from the dataset. As the death of a child is an emotional occurrence some mothers may not want to report these deaths. Also, infants who died very soon after birth may not be reported, even though the interviewer is asked to prompt for these infants. Again, infants who have died are more likely have a lower birth weight, and thus the exclusion of these infants may skew the results.

Many of the analyses in the thesis require birth weight to be categorised into groups. There are many ways by which this can be done, and this thesis uses standard deviations from the mean birth weight in each country to do this. This method was used as it is seen that the distribution of birth weight is essentially Gaussian (Wilcox and Russell, 1983), albeit with a long left hand tail. Categorisation into very light, lighter than average, average, heavier than average and very heavy categories can easily be conducted. However, the boundary points can differ. Here the cut-off points were set at +/- 1 and 2 standard deviations from the mean. Arguments can be made of choosing different values, such as +/- 0.5 and 1.5, although it is felt that the classification method used is as good, if not better, than any other method. Alternative methods that could have been used were to set certain weights as boundary points (i.e. all those weighing under 2000g to be classified as very light). To be of any use these boundaries should change in each country (especially in India) due to the different mean birth weights in each country, and to obtain consistency across countries this was not done.

By combining the reported birth weights with perception of size it is hoped that more accurate estimates of the proportion of infants with LBW can be obtained. It is thought that this method, developed by Boerma *et al.* (1996), leads to more accurate estimates. Yet this is difficult to verify. Due to the large percentage of infants who are not weighed it is unknown whether the estimates obtained when using the reported birth weights are biased, and if they are biased, to what extent. After applying the method it is also unknown whether the potential bias has been reduced or increased, as there is not a definitive source against which to judge. The results are thought to be more accurate, because the estimates of the percentage of LBW infants' increase, which is to be expected in countries with poorer nutrition when compared with developed countries. Yet this is a limitation of the thesis as the results cannot be verified.

Chapter 7 studied the determinants of size at birth. Firstly this was conducted for all infants, and secondly for those infants with a reported birth weight. It was seen that birth weight was a very strong predictor of size at birth for those infants with a reported birth weight. It was also hypothesised that size at birth is not just judged on birth weight, but also on other factors which are used in conjunction with the weight. These other factors, such as length at birth, arm circumference and the amount of fat, were not collected in the DHS (and indeed are rarely collected at the time of the birth). These are likely to be correlated with birth weight, but could have helped explain the variations in size perception.

Using different missing data methods in the analysis of mortality in the first year of life requires a number of assumptions. Both the inverse probability weighting and multilevel multiple imputation methods assume that the data is missing at random (MAR). This assumption can be challenged, as it is possible that the chances of a birth weight being reported are related to the actual weight, i.e. the weights of very light infants may be less likely to be reported than infants of average weight, and thus the data would be missing not at random (MNAR). This supposition can be challenged that although lighter infants may not be reported this is more likely to be due to the infant's survival status rather than the actual weight of the infant. Lighter babies are more likely to die than heavier babies and thus the higher chances of infants with lighter weights having missing birth weight information is due to survival status and not the birth weight itself. As a result the missing data mechanism is MAR. However, this cannot be verified, and there is a possibility that the missing data mechanism is MNAR.

The assessment of the four different models used in Chapter 8 also has limitations, many of which have been discussed earlier. Comparisons of the odds ratios estimated from each of the models can only be conducted through contrasting the results against each other and also by referring to previous research to assess their accuracy. Yet the studies that are used in the comparison are either from a developed country or from studies from countries with missing birth weight information. As the determinants of infant mortality differ in developed countries for those in developing countries the comparison of the results may not be reliable. Studies which use information which is partially missing may not produce accurate estimates, and thus comparison against these studies is not valid. However, due to the paucity of studies in developing countries which are not based in hospitals or with a population which has fully enumerated birth weight there are few studies which can be used as a comparison. In most cases the weight of evidence from all studies into the relationship between birth weight and mortality do give a clear idea about the relationships expected in the developing countries.

A final limitation is the weighting due to the survey design in multilevel models. Due to the sample selection procedure households are not selected with an equal probability, and therefore weighting is required to obtain representative estimates of statistics. Applying weights when using multilevel modelling techniques is difficult unless the weights at each of the different levels in the model are known, which typically they are not. In this study, sampling weights are commonly applied at the individual level, leading to incorrect estimates of the variation at the different levels. This weighting for the sample design was not conducted if the variation at the different levels itself was of interest. In the instances when sample weighting was performed the coefficient parameters will be unbiased and account for the clustering of the data (Pfefferman *et al.*, 1998). However, a recent article has indicated that this may not be the case for logistic models (Rabe-Hesketh and Skrondal, 2006) and that the parameter estimates may be biased when applying weights at the individual level. This finding may give rise to some estimates in this thesis being biased, although the scale of this bias is not known. Further work needs to be conducted in this area to understand exactly what the effect of applying survey weights at the individual level is, and as the effect is not fully understood no changes were made to the estimates in light of this recent research.

9.3. Further Work

The work presented in this thesis can easily be extended in order to obtain further understanding of birth weight in developing countries. Further analyses will also enable the improvement of estimates when using birth weight which is not fully enumerated. A number of suggestions for studies which could aid in the understanding of these issues are noted in this section.

It is clear that this thesis is concerned with the quantitative analysis of birth weight and size at birth. The association between weight and size can easily be demonstrated. Yet this does not indicate the process by which a mother decides on the size assessment. It would be very interesting to conduct qualitative analysis to enable better understanding of the underlying process behind this decision. Interviewing mothers and attempting to get these mothers to elucidate the reasons behind the size assessment would be very interesting. Focus groups could also help to identify the infants that are used for the comparison of size by the mother, and to clarify what exactly 'size' means to a mother when asked. This will confirm or refute the idea that size can be used as a proxy for birth weight.

The accuracy of retrospective surveys in obtaining birth weight information can be tested for those with a health card. Mothers who do have a health card containing the birth weight can be asked to recall the birth weight of their infant from memory. This can then be compared to the birth weight stated on the card. The relative accuracy of retrospective surveys in developed and developing countries can then be compared. This study must assume that the birth weights reported on health cards are correct, although this assumption has been seen to be incorrect in a number of countries in this thesis.

In countries where the health card birth weight data are highly heaped it would be interesting to analyse hospital records. These records will inform if the card recorded birth weights are heaped at the time of measurement or when the weights are written onto the health card. Conducting a hospital study will also indicate the degree of accuracy when the weights are taken and whether this accuracy is driven by the equipment or rounding by the doctors. It will also be able to identify how many of those weighing 2500g are actually of LBW if exact weights are taken, using precise weighing scales. These precise weights can be compared with the weights recorded using the standard equipment currently used in the hospitals and with the birth weights reported to the mothers.

Multilevel multiple imputation is an interesting advancement in the missing data methodology, and is seen to provide good estimates of parameter values even when there are high levels of missing data. More research is needed on this technique, and applying the technique on a dataset with fully enumerated birth weight would allow the confirmation of the applicability of the method to impute birth weight. By randomly making some of the birth weights missing following a predefined rule and imputing these weights will validate this method. The presence of a dataset with all birth weights available is not difficult to find in developed countries. However, to mirror this study the dataset will also need to contain the mother's perception of size, which is rarely asked of a mother in developed countries where birth weights are routinely measured.

One benefit of using the multilevel multiple imputation procedure is that continuous birth weights are imputed, and these can be used in further studies. In this thesis the imputed weights were categorised into five groups in order to be able to compare with mother's perception of size, but doing this loses much information. Using the continuous imputed birth weight variable, and using splines or fractional polynomials of birth weight will produce a more realistic picture of the relationship between birth weight and mortality. Alternative outcome variables can also be investigated, such as morbidity and educational outcome, with the imputed dataset.

9.4. Summary

The aim of this thesis was to investigate birth weight data collected in 15 Demographic and Health Surveys. From the results of the analysis it is clear that the quality of the data is generally poor in comparison to the standard of the data obtained in retrospective surveys in developed countries. The main reason for this conclusion is the amount of missing data that is seen in the surveys, and the fact that these missing data are not spread randomly across the respondents. These missing data are not found as a result of the retrospective survey process, but due to the poor health systems within many of these countries. Birth weights cannot be reported unless they were taken at the time of the birth, and it must be a long-term aim to improve coverage of health facilities to increase the proportion of infants with a recorded birth weight. Increasing the proportion of infants weighed is not an aim in itself, but will be a by-product of general improvements to health systems. Health statistics are a vital part of any health system, as seen by the success of the Health Metrics Network which aims to improve the ability of countries to provide such information (Health Metrics Network, 2006).

But how good is the birth weight data that are actually reported in the DHS? The results are not encouraging, with a high proportion of heaped weights in weights reported both from a health card and from memory. Calculating statistics from these data is laden with problems, especially for such estimates as the proportion of infants with LBW, due to heaping. It is clear though that the combination of reported birth weight with an infant's size assessment allows the full dataset to be employed in the calculation of national statistics and improves the validity of the birth weight estimates.

Mother's perception of size is strongly related to birth weight, although there are many mothers who overestimate the size of their infant. It is seen that the assessments of size change over time and that the characteristics of the infant and parents, especially mothers, influence the accuracy of the assessment. The judgement of size appears to be the same irrespective of whether the infant has or does not have a recorded birth weight. Using birth weight in countries where there is a large proportion of missing birth weight information is difficult to justify, so alternative methods need to be applied. For statistical models which need to control for birth weight it appears valid to use mother's perception of size instead of birth weight when birth weight is needed to be controlled for. The missing data method of multilevel multiple imputation, recently developed by Carpenter and Goldstein (2004) is encouraging, at least for the estimated values of parameters for covariates if not for birth weight itself. More work needs to be conducted on this technique, but the use of mother's perception of size in the imputation model is important to improve accuracy of imputation of weights. Birth weight data can be combined with mother's perception in order to obtain better estimates. The use of mother's perception by itself should be conducted with caution due to the varying degrees of misclassification by the mothers.

The amount of missing birth weight data in some countries precludes the use of any techniques to obtain good statistics. When three-quarters of infants in a survey do not have a reported birth weight then it will always be difficult to obtain estimates which are not viewed with scepticism, and even when there is far less missing data than this, the estimates can be questioned. The only option in these countries is to exclude birth weight from the analyses, or use mother's perception as a proxy variable. However, the collection of birth weight is important in surveys such as the DHS, but until the health systems develop to a standard where weights are taken to a good degree of accuracy there will always be issues surrounding estimates which use birth weight.

Appendix A

Figure 4.6 displayed each of 14 countries birth weight distributions against the theoretical normal distribution. This Appendix shows Q-Q plots of birth weights in each country plotted against the birth weights in each of the other countries. These plots aid the assessment of similarity of birth weight distributions for the different countries in the analysis.

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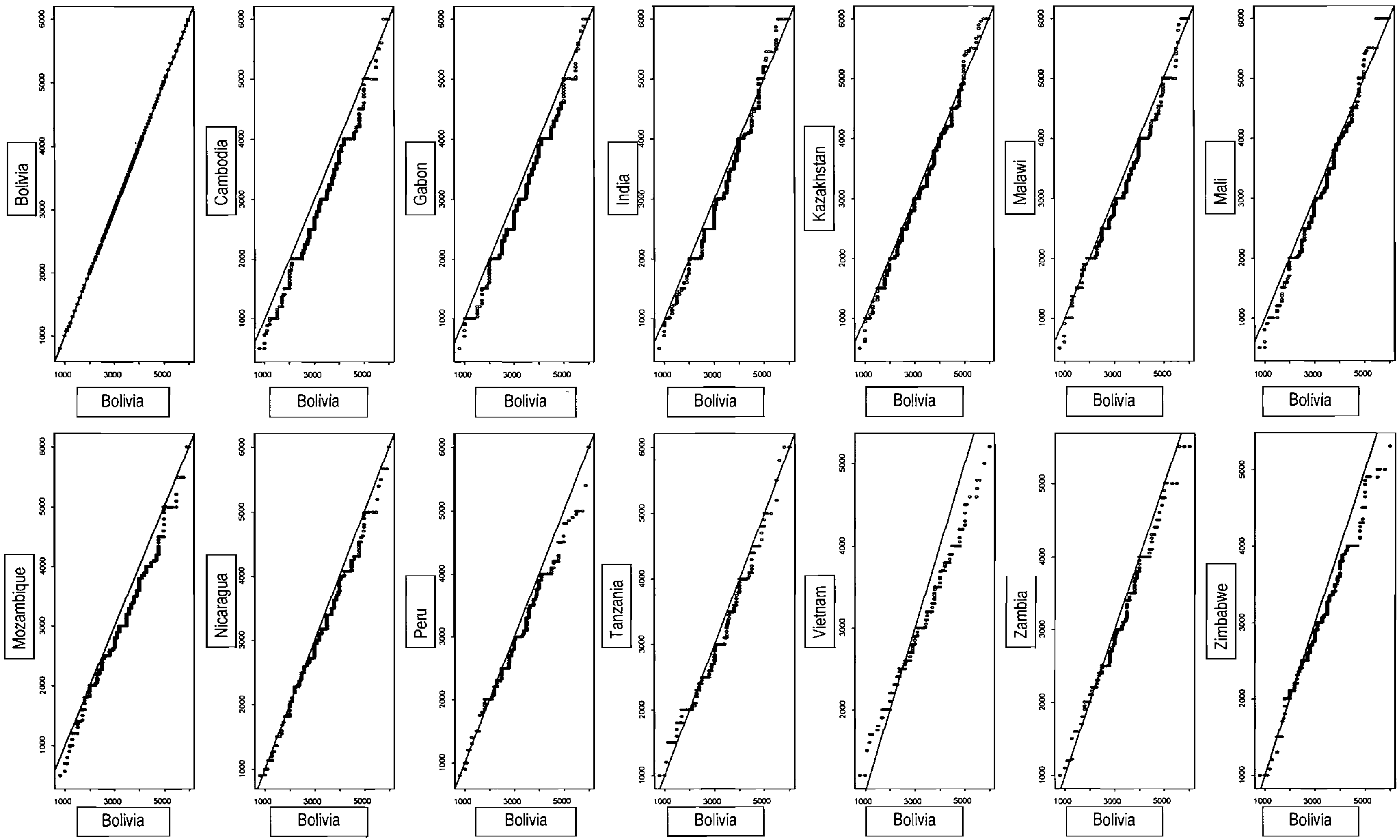

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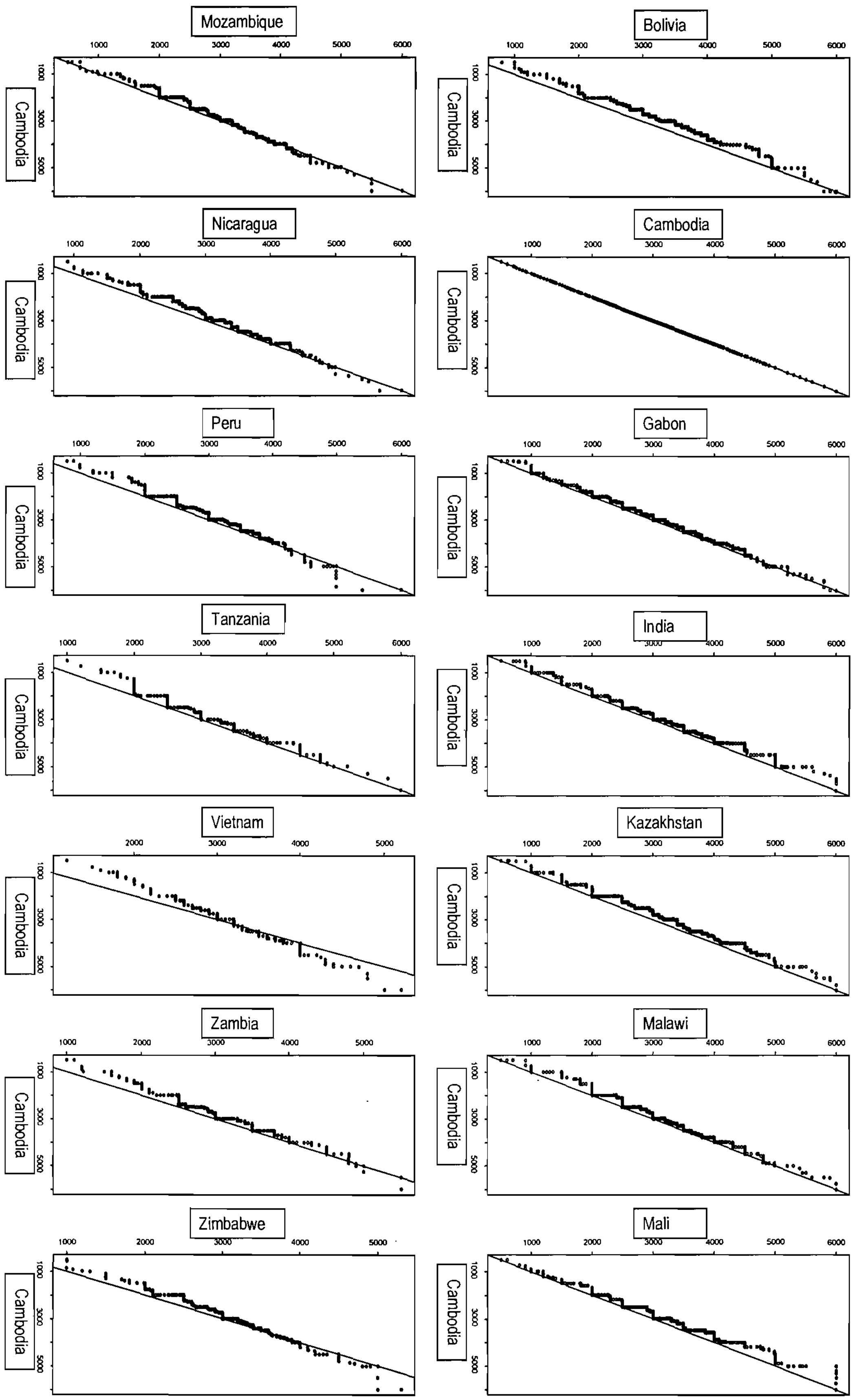
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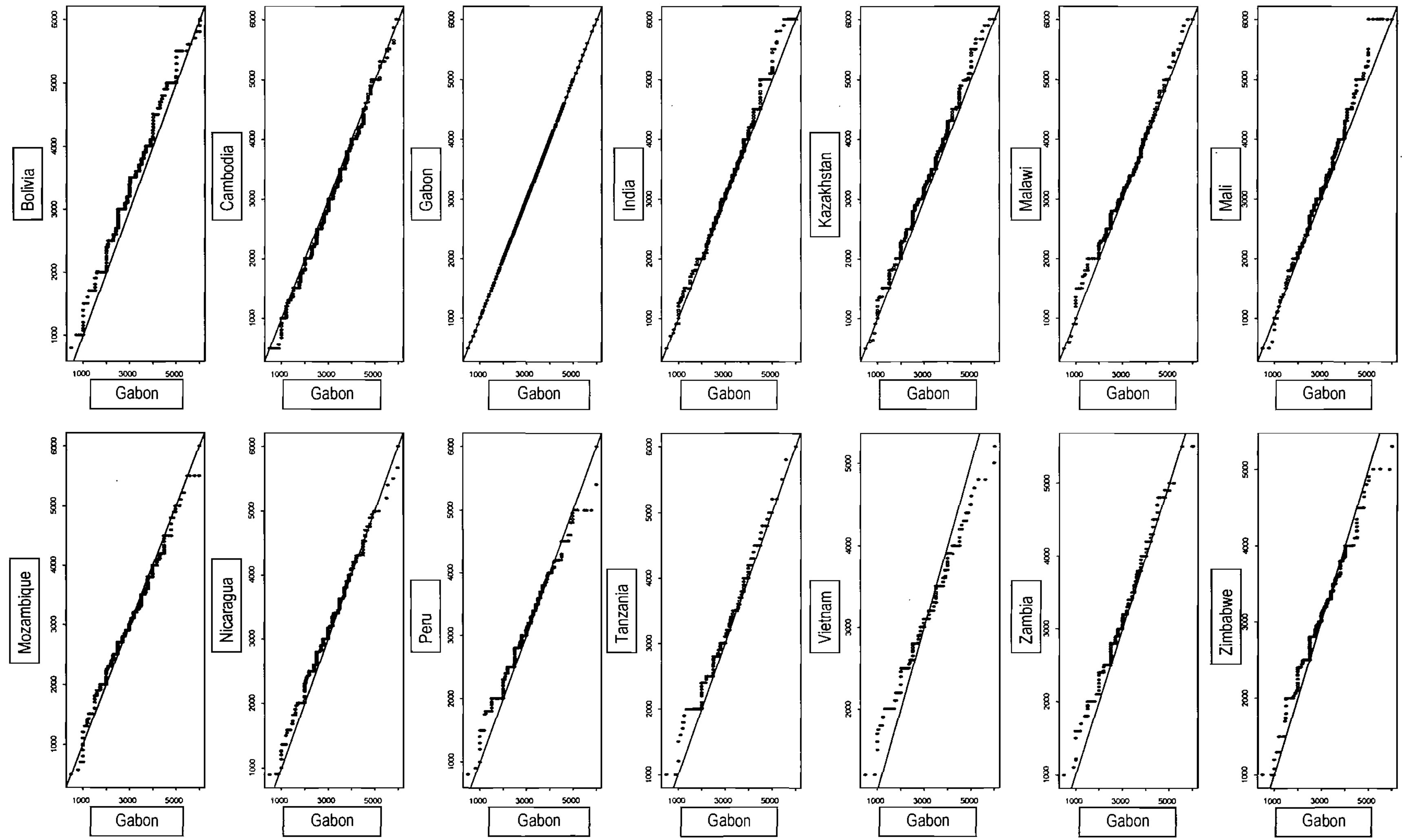

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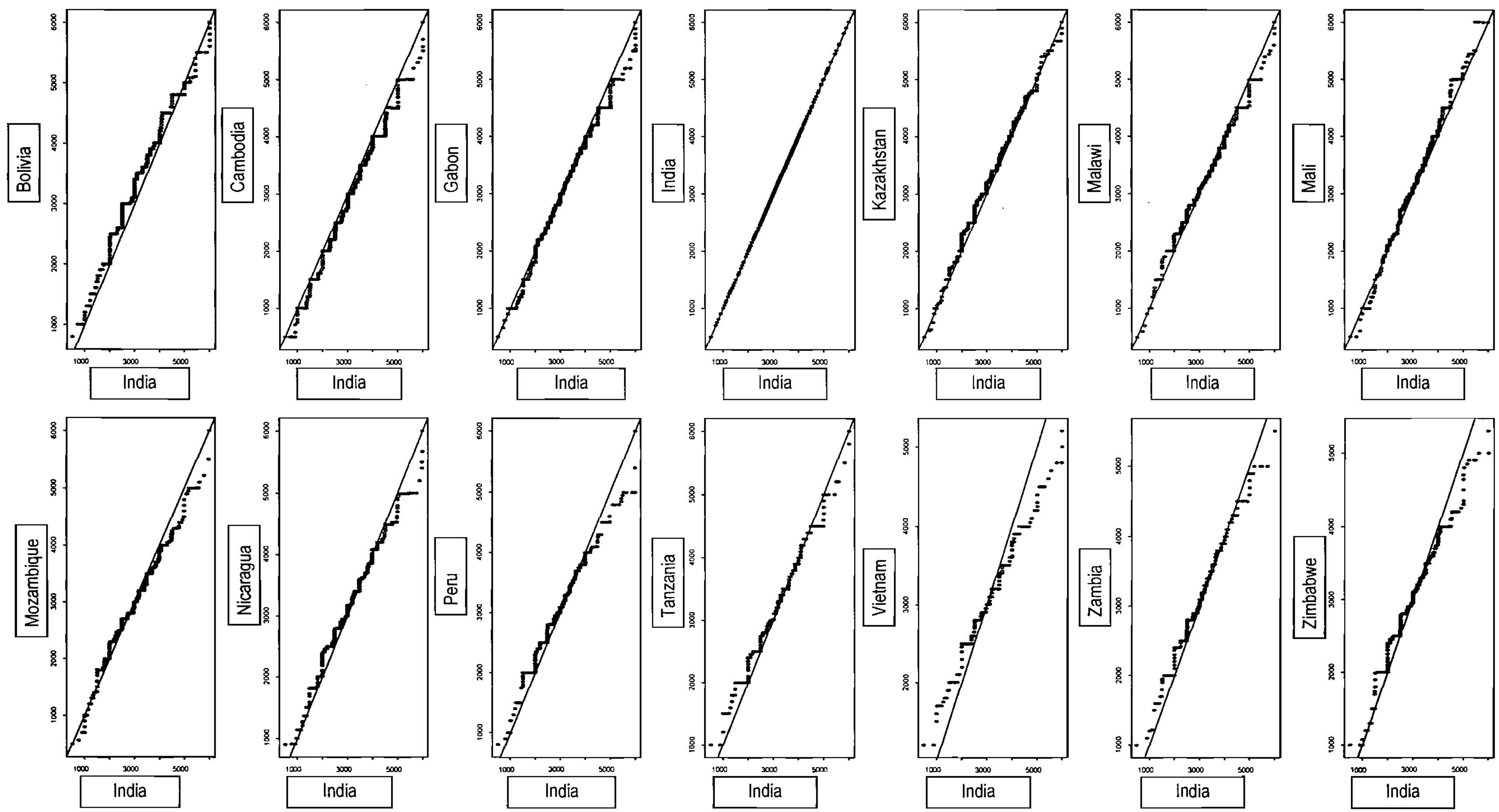
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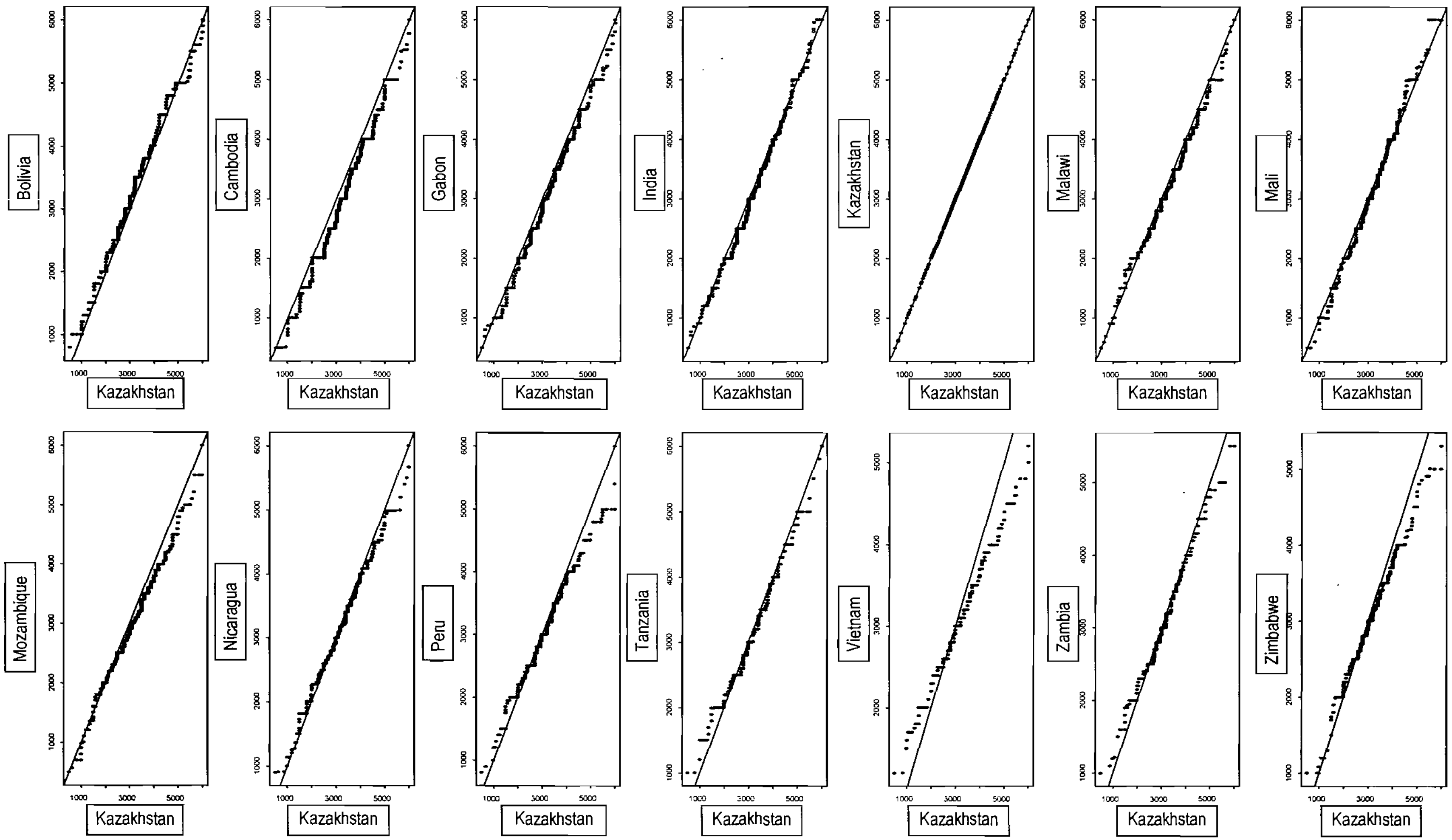
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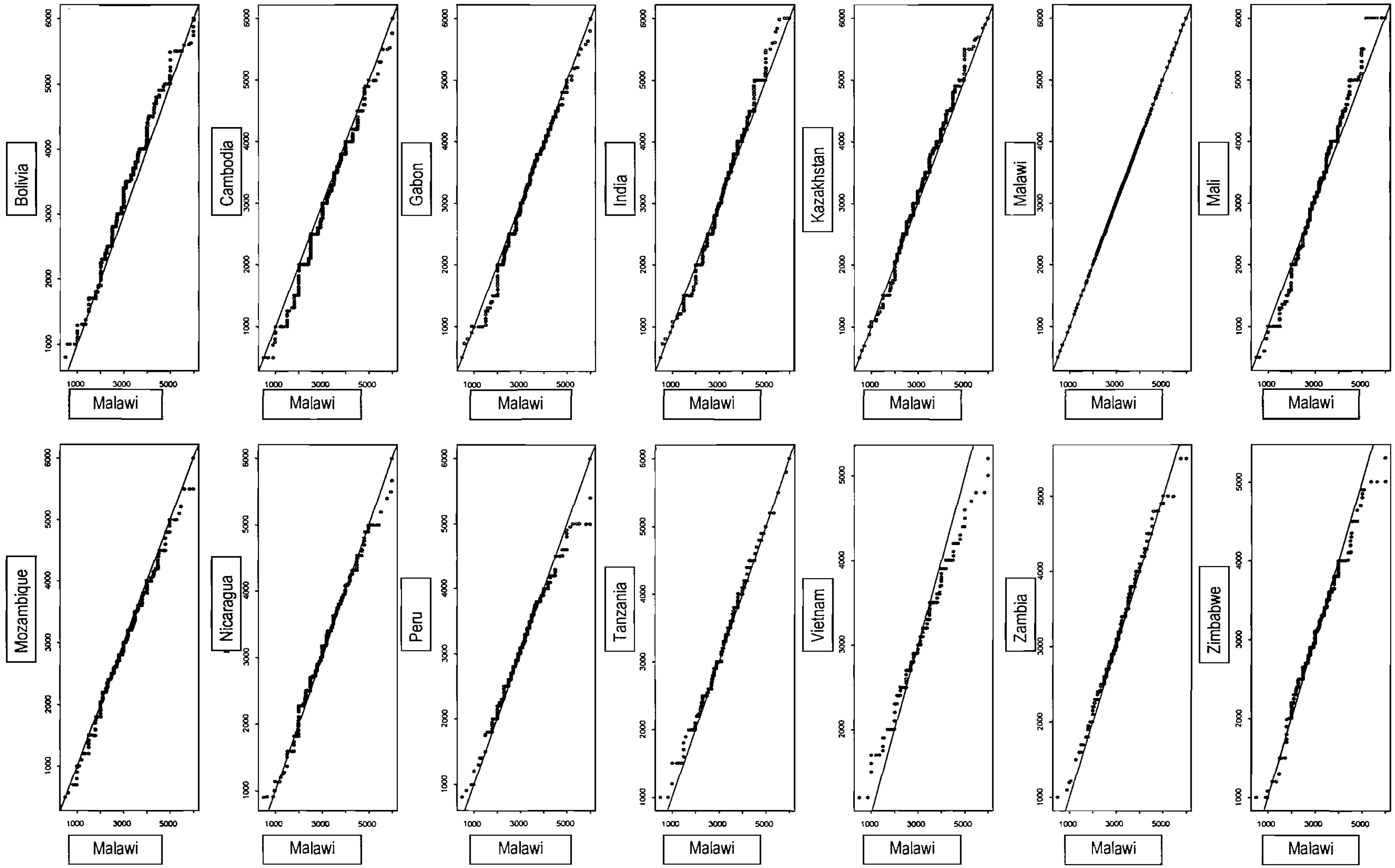
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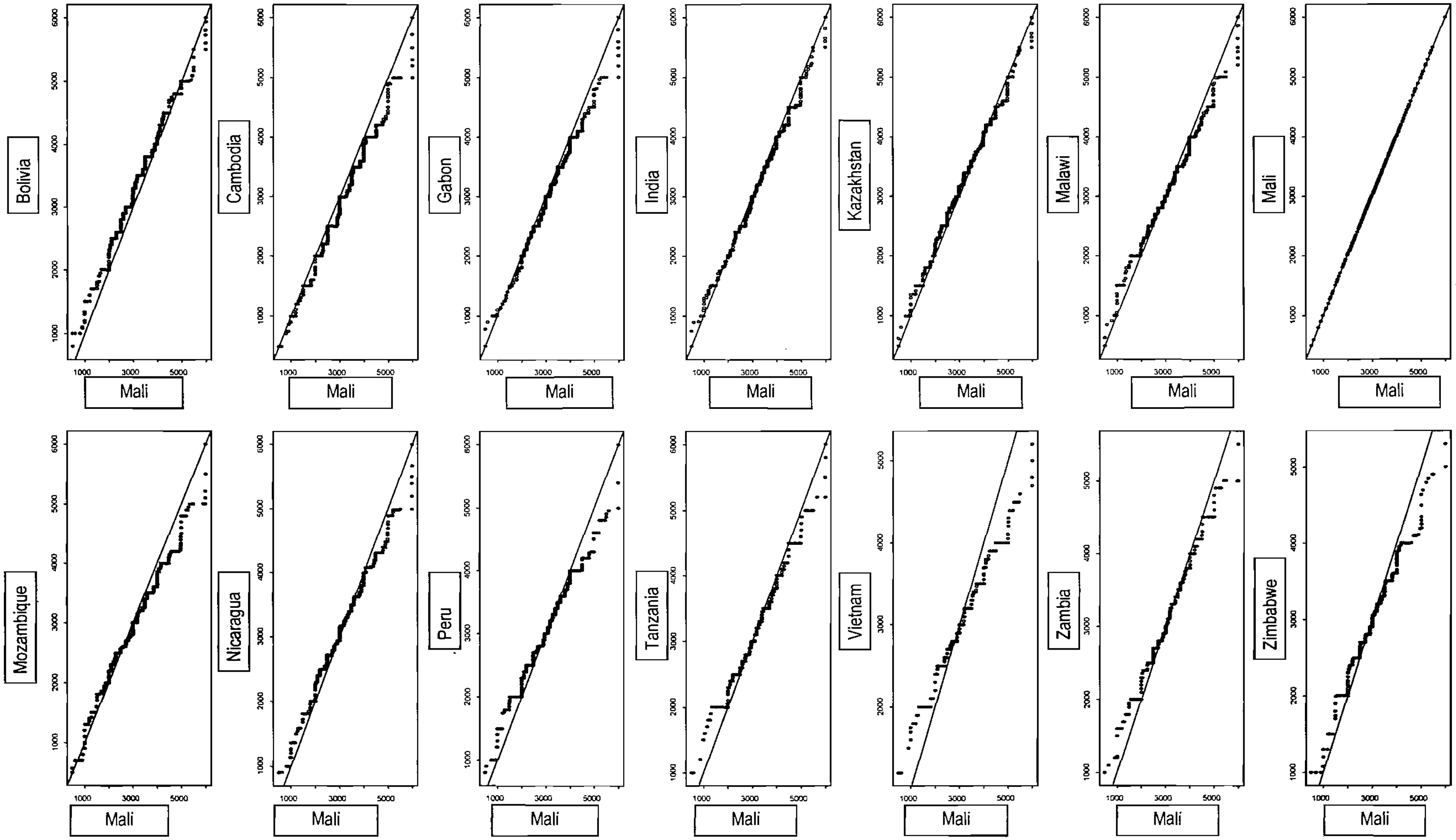

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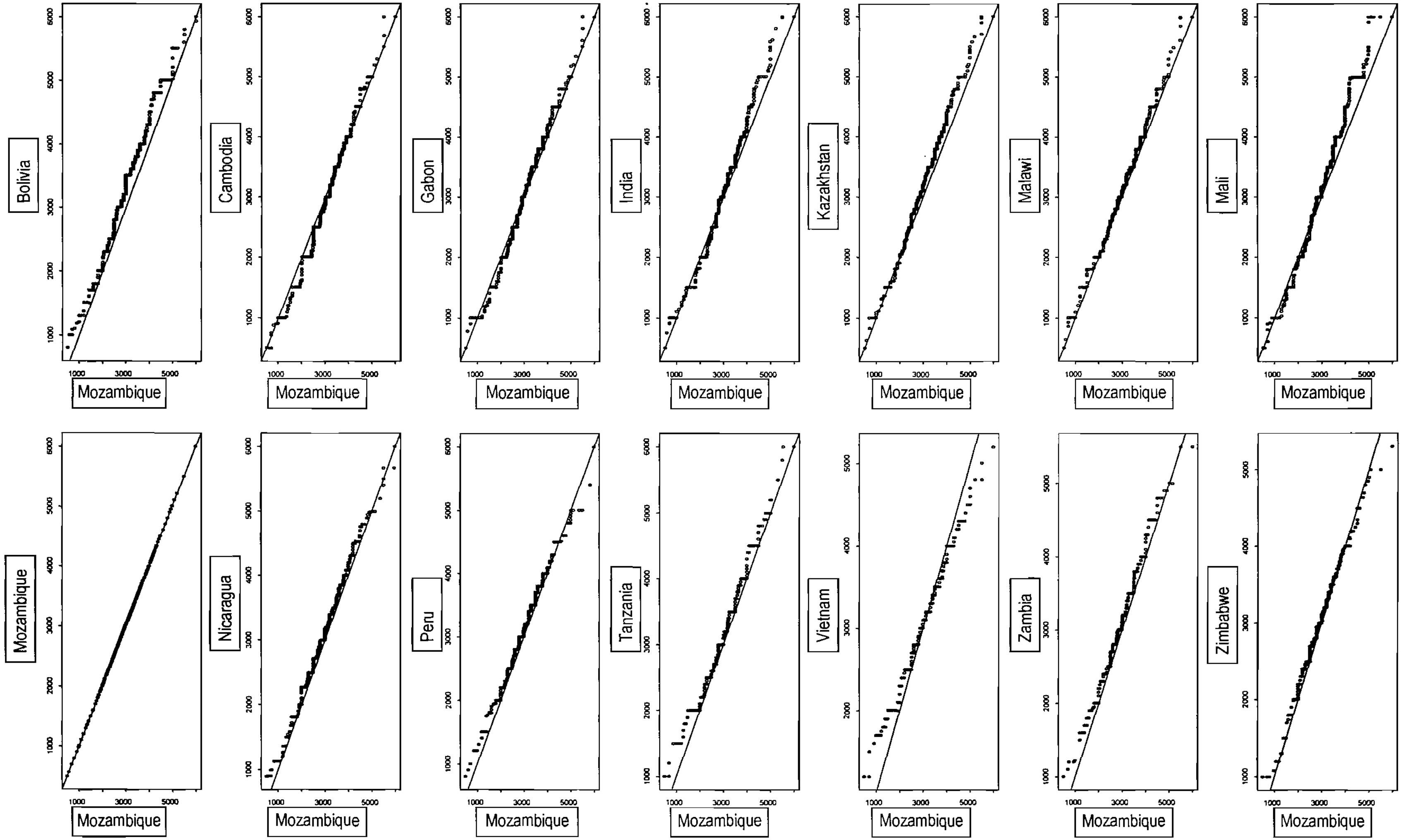
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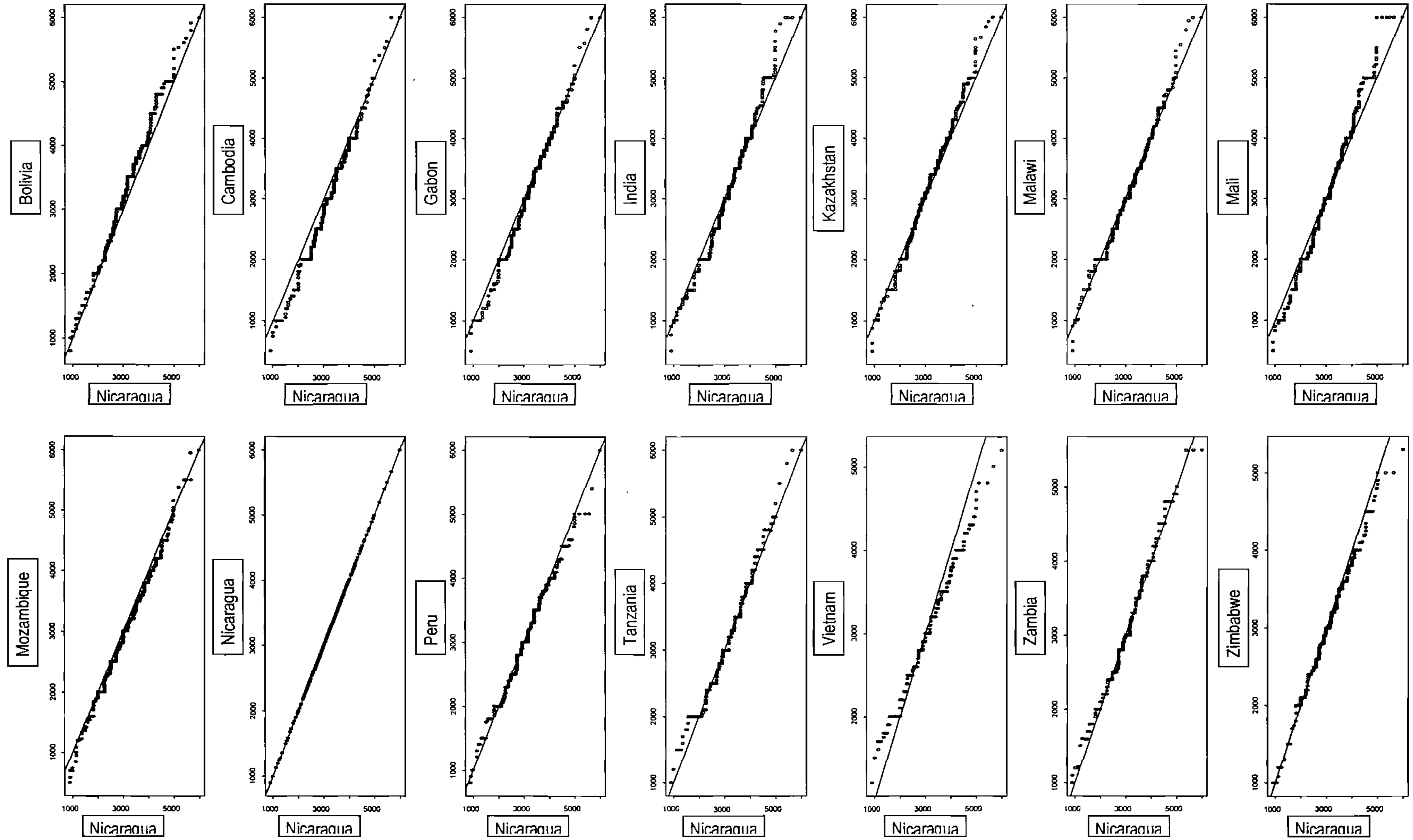

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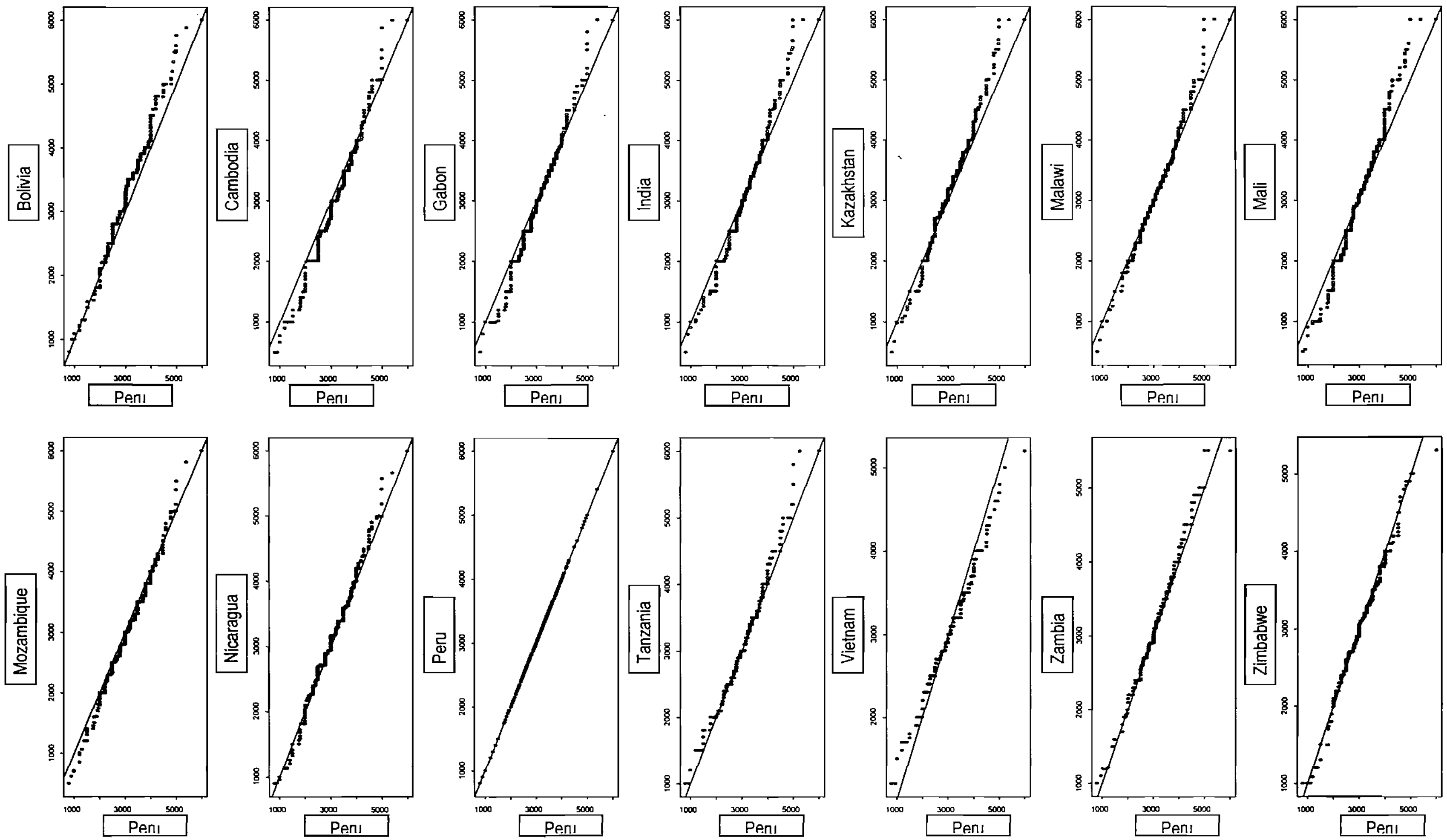
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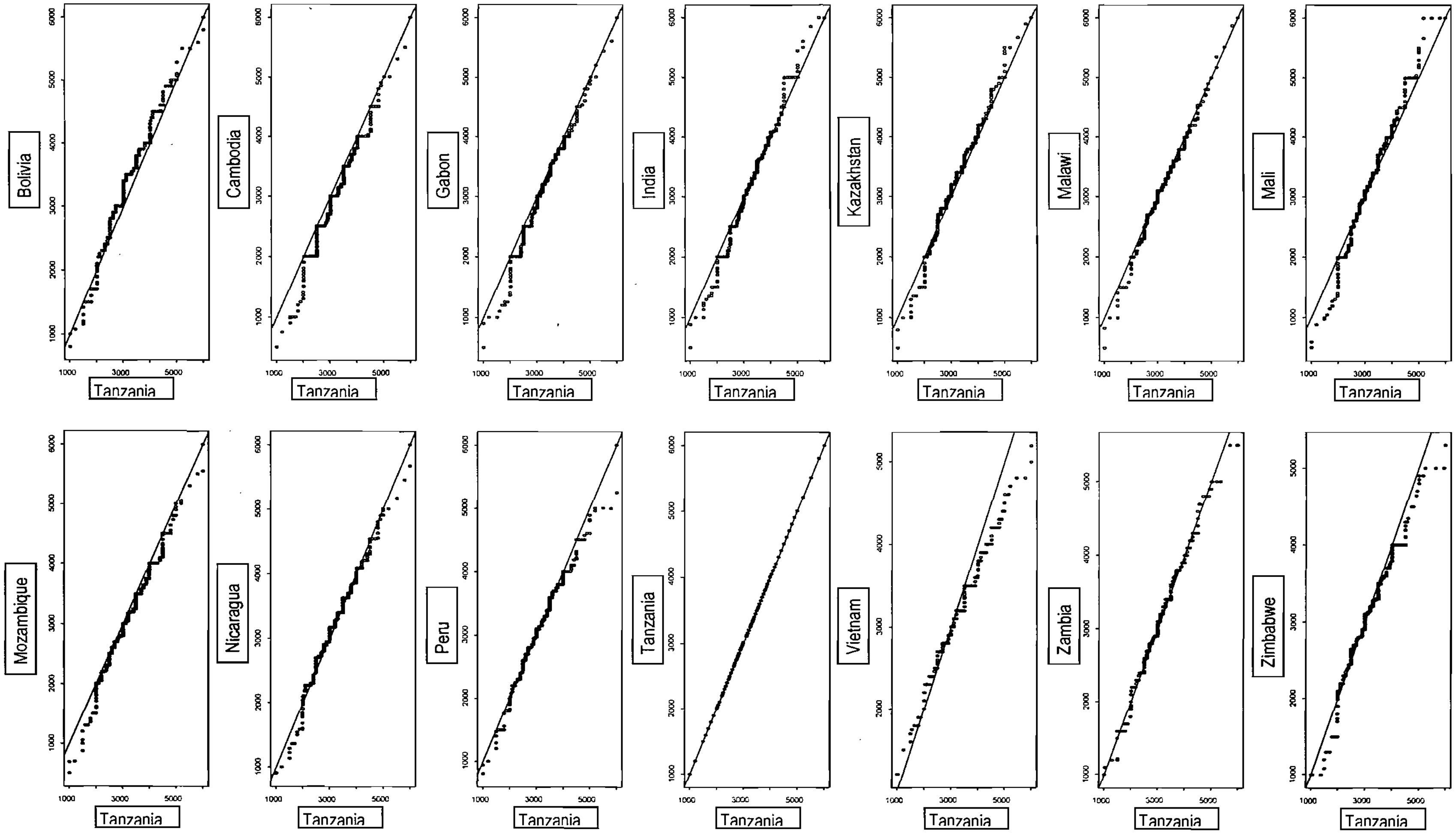
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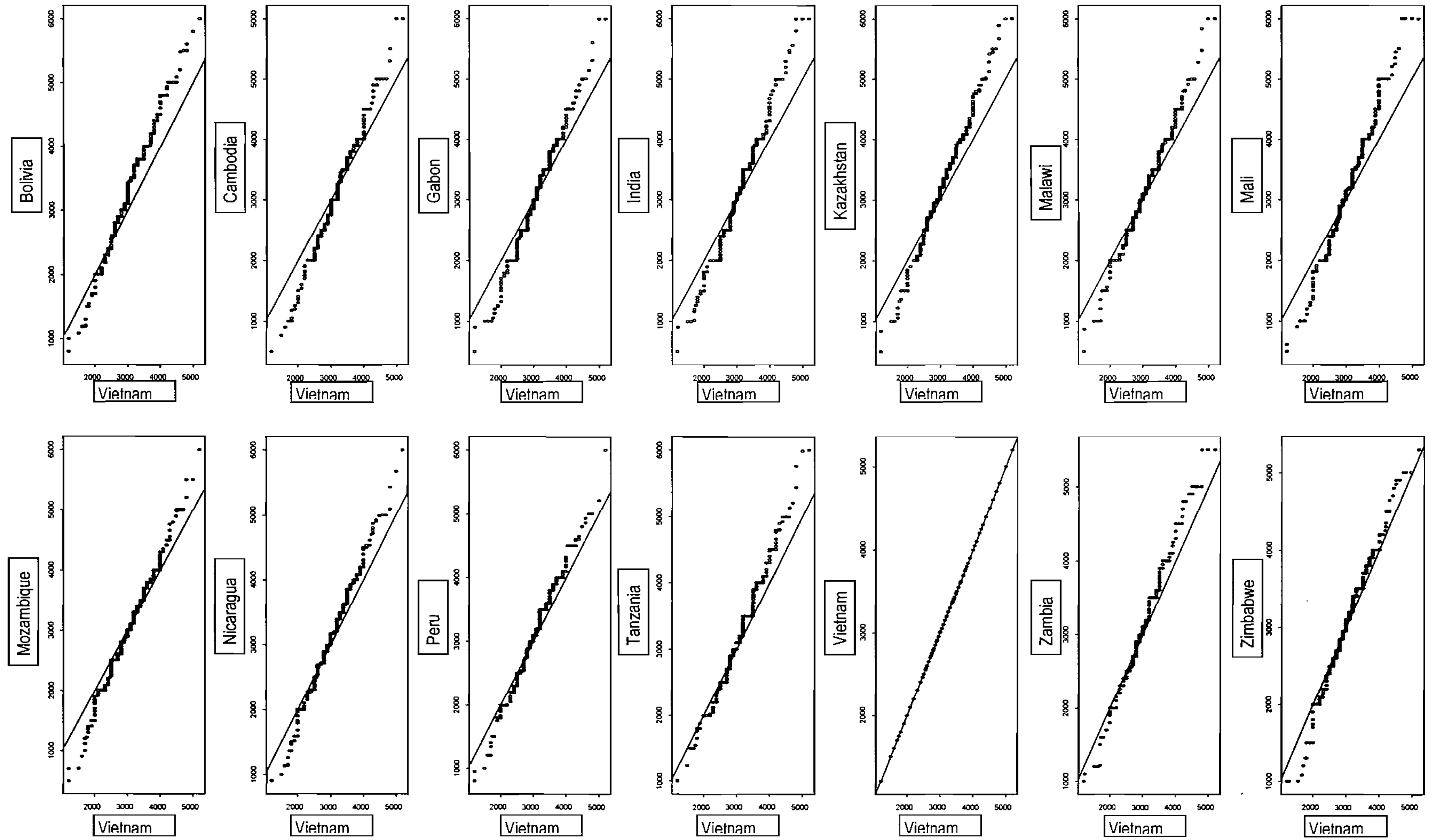
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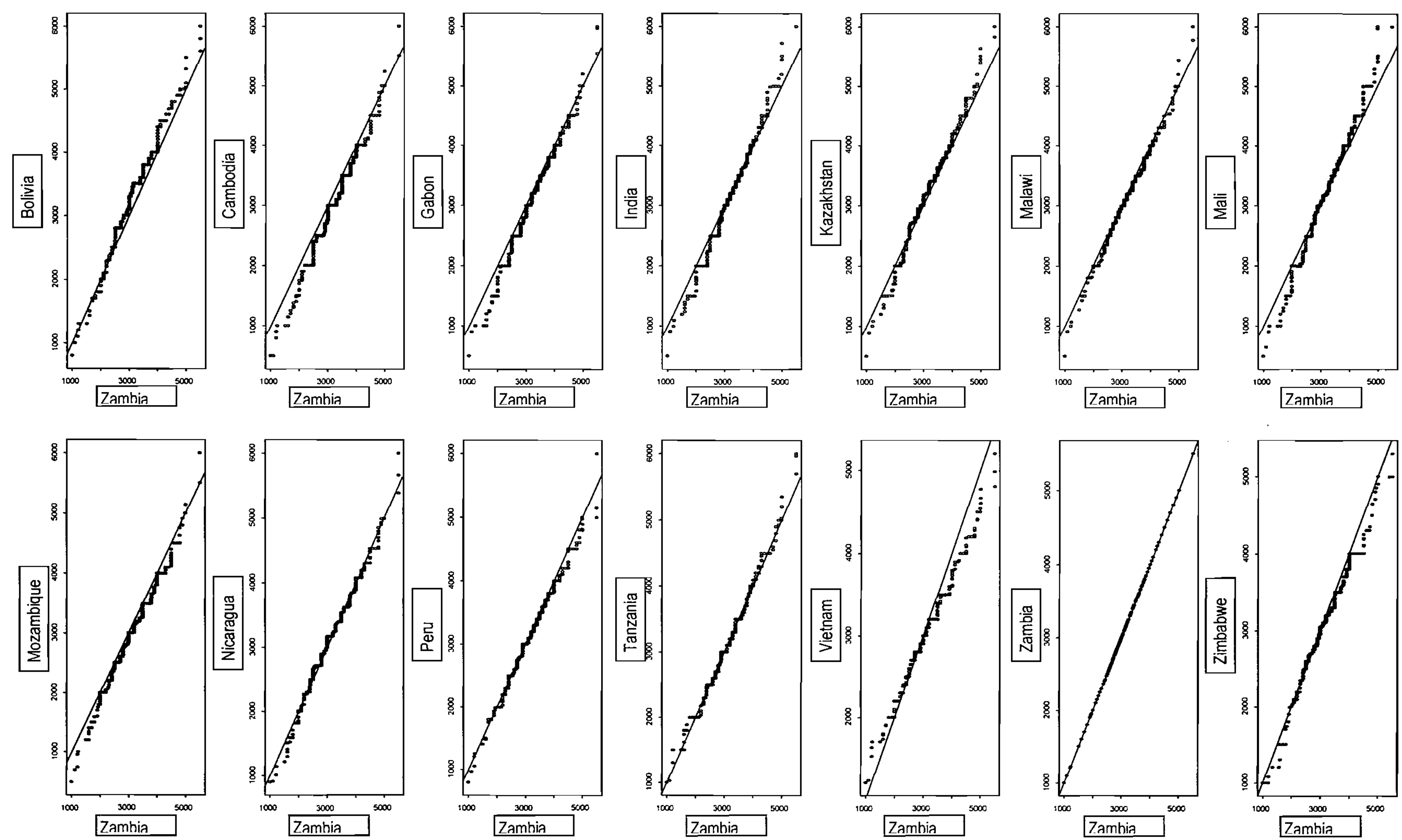

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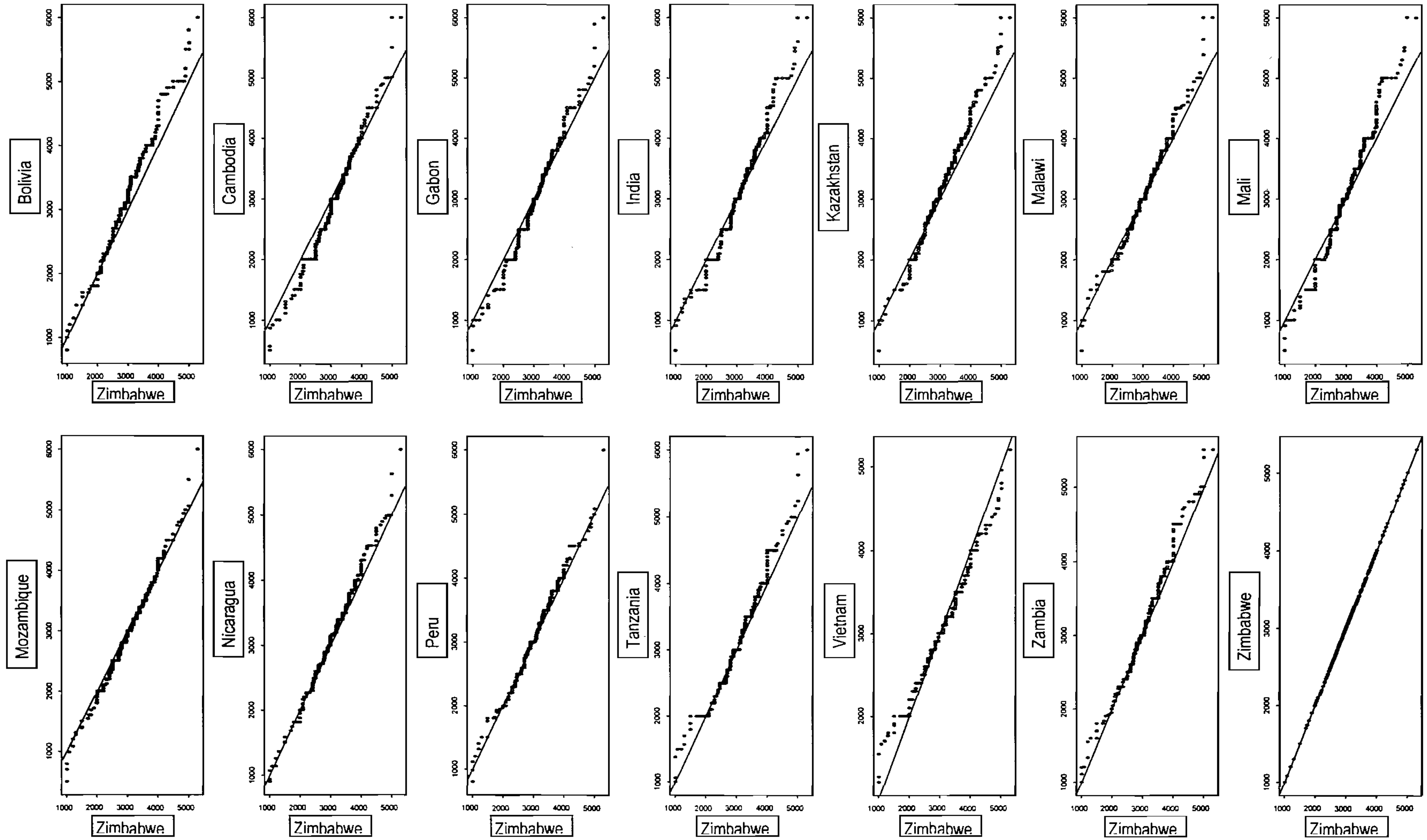
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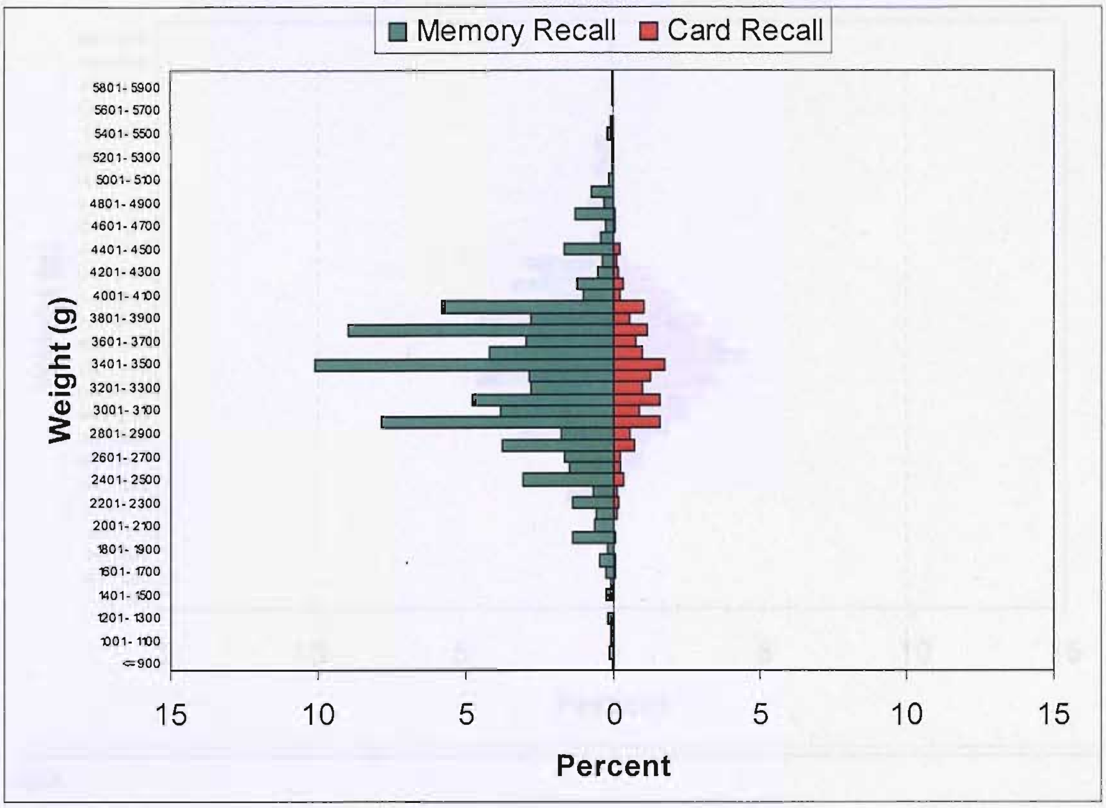
Appendix B

This Appendix displays birth weight pyramids for each of the 14 countries in the analysis. These pyramids compare the distribution of birth weights by reporting methods, either recalled from memory or reported from a health card. Pyramids for six of the countries are also shown in Figure 4.9.

Bolivia



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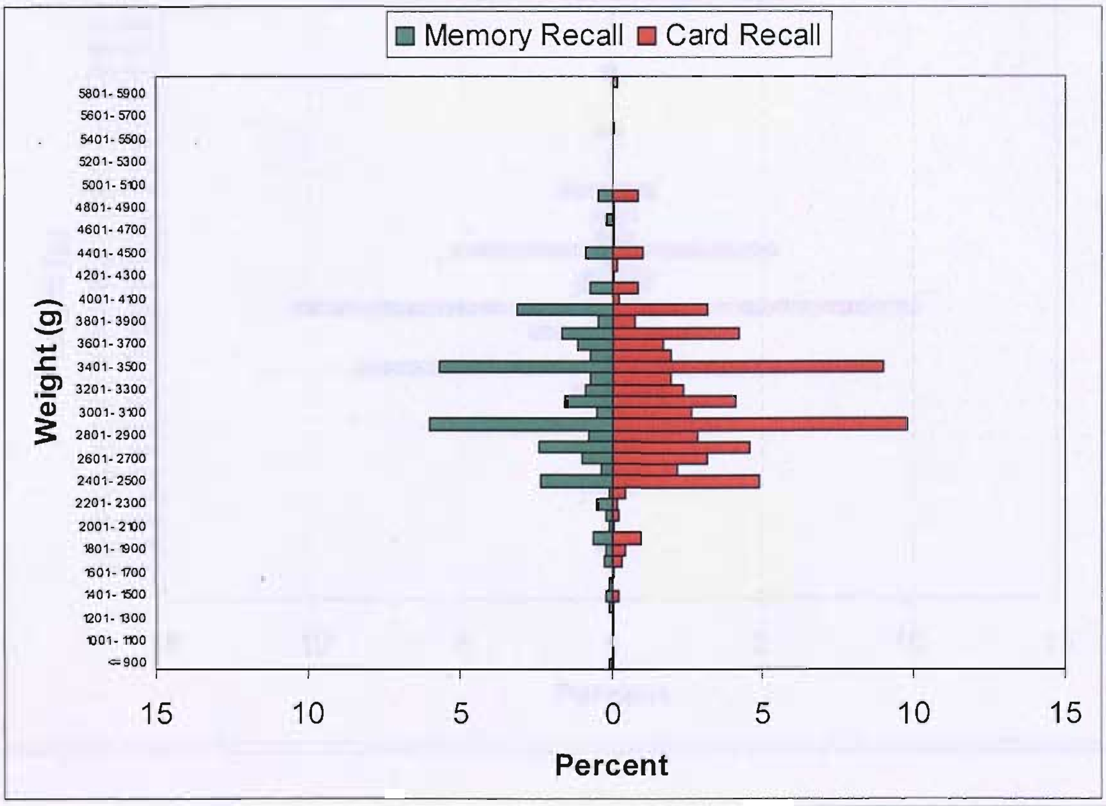
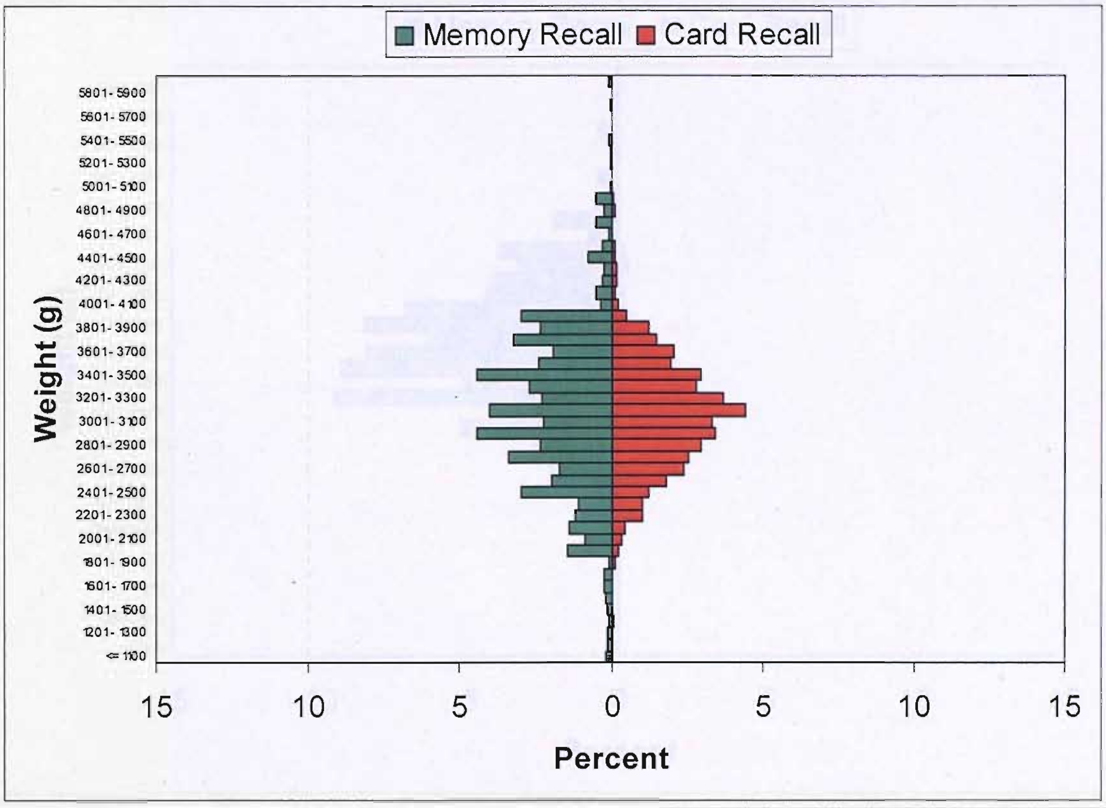


Gabon


Memory Recall
Card Recall
Weight (g)
5801-5900
5601-5700
5401-5500
5201-5300
5001-5100
4801-4900
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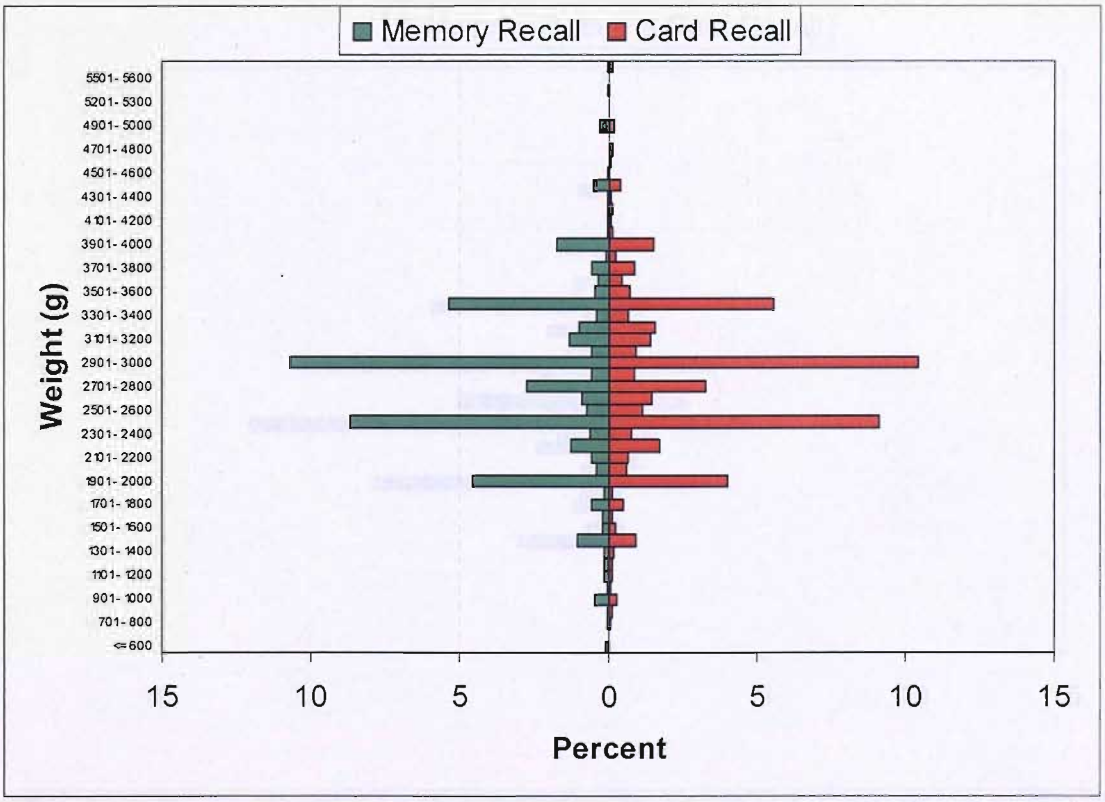
4401-4500
4201-4300
4001-4100
3801-3900
3601-3700
3401-3500
3201-3300
3001-3100
2801-2900
2601-2700
2401-2500
2201-2300
2001-2100
1801-1900
1601-1700
1401-1500
1201-1300
<= 1100
15 10 5 0 5 10 15
Percent

India


Memory Recall
Card Recall
Weight (g)
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5201-5300
4901-5000
4701-4800
4501-4600
4301-4400
4101-4200
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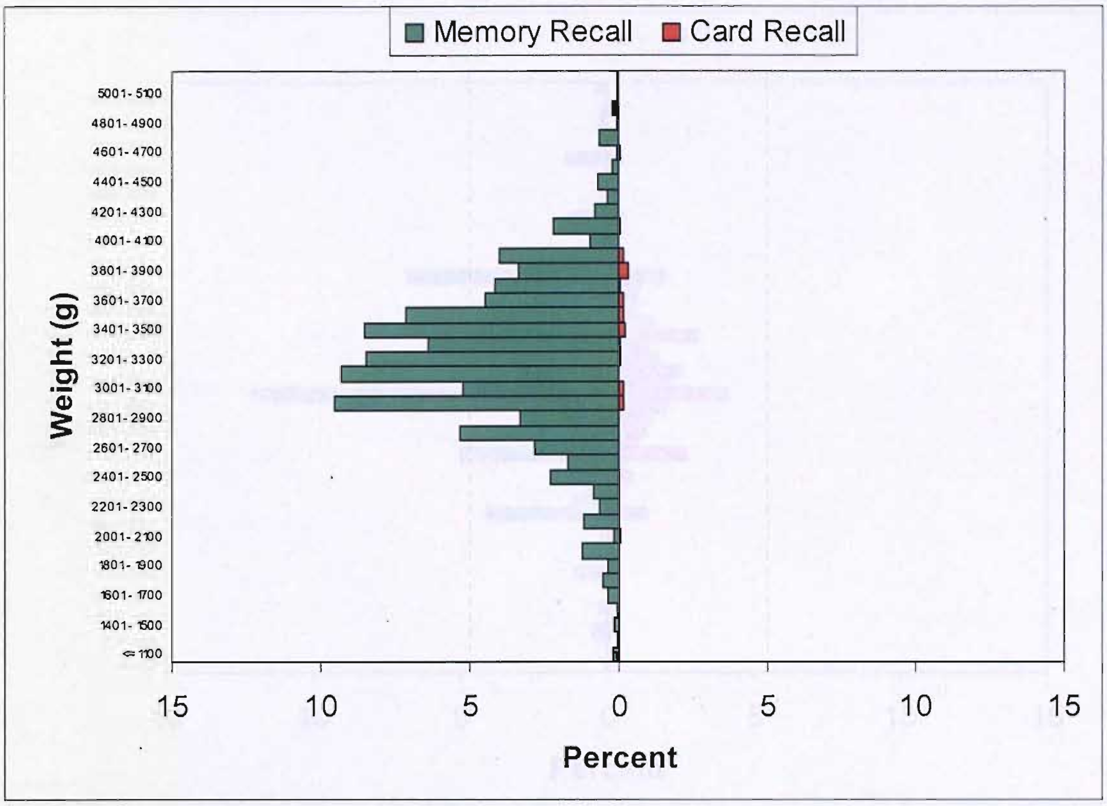
3701-3800
3501-3600
3301-3400
3101-3200
2901-3000
2701-2800
2501-2600
2301-2400
2101-2200
1901-2000
1701-1800
1501-1600
1301-1400
1101-1200
901-1000
701-800
<=600
15 10 5 0 5 10 15
Percent

Kazakhstan



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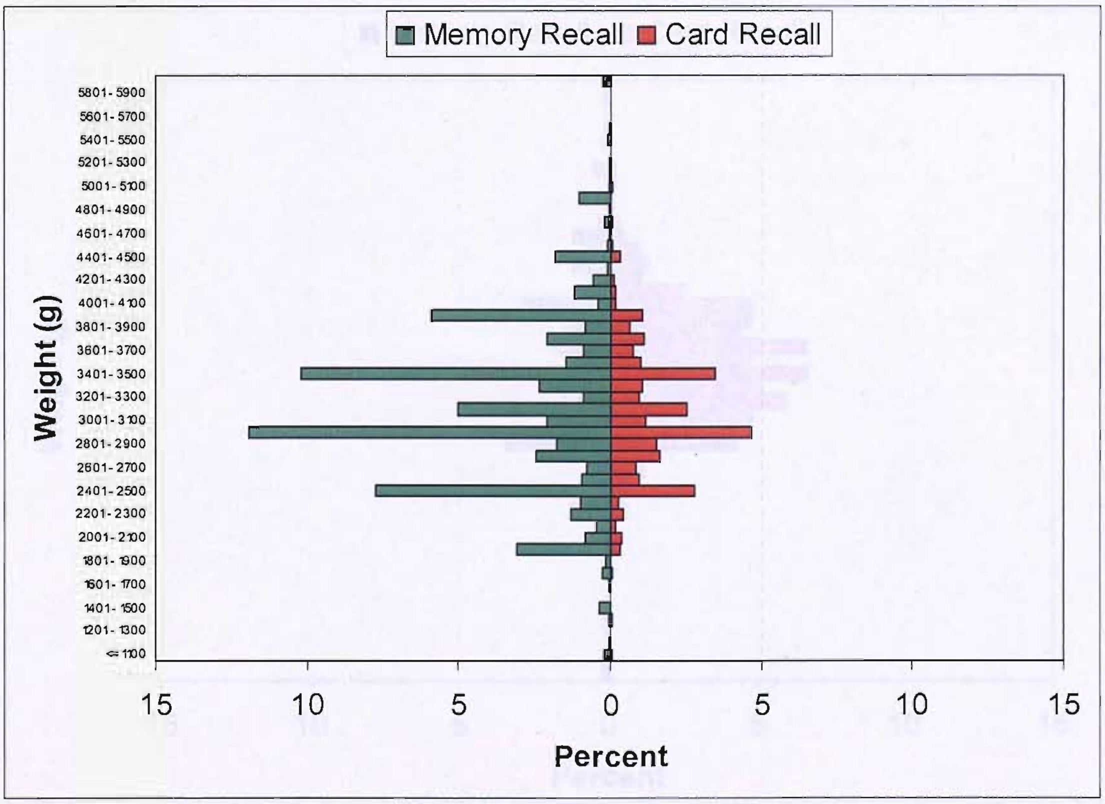

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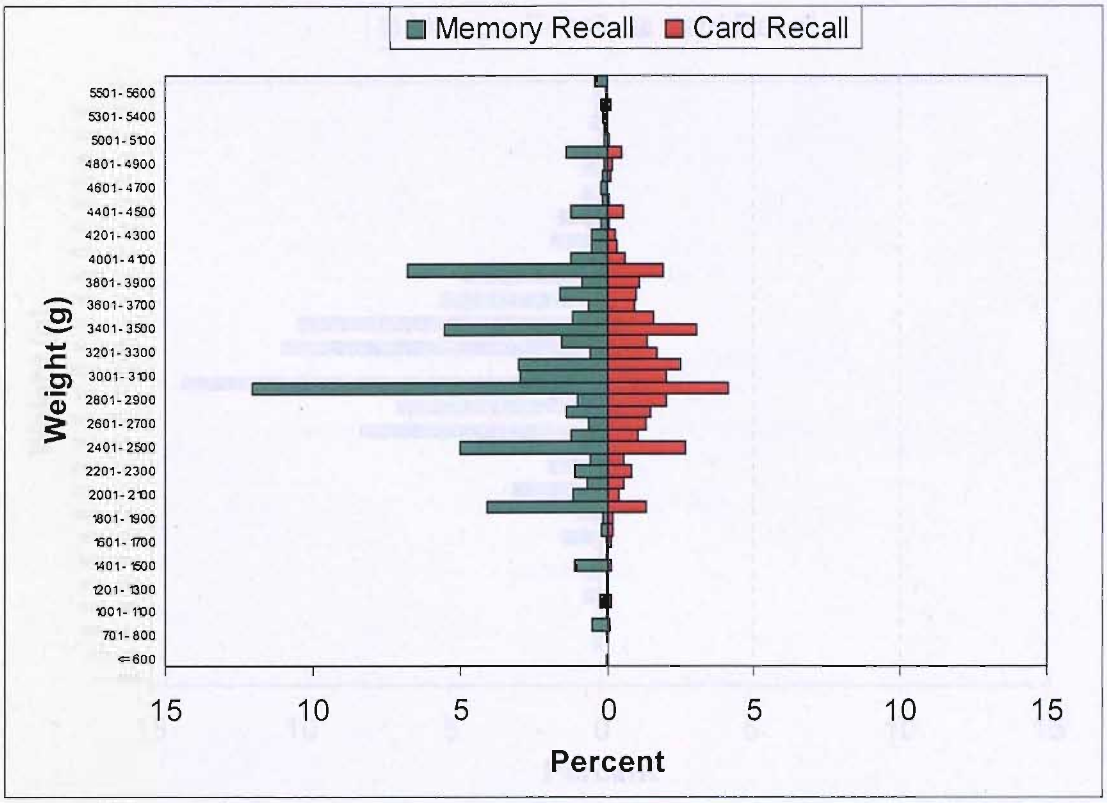
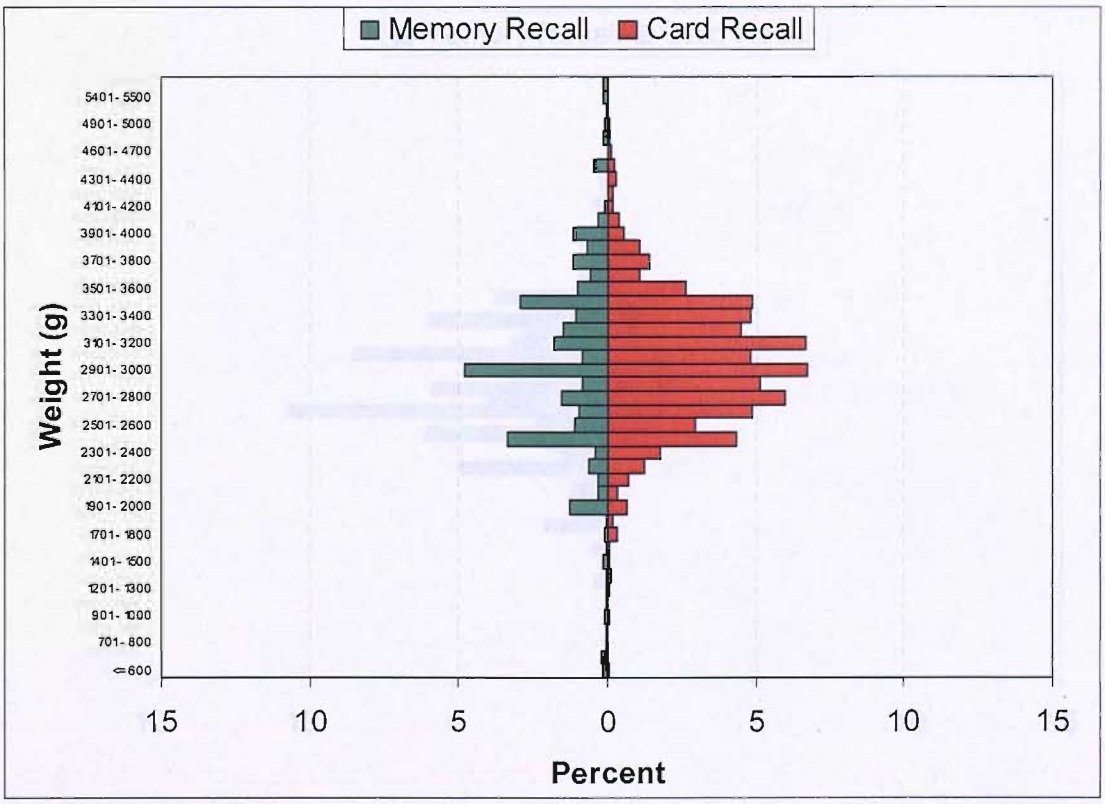


Mozambique



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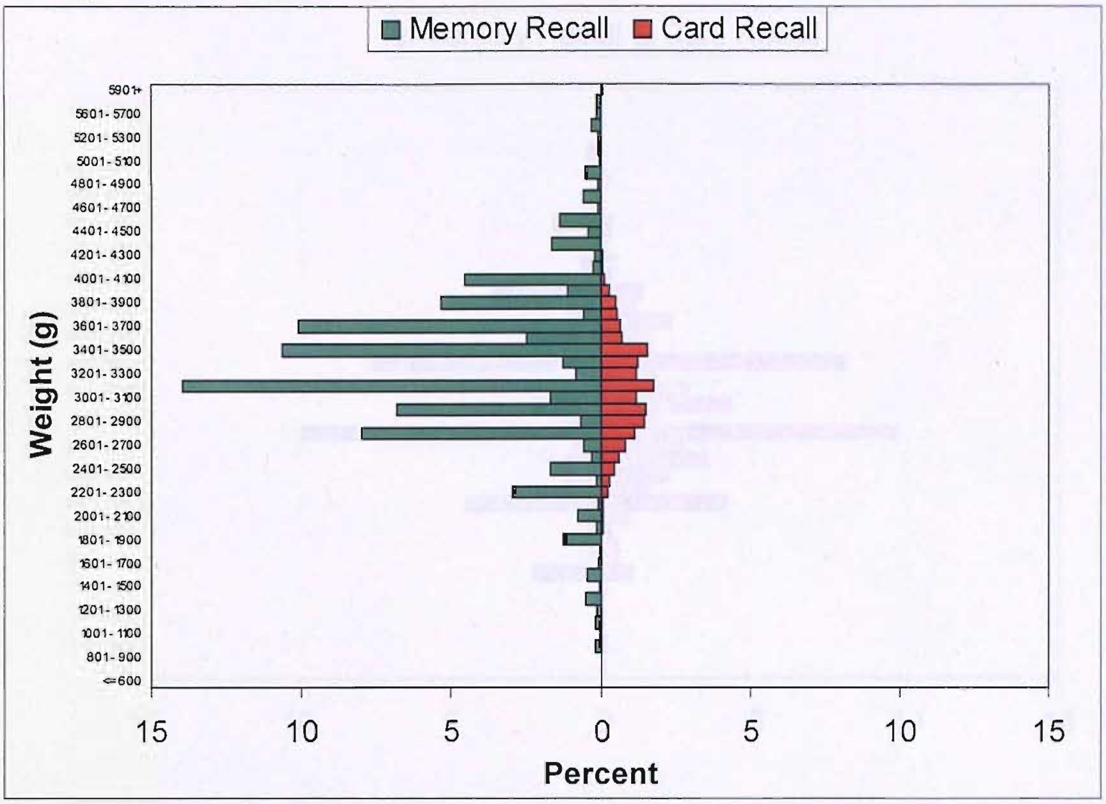

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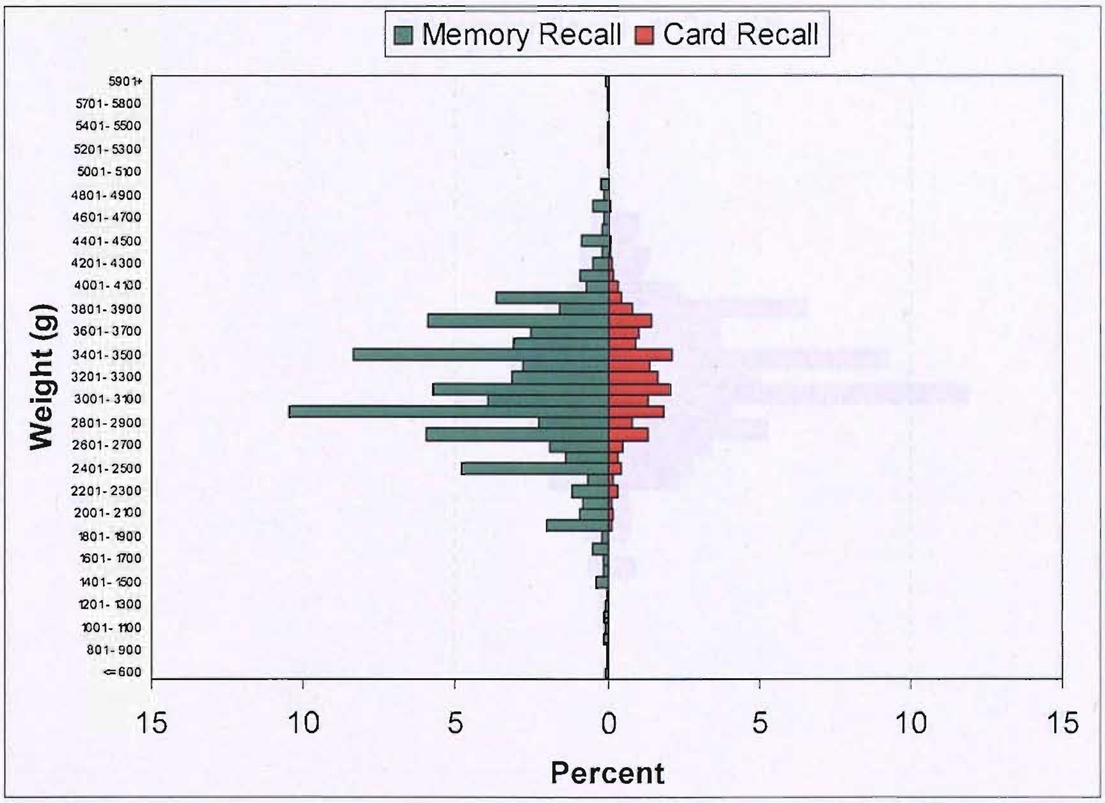

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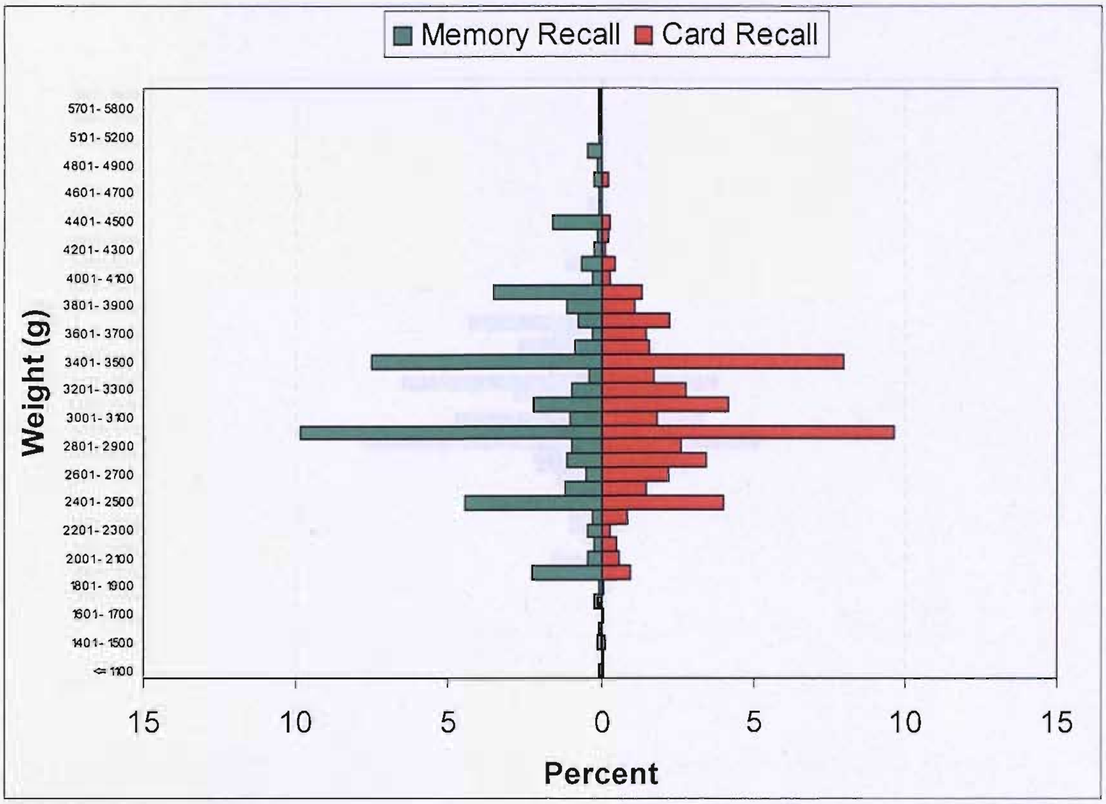

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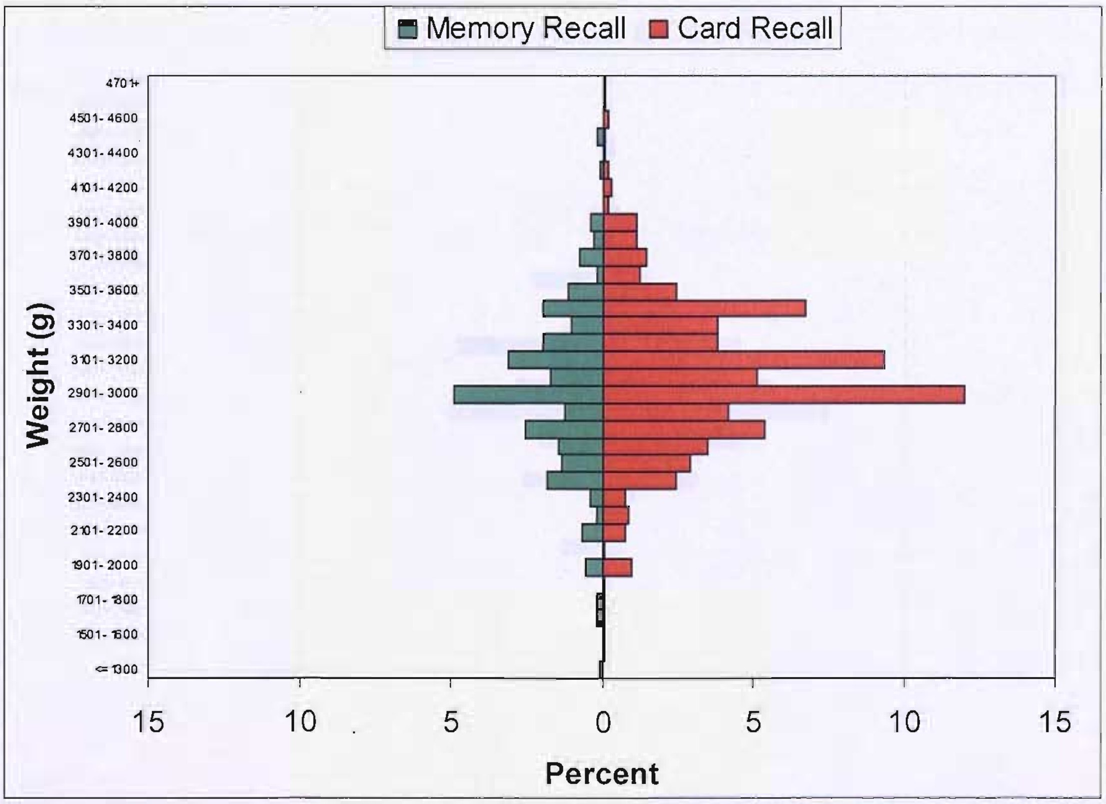
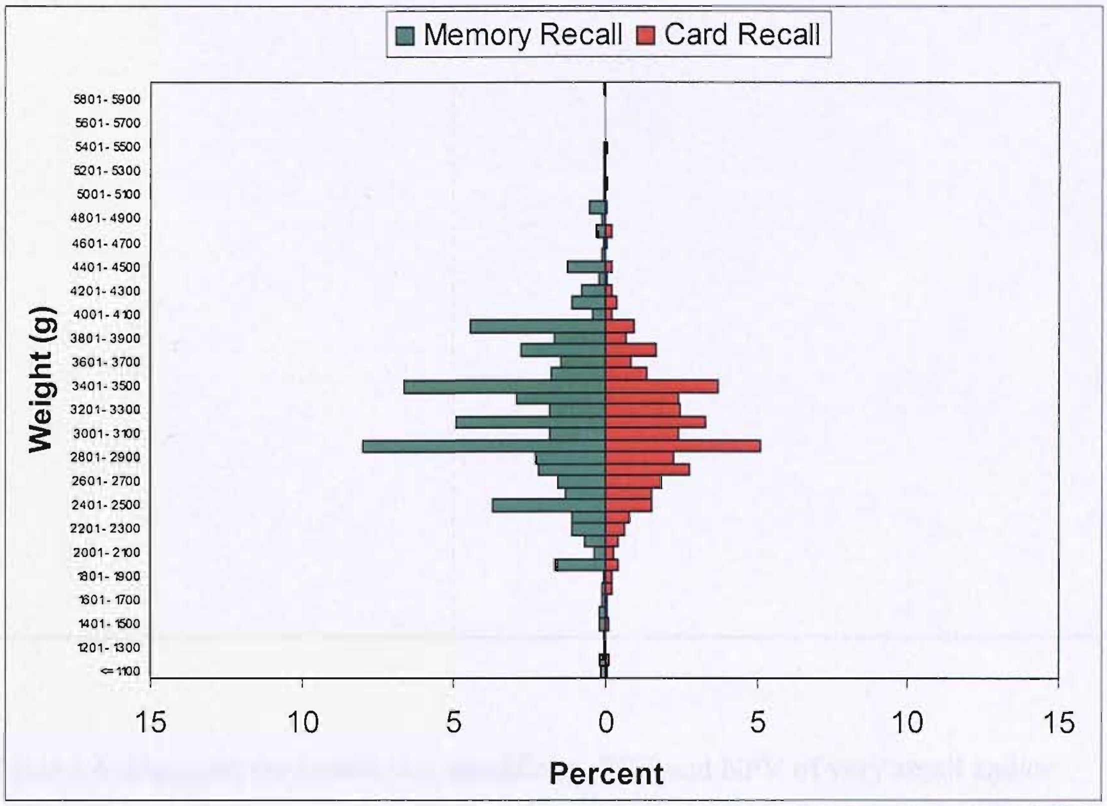
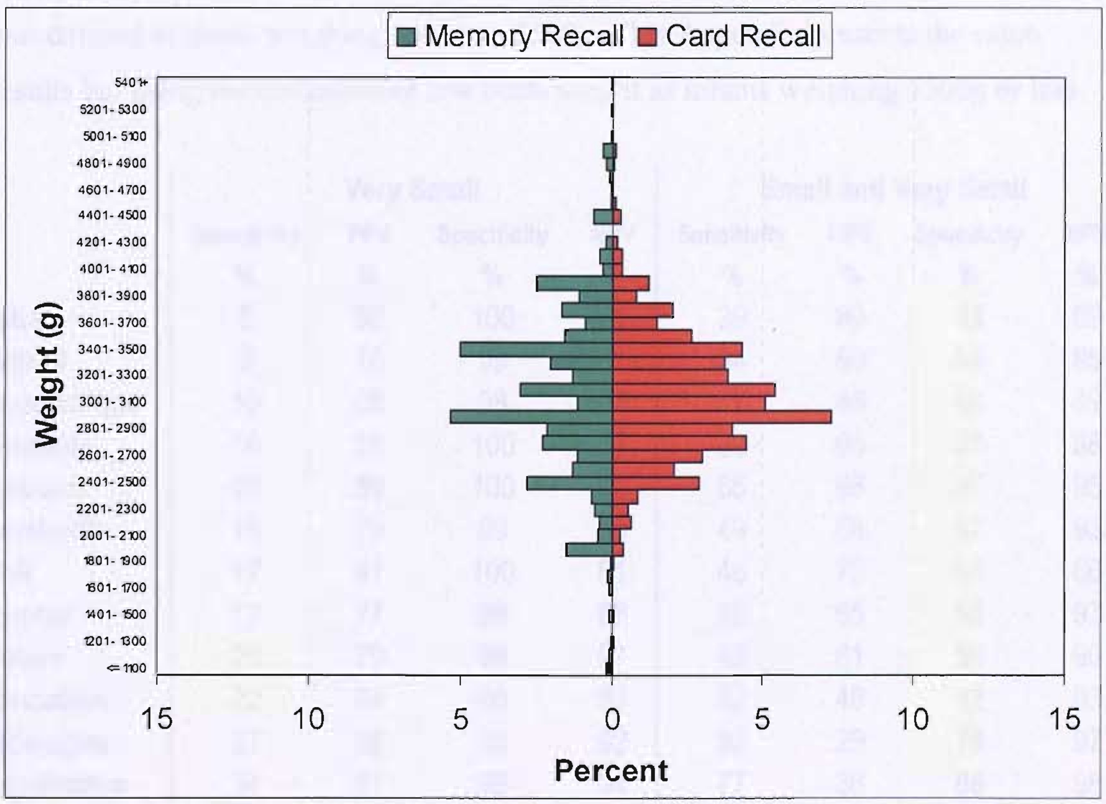


Zambia



Zimbabwe



Appendix C

Table 5.6 displayed the sensitivity, specificity, PPV and NPV of very small and/or smaller than average being used to predict low birth weight, when low birth weight was defined as those weighing less than 2500g. This Appendix presents the same results but using the definition of low birth weight as infants weighing 2500g or less.

	Very Small				Small and Very Small			
	Sensitivity %	PPV %	Specificity %	NPV %	Sensitivity %	PPV %	Specificity %	NPV %
India	8	92	100	61	39	80	93	69
Malawi	9	70	99	81	34	60	94	85
Mozambique	10	58	98	84	47	46	88	89
Tanzania	10	86	100	85	30	66	97	88
Vietnam	10	89	100	90	55	66	97	95
Cambodia	15	79	99	89	49	68	97	93
Mali	17	91	100	81	46	73	95	86
Zambia	19	77	99	88	58	65	95	93
Gabon	20	70	98	87	46	61	95	90
Zimbabwe	22	64	98	89	52	48	92	93
Nicaragua	27	65	98	92	82	29	78	97
Kazakhstan	34	61	98	94	77	36	88	98
Bolivia	38	49	96	93	74	41	88	97

Appendix D

Tables 5.7 and 5.8 displayed the estimated proportion of infants with LBW and the mean birth weight in each country after combining reported birth weight with mother's perception of size. This Appendix present the standard errors associated with the LBW and mean estimates for 13 countries.

Estimated Mean Birth Weight (Standard Errors)

Country	*Birth Weight Recorded*	*Mothers' Perception Only*	*Overall*
Kazakhstan	3311 (15.8)	3118 (78.4)	3306 (15.6)
Vietnam	3083 (13.9)	3007 (17.3)	3068 (11.8)
Bolivia	3379 (10.2)	3310 (7.5)	3350 (6.7)
Cambodia	3202 (17.8)	3043 (4.4)	3065 (4.5)
Zimbabwe	3141 (10.8)	3109 (11.9)	3133 (8.7)
Zambia	3201 (12.3)	3180 (6.3)	3188 (6.2)
Nicaragua	3281 (9.7)	3184 (8.7)	3249 (7.1)
Tanzania	3188 (17.0)	3088 (9.4)	3132 (9.2)
Mozambique	3036 (13.2)	3017 (5.2)	3026 (6.9)
Gabon	3152 (10.4)	3123 (18.5)	3148 (9.4)
Malawi	3188 (9.3)	3102 (4.5)	3142 (4.9)
Mali	3190 (15.9)	2980 (5.6)	3021 (5.5)
India	2793 (7.3)	2708 (2.3)	2730 (2.6)

Estimated Proportion of Infants with LBW (Standard Errors)

	Birth Weight Recorded			*Mothers' Perception Only*			*Overall*		
	Under 2500g	Including some who weigh 2500g[1]	Under 2501g	Under 2500g	Including some who weigh 2500g[1]	Under 2501g	Under 2500g	Including some who weigh 2500g[1]	Under 2501g
Kazakhstan	6.1 (0.67)	6.6 (0.69)	8.2 (0.77)	12.6 (5.46)	13.0 (5.53)	14.6 (5.81)	6.3 (0.67)	6.7 (0.69)	8.4 (0.76)
Vietnam	6.5 (0.76)	7.2 (0.79)	10.7 (0.95)	8.5 (1.78)	9.1 (1.84)	13.4 (2.18)	6.9 (0.70)	7.5 (0.73)	11.2 (0.87)
Bolivia	6.9 (0.39)	7.6 (0.41)	9.9 (0.46)	8.4 (0.50)	9.3 (0.52)	12.0 (0.59)	7.5 (0.31)	8.3 (0.32)	10.8 (0.37)
Cambodia	5.6 (0.67)	6.2 (0.71)	12.6 (0.97)	8.2 (0.32)	9.2 (0.33)	18.8 (0.45)	7.9 (0.29)	8.8 (0.30)	17.9 (0.41)
Zimbabwe	8.5 (0.54)	9.4 (0.57)	13.2 (0.66)	9.8 (1.00)	10.7 (1.04)	14.9 (1.20)	8.8 (0.48)	9.7 (0.50)	13.6 (0.58)
Zambia	9.1 (0.56)	10.2 (0.59)	13.9 (0.68)	9.5 (0.46)	10.4 (0.48)	14.6 (0.55)	9.4 (0.36)	10.4 (0.37)	14.3 (0.43)
Nicaragua	9.6 (0.44)	9.7 (0.44)	10.0 (0.45)	12.8 (0.69)	12.9 (0.69)	13.3 (0.70)	10.7 (0.37)	10.8 (0.38)	11.1 (0.38)
Tanzania	7.6 (0.72)	9.2 (0.78)	15.9 (0.99)	10.7 (0.74)	12.5 (0.79)	19.9 (0.96)	9.3 (0.52)	11.0 (0.56)	18.1 (0.69)
Mozambique	11.5 (0.73)	12.7 (0.77)	17.3 (0.87)	11.9 (0.70)	13.2 (0.74)	18.6 (0.85)	11.7 (0.51)	12.9 (0.53)	18.0 (0.61)
Gabon	12.0 (0.54)	13.1 (0.56)	15.6 (0.61)	13.7 (1.37)	14.7 (1.41)	17.2 (1.50)	12.2 (0.50)	13.3 (0.52)	15.8 (0.56)
Malawi	9.7 (0.41)	13.0 (0.47)	20.2 (0.56)	12.9 (0.43)	16.5 (0.47)	24.5 (0.55)	11.5 (0.30)	14.9 (0.33)	22.5 (0.39)
Mali	14.2 (0.72)	17.0 (0.77)	21.6 (0.84)	21.6 (0.41)	24.9 (0.43)	31.2 (0.46)	20.2 (0.36)	23.4 (0.38)	29.4 (0.40)
India	21.9 (0.45)	28.4 (0.49)	40.5 (0.53)	25.7 (0.28)	32.7 (0.30)	45.7 (0.32)	24.7 (0.24)	31.6 (0.26)	44.4 (0.28)

Appendix E

Table 5.11 showed the estimates of the mean birth weight and the proportion of infants with LBW using birth weights recorded by each of the two reporting methods. The standard errors of these estimates are displayed in the tables below for the 13 countries in the analysis.

Estimated Proportion of Infants with LBW (Standard Errors)

	Recall from Card			Recall from Memory		
	% with LBW			% with LBW		
	Under 2500g	Inc. % of 2500g[1]	Under 2501g	Under 2500g	Inc. % of 2500g[1]	Under 2501g
Bolivia	6.2 (0.28)	6.8 (0.30)	8.6 (0.33)	7.8 (0.32)	8.6 (0.33)	11.2 (0.37)
Kazakhstan	6.2 (0.66)	6.6 (0.68)	8.2 (0.76)	6.3 (0.67)	6.7 (0.69)	8.4 (0.76)
Nicaragua	9.9 (0.36)	10.1 (0.36)	10.8 (0.38)	10.9 (0.38)	10.9 (0.38)	11.2 (0.38)
Zambia	8.9 (0.35)	9.7 (0.36)	13.0 (0.41)	9.7 (0.36)	10.8 (0.38)	15.4 (0.44)
Gabon	12.1 (0.50)	13.0 (0.52)	15.4 (0.56)	12.4 (0.51)	13.4 (0.52)	16.1 (0.57)
Zimbabwe	8.4 (0.47)	9.3 (0.49)	12.9 (0.56)	9.1 (0.48)	10.1 (0.51)	14.3 (0.59)
Malawi	9.9 (0.28)	13.1 (0.32)	20.2 (0.38)	12.1 (0.31)	15.6 (0.34)	23.4 (0.40)
Tanzania	8.7 (0.51)	10.3 (0.55)	17.1 (0.68)	10.2 (0.54)	12.0 (0.58)	19.5 (0.71)
Vietnam	7.0 (0.71)	7.5 (0.73)	11.1 (0.87)	6.9 (0.70)	7.6 (0.73)	11.7 (0.89)
Cambodia	7.1 (0.28)	8.1 (0.29)	17.7 (0.41)	9.7 (0.32)	10.5 (0.33)	18.5 (0.42)
Mozambique	11.0 (0.49)	12.1 (0.52)	16.6 (0.59)	13.0 (0.53)	14.6 (0.56)	20.5 (0.64)
Mali	18.6 (0.35)	21.3 (0.36)	27.3 (0.4.0)	21.0 (0.36)	24.5 (0.38)	30.5 (0.41)
India	24.3 (0.24)	31.1 (0.26)	43.5 (0.27)	24.9 (0.24)	32.1 (0.26)	45.2 (0.28)

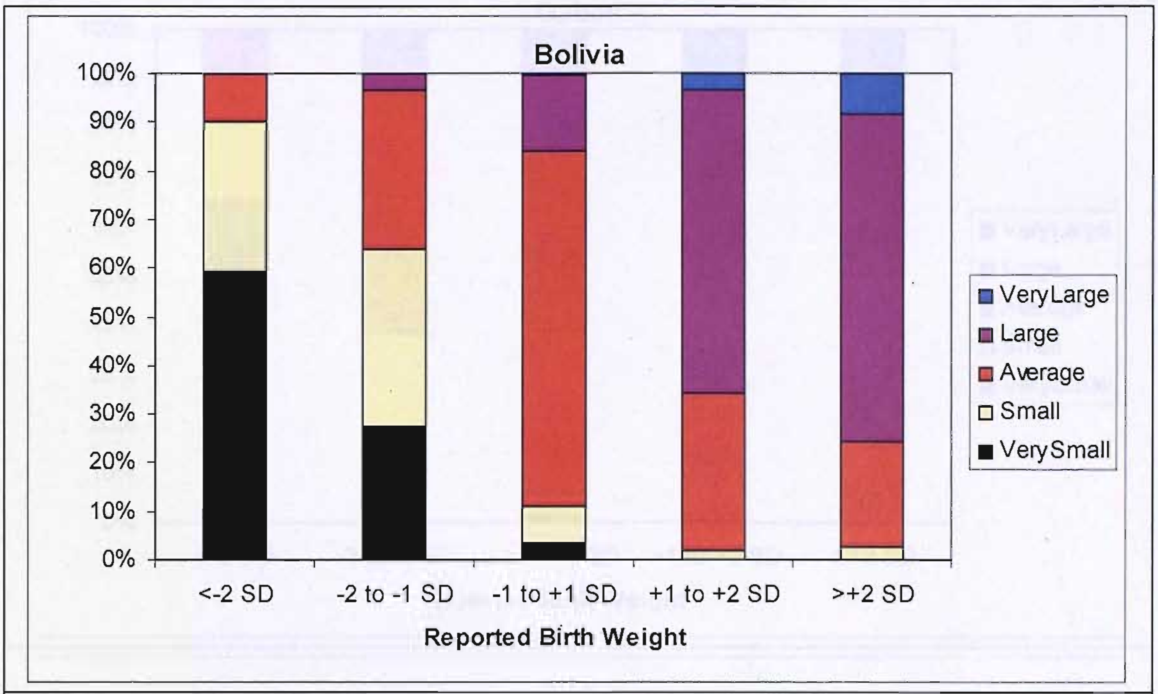
[1]See Table 4.4 for percentage of infants weighing exactly 2500g classified as LBW for each country

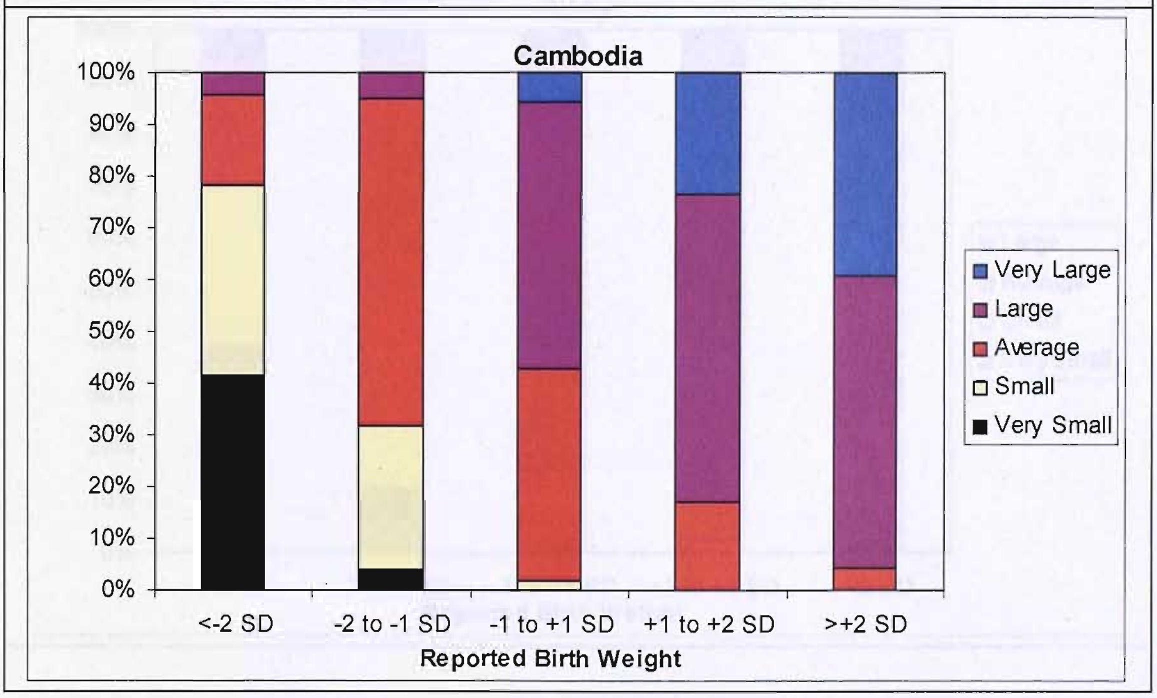
Estimated Mean Birth Weight (Standard Errors)

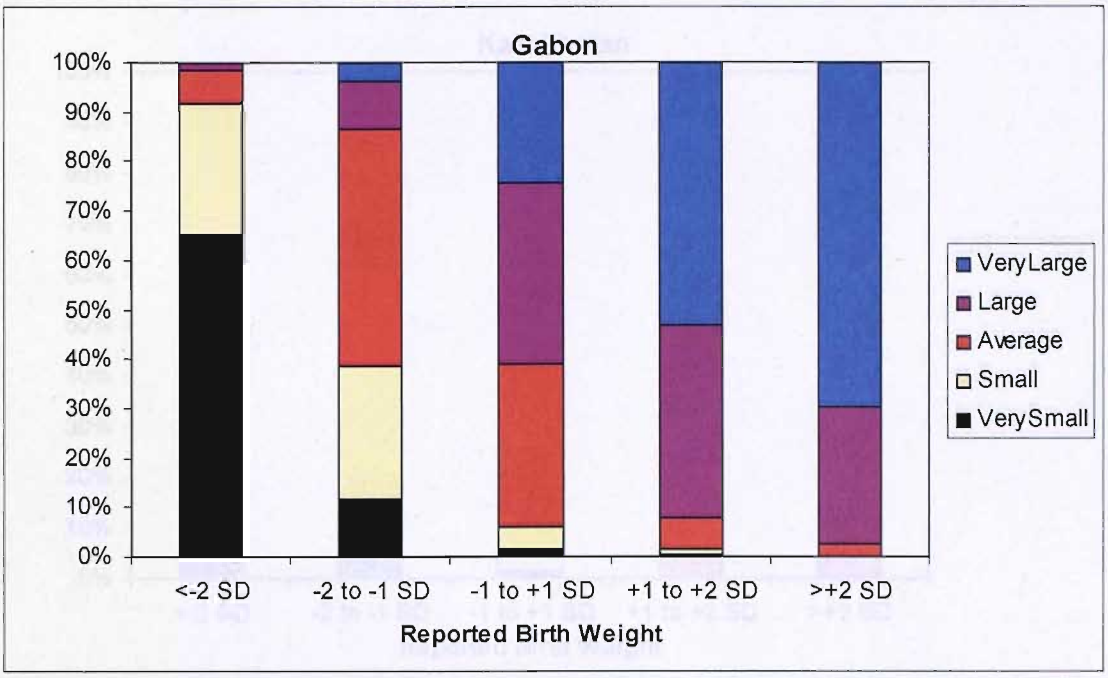
	Recall from Card	Recall from Memory
Bolivia	3358 (6.4)	3348 (6.8)
Kazakhstan	3298 (16.5)	3307 (15.6)
Nicaragua	3217 (6.7)	3254 (7.2)
Zambia	3143 (5.9)	3154 (6.3)
Gabon	3068 (9.3)	3062 (9.5)
Zimbabwe	3050 (8.5)	3094 (8.9)
Malawi	3116 (4.8)	3151 (5.0)
Tanzania	3113 (8.9)	3148 (9.5)
Vietnam	3029 (11.9)	3024 (11.8)
Cambodia	3158 (4.3)	3211 (5.0)
Mozambique	3015 (6.8)	3028 (7.0)
Mali	3127 (4.9)	3141 (5.9)
India	2737 (2.5)	2725 (2.6)

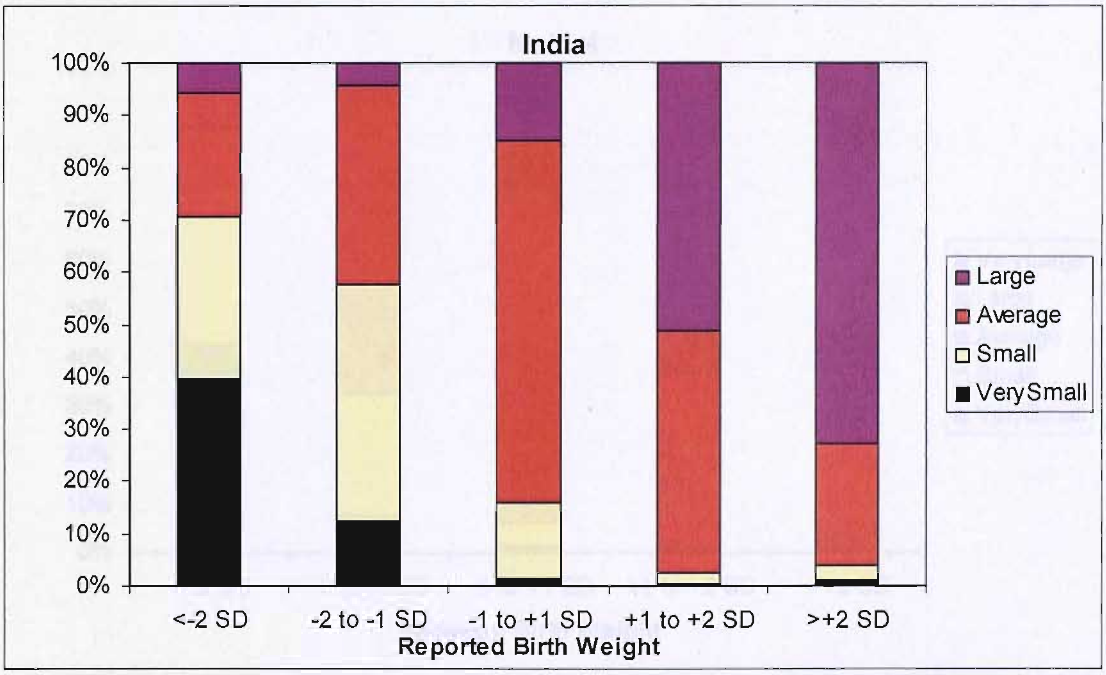
Appendix F

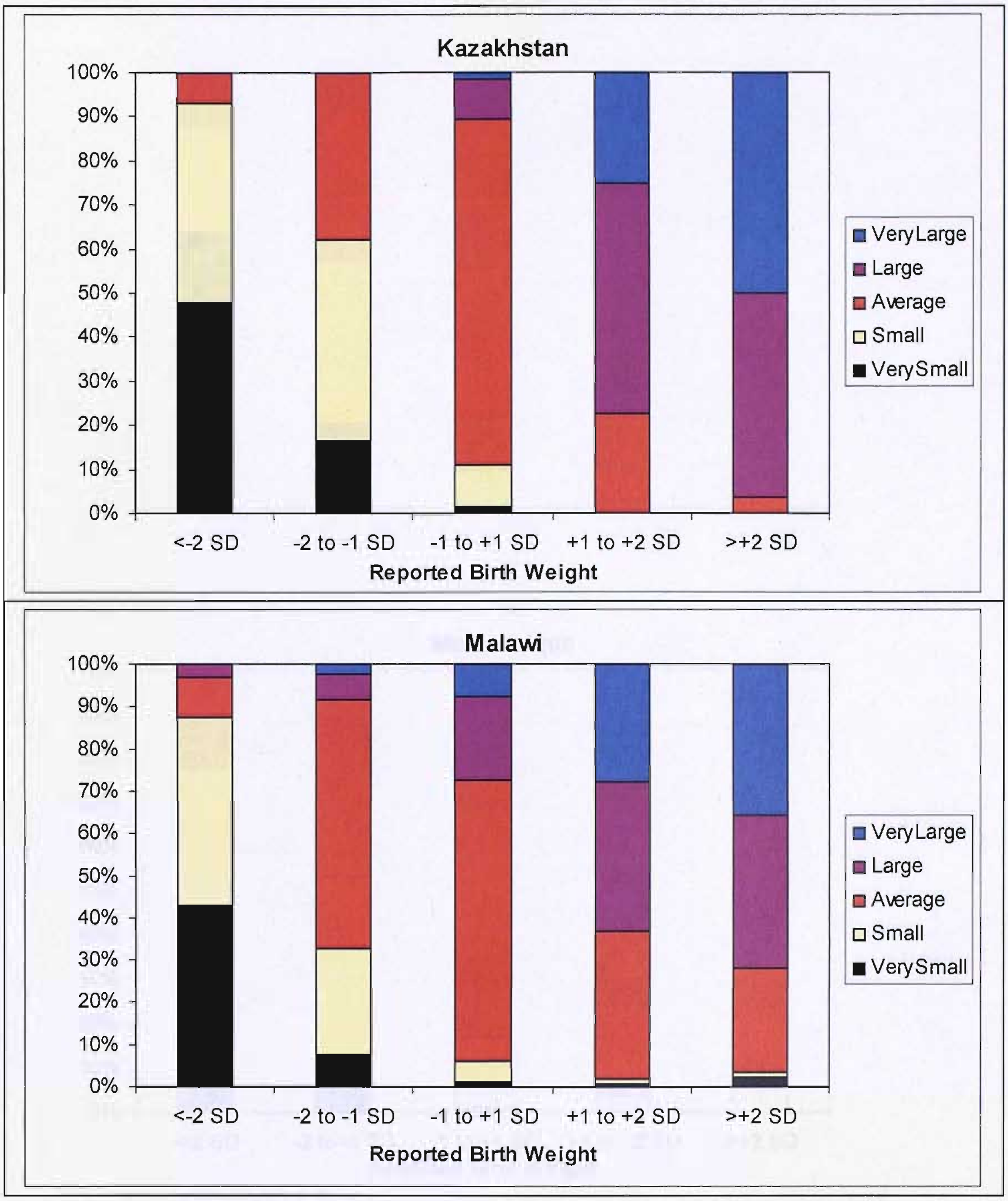
Stacked bar charts showing mother's perception of size within actual birth weight categories were displayed for three countries in Figure 6.1. The birth weight categories were formed by taking standard deviations from the mean birth weight in each country. The stacked bar charts for all countries are shown in this Appendix.

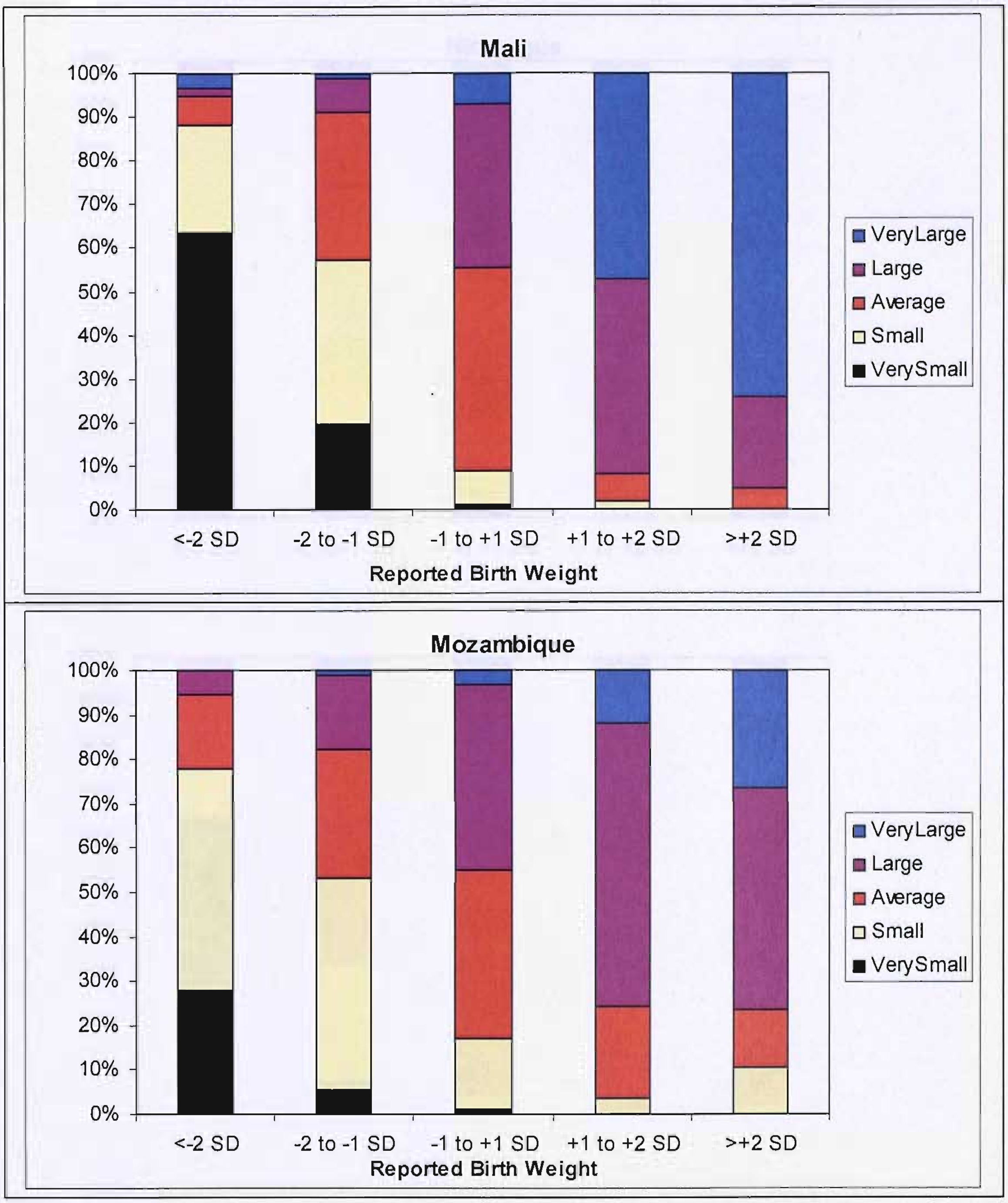

Bolivia
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall

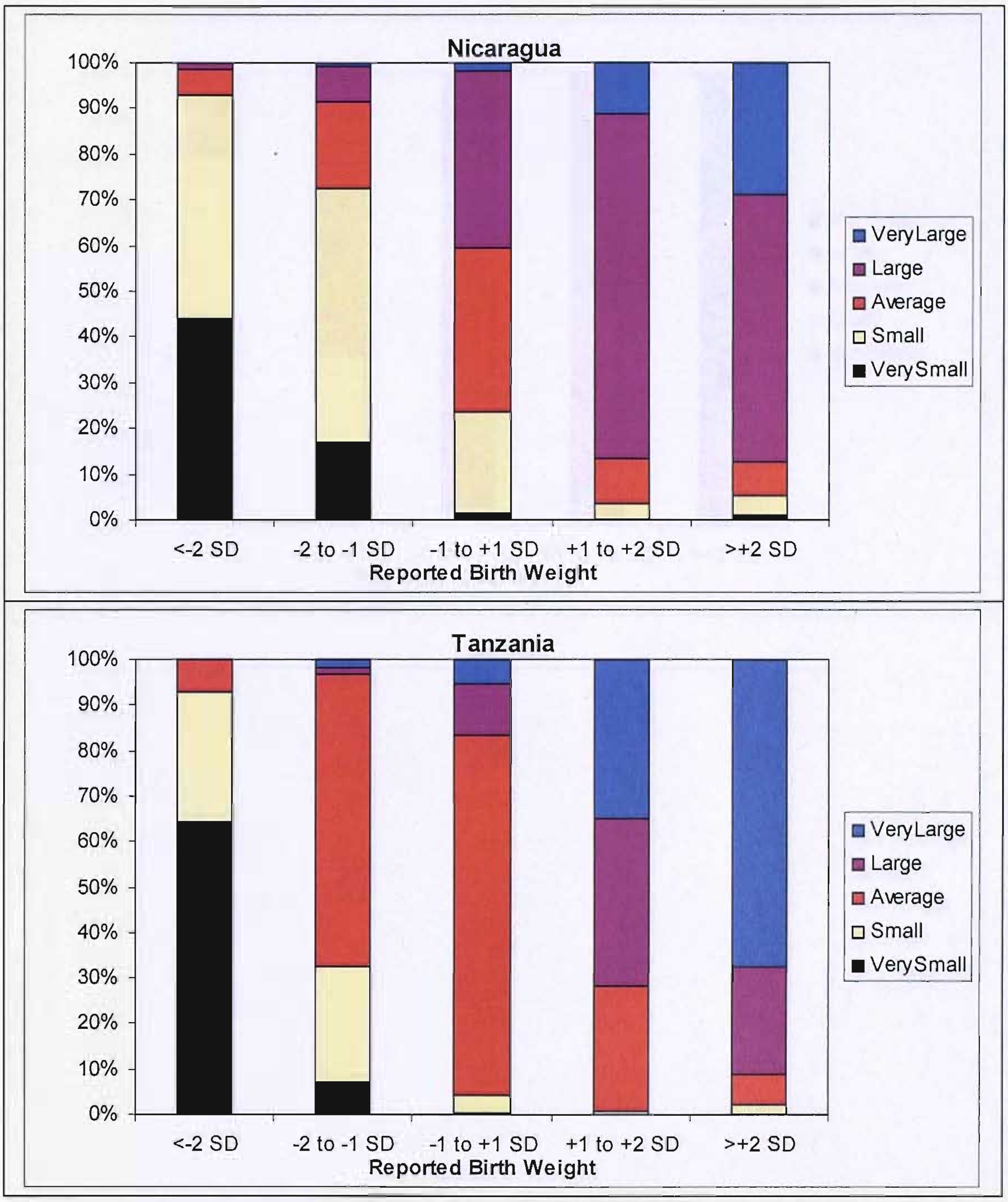

Cambodia
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
Very Large
Large
Average
Small
Very Small

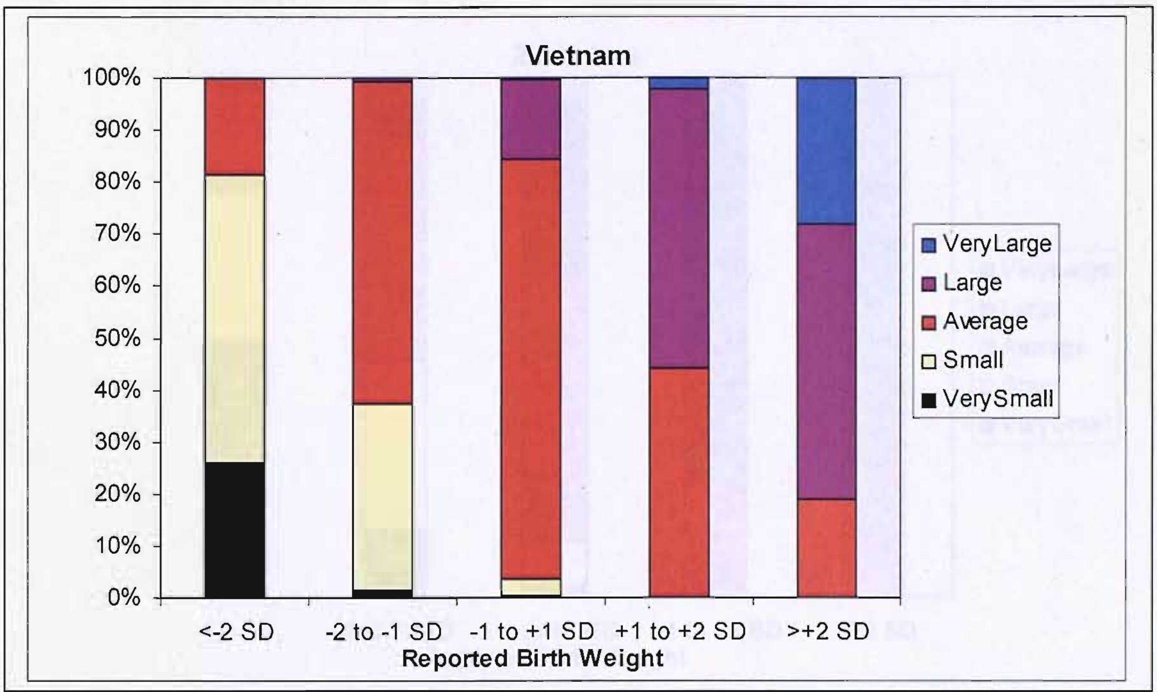

Gabon
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
Very Large
Large
Average
Small
Very Small

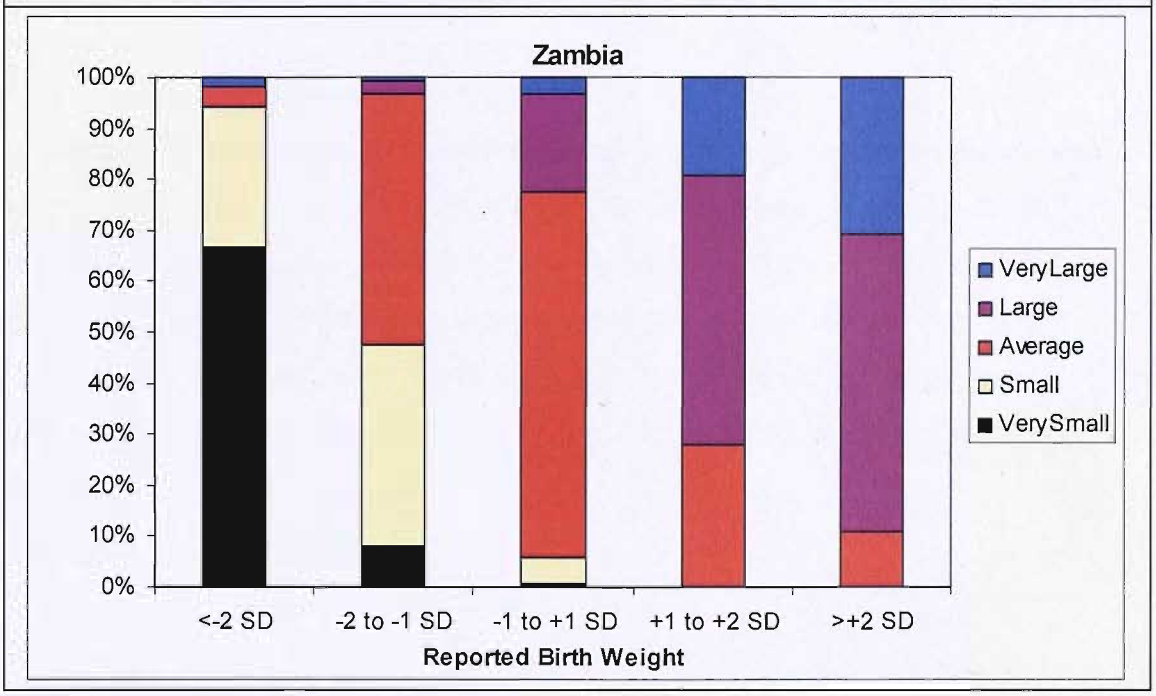

India
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
Large
Average
Small
Very Small

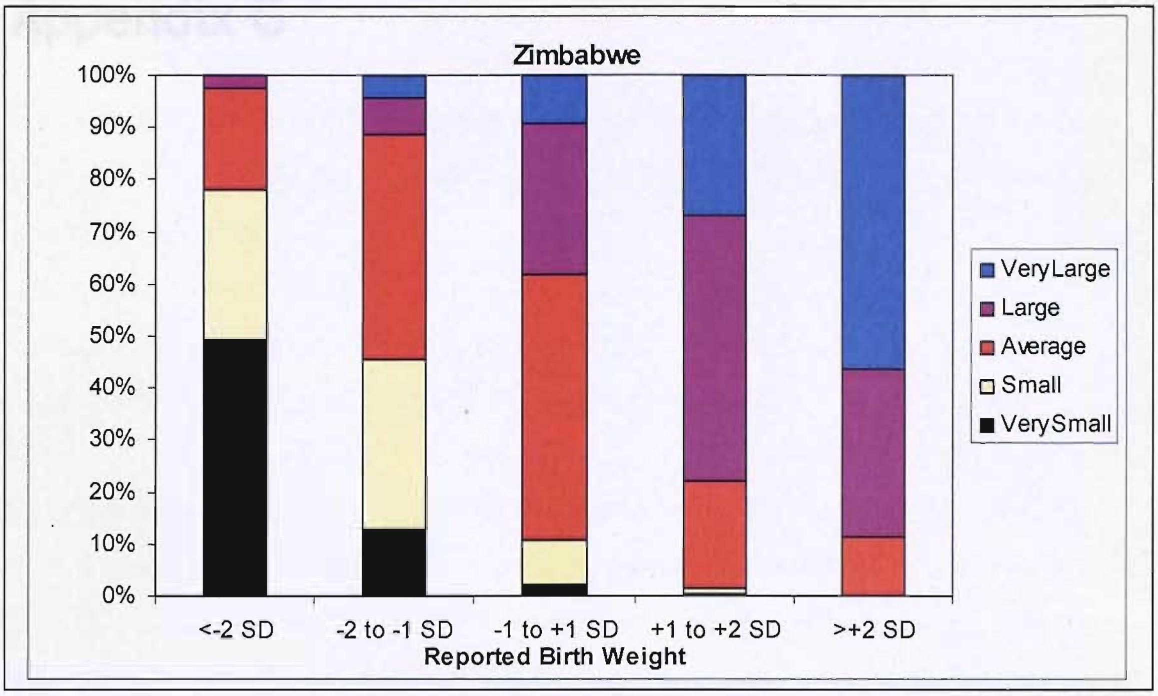

Kazakhstan
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall
Malawi
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall


Mali
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall
Mozambique
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall


Nicaragua
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall
Tanzania
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall


Vietnam
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall


Zambia
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall


Zimbabwe
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
<-2 SD
-2 to -1 SD
-1 to +1 SD
+1 to +2 SD
>+2 SD
Reported Birth Weight
VeryLarge
Large
Average
Small
VerySmall

Appendix G

Box 6.1 displayed the residual analysis from the multilevel multinomial logistic regression model studying a correct assessment of size in Cambodia for variation at the cluster level. Results of the residual analysis for both Malawi and Cambodia for the same analysis are presented here. For each level which is significant in each country a histogram of the residuals was plotted, to assess normality of residuals, coupled with a P-P plot of the residuals. Scatterplots of the residuals against their respective cluster/district level identifier were also plotted to assess constancy of variance.

Cambodia

The residuals for the multinomial logistic model studying mother's perception of size in Cambodia at the cluster level are displayed in Box 6.1. The results at the province level are shown below.

There are two sets of residuals: one set for mothers who make a larger assessment, and one set for mothers who make a smaller assessment.

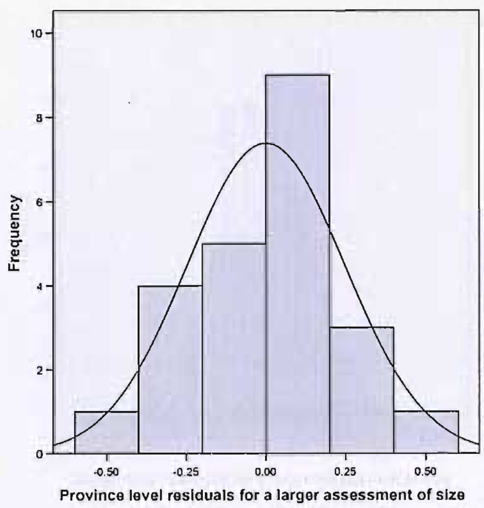
The histograms, although not perfectly normal, do show a general normal pattern. This is corroborated by the P-P plots which show the residuals for each province lying close to the normal line. Deviations from this line are expected as there are only 23 provinces, and hence only 23 residuals. The scatterplots show no discernable trends. The assumptions for the multilevel model are therefore shown to hold.

Malawi

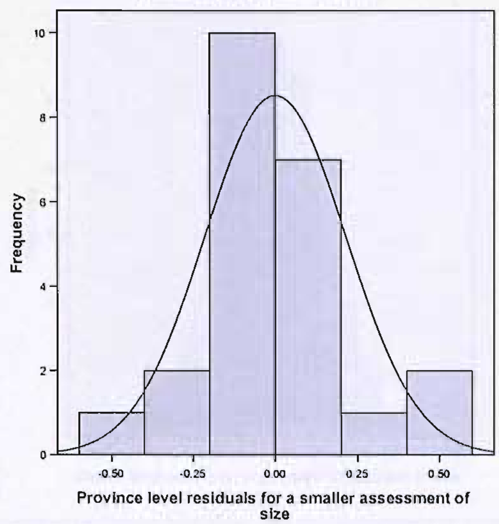
The residuals at both the cluster and district levels for Malawi are shown below. The residuals at the cluster level are normally distributed (shown in the histogram and the P-P plot) and there are no trends observed in the scatterplot. At the district level the histograms for both larger and smaller assessments do not appear normal, although the P-P plots indicate that the departure from normality is not large. With the small number of districts the departure from normality is not unexpected, and thus the assumption of normality is not seen to be violated. Again, no trends are seen in the scatterplot. It is therefore concluded that the assumptions of the multilevel model hold for Malawi.

Cambodia Province Level

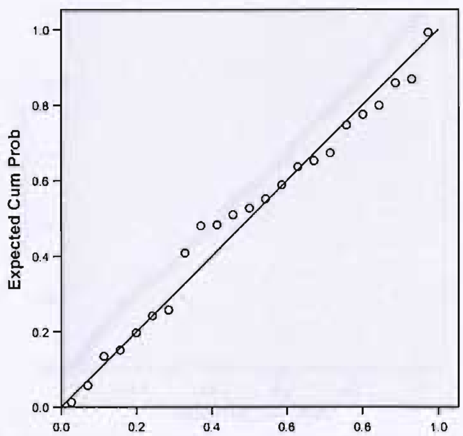
Histogram of Province Level Residuals
(Larger Assessment of Size)



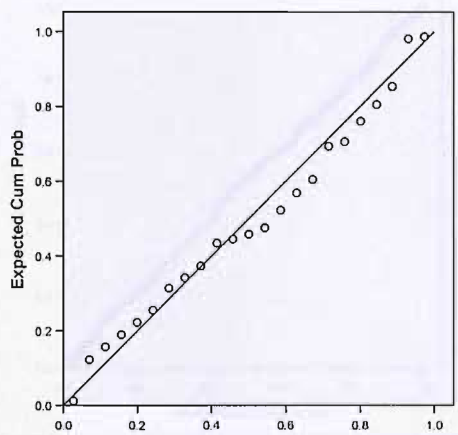
Histogram of Cluster Level Residuals
(Smaller Assessment of Size)



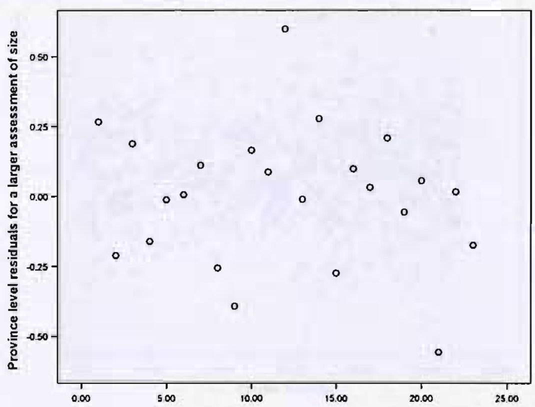
Normal P-P Plot of Province Level Residuals
(Larger Assessment of Size)



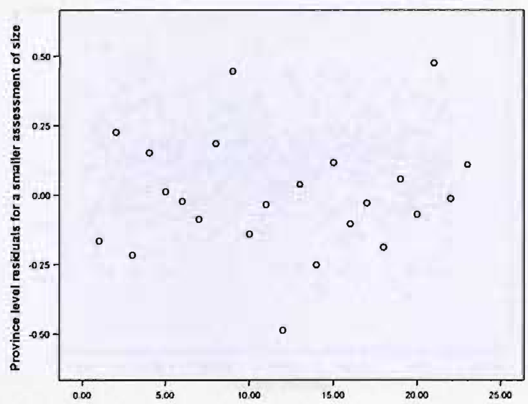
Normal P-P Plot of Province Level Residuals
(Smaller Assessment of Size)



Scatterplot of Province Level Residuals Against Province Level Identifier (Larger Assessment of Size)

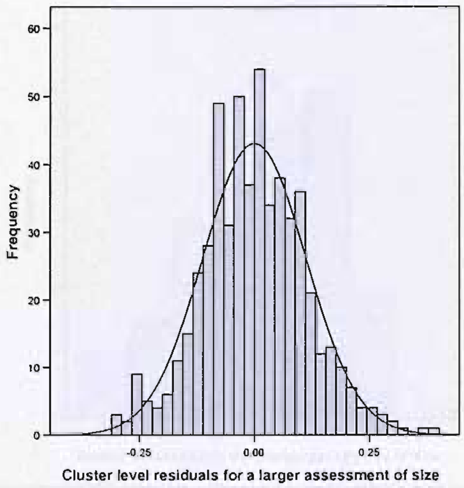


Scatterplot of Province Level Residuals Against Province Level Identifier (Smaller Assessment of Size)

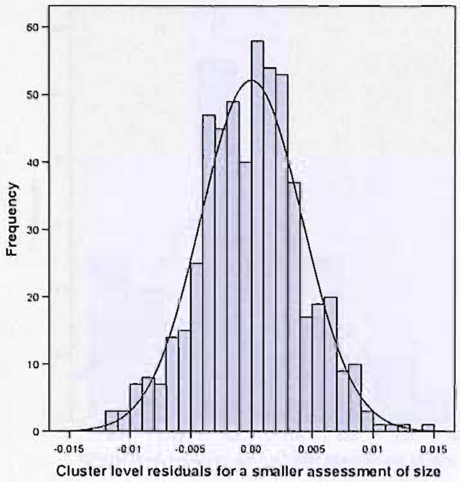


Malawi Cluster Level

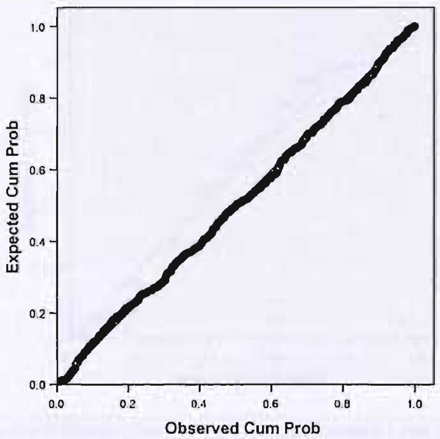
Histogram of Cluster Level Residuals (Larger Assessment of Size)



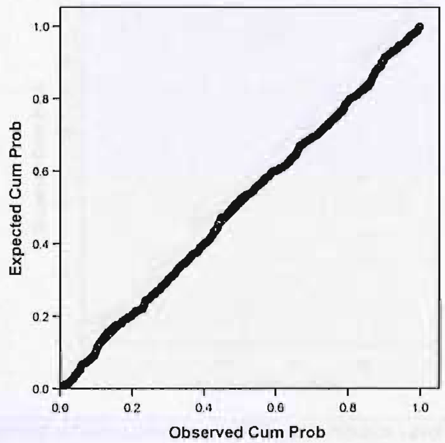
Histogram of Cluster Level Residuals (Smaller Assessment of Size)



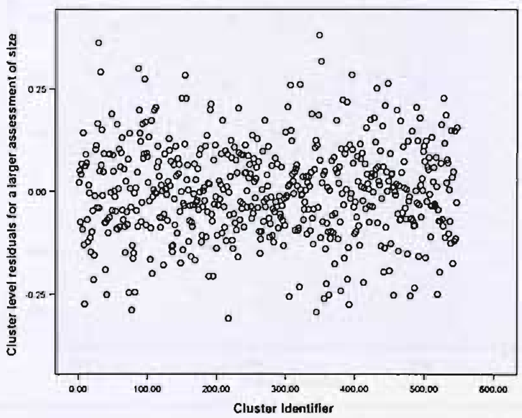
Normal P-P Plot of Cluster Level Residuals (Larger Assessment of Size)



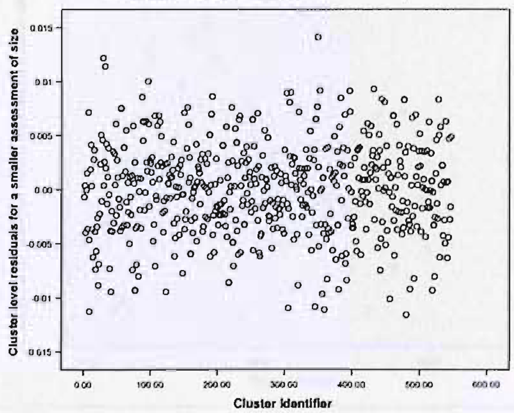
Normal P-P Plot of Cluster Level Residuals (Smaller Assessment of Size)



Scatterplot of Cluster Level Residuals Against Province Level Identifier (Larger Assessment of Size)

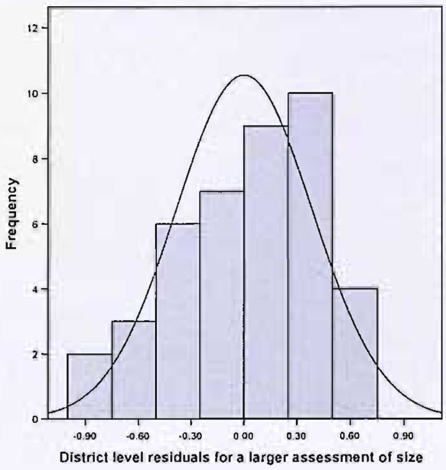


Scatterplot of Cluster Level Residuals Against Province Level Identifier (Smaller Assessment of Size)

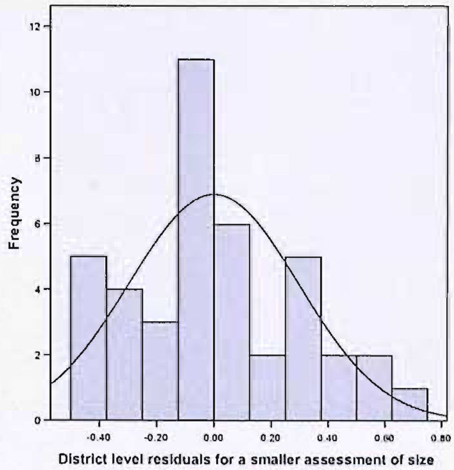


Malawi District Level

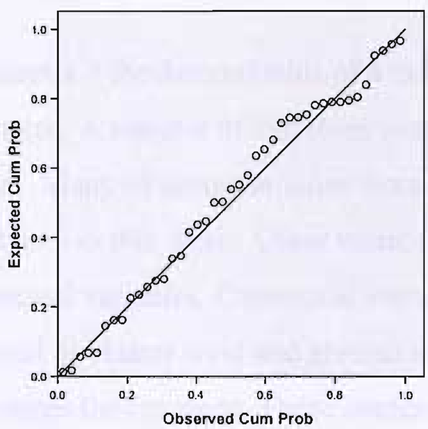
Histogram of District Level Residuals
(Larger Assessment of Size)



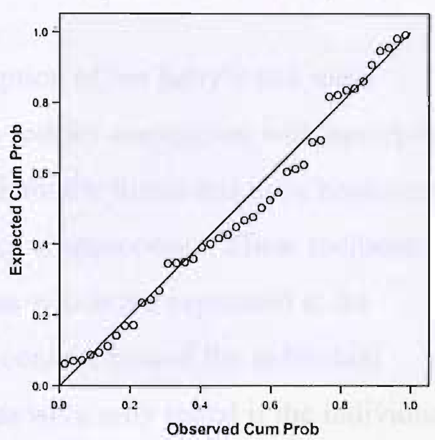
Histogram of District Level Residuals
(Smaller Assessment of Size)



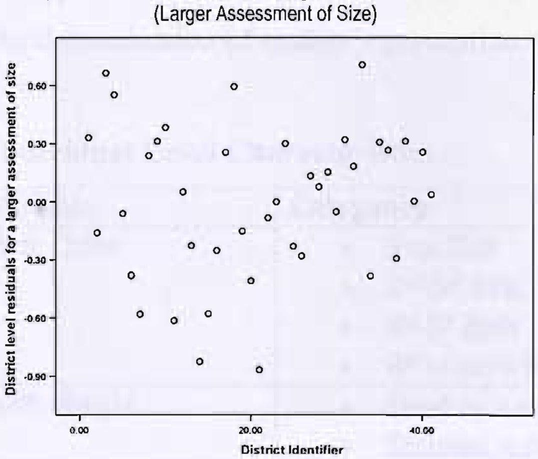
Normal P-P Plot of District Level Residuals
(Larger Assessment of Size)



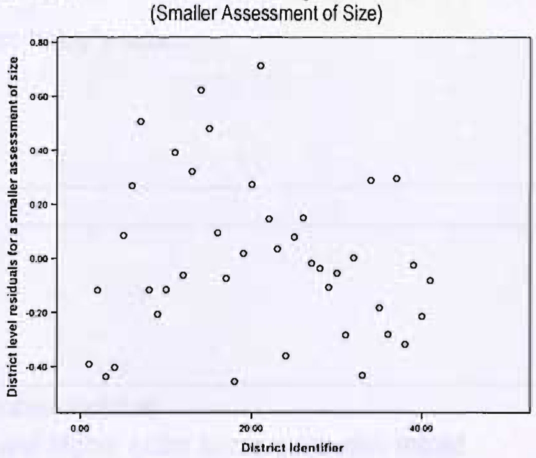
Normal P-P Plot of District Level Residuals
(Smaller Assessment of Size)



Scatterplot of District Level Residuals Against Province Level Identifier
(Larger Assessment of Size)



Scatterplot of District Level Residuals Against Province Level Identifier
(Smaller Assessment of Size)



Appendix H

In Chapter 7 the determinants of a mother's perception of her baby's size were estimated. A number of variables were selected to test for association with perception of size. Many of these variables were used throughout the thesis and have been noted elsewhere in this thesis. Other variables were tested if appropriate. These included contextual variables. Contextual variables are those which are expressed at the regional or cluster level and give an idea how the context around the individual influences the response. These contextual variables were only tested if the individual level parameter was significant in the model. This Appendix lists the variables used in the determination of mother's perception of her baby's size.

Individual Level Characteristics

Variable	Categories
Birth Order	• First Birth • 2nd-3rd Birth • 4th-5th Birth • 6th or more Birth
Birth Weight	• Used as a continuous variable • Squared, cubed and higher order terms were also tested
Gender of the Child	• Male • Female
Literacy	• Cannot Read • Can Read to a Limited Extent • Can Read

Variable	Categories
Marital Status	• Currently Married • Never Married • Formerly Married
Maternal Highest Educational Level	• No Education Obtained • Primary School • Secondary School or Higher education
Method of reporting birth weight	• Recall from memory • Reported from a card
Mother's Age at the Time of the Birth	• Under 19 Years Old • Between 20 and 29 Years Old • Between 30 and 39 Years Old • Between 40 and 49 Years Old
Partner's Highest Educational Level	• No Education Obtained • Primary School • Secondary School or Higher education • Not Applicable/Missing (if mother does not have a partner)
Place of Delivery	• Home/Unknown • Institution (i.e. Hospital, Community Centre)
Place of Residence	• Urban Area • Rural Area
Region	• Region of the country differed between countries o Cambodia – five different regions (ecozones) o Kazakhstan – six different regions o Malawi – three different regions
Religion	• Religion differed between countries o Cambodia – two groups; Buddhist and Other o Kazakhstan – three groups; Muslim, Christian and Other o Malawi – seven different groups
Time since birth	• Continuous variable measuring time since the birth to the interview in months
Wealth	• Quintiles generated from DHS macro files (Wealthiest Used as reference category) • The continuous wealth factor scores were also used as an alternative to quintiles
Working Status	• Currently Working • Not Currently Working

Contextual Variables

Variable	Description
Females	• Proportion of female infants calculated within each cluster and district
Home deliveries	• Proportion of infants delivered at home in each cluster and district
Birth weight	• Average birth weight in each cluster and district • Difference between an individual's weight and the mean weight in each cluster, divided into five categories: o Below -1.5 SD from mean weight o Between -1.5 SD and -0.5 SD from mean weight o Between -0.5 SD and +0.5 SD from mean weight o Between +0.5 SD and +1.5 SD from mean weight o Above +1.5 SD from mean weight • Difference between an individual's weight and the mean weight in each cluster used as a continuous variable
Wealth	• Average wealth in each cluster and district
Survival	• Proportion of infants in each cluster and district who have survived

Appendix I

Chapter 8 conducts an analysis of mortality in three periods of time within the first year of life. This is to assess the validity of applying a number of different techniques to mitigate the impact of missing birth weight information. In these models a number of covariates were used. These are listed in this Appendix. Also noted are the reference categories for each covariate.

Variable	Categories
Birth Weight	• Less than 2 S.D.'s Below the Mean Birth Weight • Between 1 S.D. and 2 S.D. Below the Mean Birth Weight • Between +1 and -1 S.D. From the Mean Birth Weight (reference) • Between 1 S.D. and 2 S.D. Above the Mean Birth Weight • More than 2 S.D.'s Above the Mean Birth Weight
Birth Order/ Birth Interval	• First Birth • 2nd-3rd Birth/Birth Interval <24 months • 2nd-3rd Birth/Birth interval >24 months (reference) • 4th or more Birth/Birth Interval <24 months • 4th or more Birth/Birth Interval >24 months
Mother's Age at the Time of the Birth	• Under 19 Years Old • Between 20 and 29 Years Old (reference) • Between 30 and 39 Years Old • Between 40 and 49 Years Old
Maternal Highest Educational Level	• No Education Obtained • Primary School • Secondary School or Higher education (reference)
Wealth	• Quintiles generated from DHS macro files (Wealthiest Used as reference category)
Gender of the Child	• Male • Female (reference)
Place of Delivery	• Home/Unknown • Institution (i.e. Hospital, Community Centre) (reference)
Place of Residence	• Urban Area (reference) • Rural Area
Marital Status	• Currently Married (reference) • Never Married • Formerly Married
Working Status	• Currently Working (reference) • Not Currently Working

Appendix J

Tables 8.6, 8.7 and 8.8 displayed the parameter values for the relationship between birth weight (categorised into 5 groups) and ENN, NN and PNN mortality for Kazakhstan, Malawi and Cambodia respectively. This Appendix presents the parameter values and standard errors for the covariates in these models. For each country the results are presented for the models studying ENN, NN and PNN mortality for complete case, multiple imputation, inverse probability weighting and using mother's perception of size as a proxy for birth weight methods.

Early Neonatal Mortality in Cambodia

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	1.72	1.17	0.98	0.82	1.38	1.29	1.46	28.45
	Smaller than Average	-1.42	1.17	0.96	0.70	0.74	1.06	-1.26	12.64
	Average	-1.48	1.00	0.22	0.69	0.36	1.03	-1.19	12.79
	Larger than Average	-0.24	1.27	-0.34	0.68	0.22	0.96	-0.45	13.06
	Very Large	0	0	0	0	0	0	0	0
Age at Birth	<20	-0.64	1.08	-0.48	0.31	-0.29	0.33	-1.53	7.60
	20-29	0	0	0	0	0	0	0	0
	30-39	-0.35	0.57	0.52	0.11	0.49	0.12	0.58	1.54
	>40	-0.31	0.82	0.72	0.34	0.71	0.37	0.25	10.53
Parity/Birth Interval	First Birth	0.33	0.46	0.54	0.22	0.48	0.22	0.75	2.68
	2-3rd Bth/<24mnths	1.18	0.33	1.00	0.33	1.11	0.27	2.62	2.32
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	0.10	0.87	0.51	0.25	0.60	0.24	-0.65	50.40
	4+ Bth/>24mnths	-0.52	0.59	-0.36	0.21	-0.29	0.20	-0.54	2.43
Maternal Education	None	1.71	0.71	0.49	0.32	0.47	0.33	1.58	2.92
	Primary	0.91	0.48	0.54	0.42	0.52	0.36	1.27	1.50
	Secondary+	0	0	0	0	0	0	0	0
Wealth Quintile	Lowest	-1.33	1.01	0.36	0.46	0.49	0.54	-1.36	6.92
	Below Average	0.18	0.85	0.30	0.48	0.44	0.58	-0.05	4.38
	Average	0.15	0.76	0.74	0.44	0.79	0.48	0.04	2.21
	Above Average	-1.53	0.57	0.18	0.25	0.27	0.27	-1.16	2.79
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.80	0.52	0.60	0.18	0.56	0.17	1.34	1.52
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	-3.28	0.90	-1.07	0.52	-1.07	0.50	-3.38	3.08
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	0.54	0.28	0.18	0.31	0.14	0.27	0.55	1.28
	Urban	0	0	0	0	0	0	0	0
Marital Status	Formerly Married	2.00	0.55	0.44	0.42	0.46	0.39	2.37	1.87
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	-0.62	0.17	-0.08	0.24	-0.09	0.21	-1.28	2.53
	Working	0	0	0	0	0	0	0	0

Neonatal Mortality in Cambodia

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	1.62	1.18	0.70	0.60	0.98	1.05	1.48	10.33
	Smaller than Average	-1.37	1.14	0.78	0.54	0.47	0.86	-1.30	3.01
	Average	-1.26	0.96	-0.08	0.55	0.04	0.81	-1.06	2.86
	Larger than Average	-0.17	1.26	-0.58	0.60	-0.08	0.80	-0.39	4.48
	Very Large	0	0	0	0	0	0	0	0
Age at Birth	<20	-0.51	1.02	-0.32	0.27	-0.18	0.30	-1.42	8.06
	20-29	0	0	0	0	0	0	0	0
	30-39	-0.34	0.57	0.38	0.15	0.36	0.14	0.67	2.05
	>40	0.57	0.77	0.56	0.34	0.53	0.37	1.12	2.79
Parity/Birth Interval	First Birth	0.26	0.45	0.46	0.20	0.40	0.19	0.71	3.18
	2-3rd Bth/<24mnths	1.02	0.33	0.82	0.26	0.91	0.23	2.56	3.15
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	0.00	0.88	0.57	0.21	0.65	0.20	-0.60	14.49
	4+ Bth/>24mnths	-0.36	0.58	-0.45	0.17	-0.37	0.16	-0.47	3.52
Maternal Education	None	1.47	0.81	0.61	0.33	0.63	0.33	1.44	4.26
	Primary	0.90	0.47	0.72	0.42	0.71	0.37	1.30	1.42
	Secondary+	0	0	0	0	0	0	0	0
Wealth Quintile	Lowest	-0.74	1.08	0.42	0.41	0.54	0.44	-0.94	7.85
	Below Average	0.18	0.58	0.27	0.44	0.41	0.51	-0.04	5.26
	Average	0.18	0.78	0.69	0.40	0.75	0.40	0.09	2.82
	Above Average	-1.41	0.57	0.20	0.26	0.33	0.25	-1.13	3.97
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.57	0.51	0.51	0.16	0.46	0.15	1.34	1.86
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	-2.84	0.58	-0.79	0.50	-0.80	0.47	-3.04	4.50
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	0.52	0.28	0.02	0.27	0.02	0.25	0.59	1.58
	Urban	0	0	0	0	0	0	0	0
Marital Status	Formerly Married	1.93	0.56	0.37	0.40	0.34	0.39	2.30	1.92
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	-0.66	0.16	-0.23	0.21	-0.23	0.19	-1.31	3.17
	Working	0	0	0	0	0	0	0	0

Post-neonatal Mortality in Cambodia

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	2.23	1.08	0.49	0.36	0.07	0.51	3.33	13.65
	Smaller than Average	2.64	0.83	0.32	0.26	0.23	0.28	3.67	13.35
	Average	1.35	0.76	-0.06	0.13	0.04	0.23	2.07	13.08
	Larger than Average/Very Large	0	0	0	0	0	0	0	0
Age at Birth	<20	-0.09	0.97	-0.06	0.30	-0.09	0.29	-0.39	1.06
	20-29	0	0	0	0	0	0	0	0
	30-39	-0.27	0.40	-0.23	0.18	-0.22	0.17	0.02	1.12
	>40	1.26	0.94	0.30	0.26	0.27	0.24	0.85	2.49
Parity/Birth Interval	First Birth	1.22	0.08	0.38	231.00	0.39	0.22	1.54	1.00
	2-3rd Bth/<24mnths	0.75	1.24	0.57	0.26	0.57	0.25	2.40	2.55
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	0.76	1.05	0.45	0.30	0.44	0.31	0.13	1.90
	4+ Bth/>24mnths	-0.20	1.18	0.11	0.13	0.12	0.13	0.73	2.32
Maternal Education	None	1.76	0.69	0.24	0.22	0.29	0.22	1.59	1.16
	Primary	0.43	0.77	0.22	0.24	0.24	0.25	0.55	1.00
	Secondary+	0	0	0	0	0	0	0	0
Wealth Quintile	Lowest	1.10	0.65	1.25	0.33	1.19	0.29	1.25	1.47
	Below Average	0.30	0.56	1.12	0.34	1.10	0.27	-0.03	1.65
	Average	-0.18	0.73	0.99	0.33	0.95	0.31	0.05	1.34
	Above Average	-1.45	1.27	0.87	0.37	0.82	0.34	-1.18	2.33
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.34	0.45	0.18	0.15	0.16	0.14	-0.10	0.79
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	0.47	0.61	0.61	0.38	0.60	0.43	0.12	1.14
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	0.60	0.42	-0.42	0.18	-0.40	0.15	0.82	1.21
	Urban	0	0	0	0	0	0	0	0
Marital Status	Formerly Married	2.05	0.90	0.67	0.22	0.68	0.23	2.14	2.19
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	0.57	0.50	0.04	0.17	0.02	0.14	0.17	0.93
	Working	0	0	0	0	0	0	0	0

Early Neonatal Mortality in Kazakhstan

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	2.95	1.03	2.47	0.90	2.68	0.82	2.98	0.92
	Smaller than Average	1.36	0.85	1.71	0.60	1.90	0.87	1.34	0.91
	Average or Larger	0	0	0	0	0	0	0	0
Age at Birth	<20	0.32	1.13	-0.05	0.79	0.11	0.86	0.38	1.55
	20-29	0	0	0	0	0	0	0	0
	>30	0.03	0.52	0.59	0.20	0.18	0.65	0.05	0.72
Parity/Birth Interval	First Birth	-0.17	1.25	0.41	1.00	-0.56	1.16	-0.20	1.54
	2-3rd Bth/<24mnths	1.32	0.55	2.06	0.70	1.02	0.31	1.30	0.90
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	1.06	0.43	1.21	0.55	0.43	0.32	1.02	1.02
	4+ Bth/>24mnths	0.43	0.46	0.80	0.44	-0.01	0.53	0.36	1.49
Wealth Quintile	Lowest	-1.02	0.90	-2.24	1.26	-1.60	1.04	-1.01	1.36
	Below Average	-2.17	0.76	-3.34	1.24	-2.80	0.95	-2.09	1.62
	Average	-3.24	1.83	-4.10	1.83	-3.38	1.45	-3.23	0.96
	Above Average	-2.14	1.29	-2.83	1.39	-2.79	1.34	-2.14	0.72
	Highest	0	0	0	0	0	0	0	0
Gender	Male	1.29	0.75	1.18	0.80	0.77	0.50	1.31	0.77
	Female	0	0	0	0	0	0	0	0
Residence	Rural	0.81	0.66	2.20	0.80	1.24	0.53	0.79	1.15
	Urban	0	0	0	0	0	0	0	0
Marital Status	Formerly/Never Married	0.62	0.88	0.30	0.65	0.21	0.77	0.62	1.35
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	0.54	0.75	0.52	0.55	-0.22	0.38	0.58	0.90
	Working	0	0	0	0	0	0	0	0

Neonatal Mortality in Kazakhstan

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	3.07	0.84	2.06	0.76	2.62	0.66	3.11	0.72
	Smaller than Average	0.84	0.76	1.39	0.55	1.34	0.84	0.82	0.89
	Average or Larger	0	0	0	0	0	0	0	0
Age at Birth	<20	0.20	1.03	-0.26	0.86	-0.06	0.83	0.25	1.34
	20-29	0	0	0	0	0	0	0	0
	>30	-0.35	0.89	0.26	0.58	-0.17	0.92	-0.31	0.77
Parity/Birth Interval	First Birth	-0.43	1.15	0.13	0.84	-0.71	0.98	-0.45	1.31
	2-3rd Bth/<24mnths	1.54	0.63	2.08	0.54	1.31	0.43	1.53	0.86
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	0.90	0.53	0.70	0.45	0.45	0.37	0.85	0.91
	4+ Bth/>24mnths	1.13	0.73	1.24	0.65	0.12	0.44	1.10	1.34
Wealth Quintile	Lowest	-1.53	0.79	-2.22	1.04	-2.09	0.96	-1.53	1.08
	Below Average	-1.91	0.96	-2.74	1.24	-2.61	1.22	-1.90	1.30
	Average	-1.60	0.91	-2.69	1.16	-2.29	0.96	-1.61	1.12
	Above Average	-2.12	1.27	-2.67	1.29	-2.75	1.31	-2.13	0.75
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.75	0.68	0.76	0.75	0.45	0.52	0.78	0.65
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	-0.82	1.70	-0.84	1.43	1.66	0.99	-0.95	1.10
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	1.30	0.50	2.26	0.61	1.47	0.38	1.30	0.75
	Urban	0	0	0	0	0	0	0	0
Marital Status	Formerly/Never Married	1.56	0.55	1.19	0.62	1.14	0.62	1.57	1.20
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	0.92	0.86	0.86	0.55	0.27	0.41	0.94	0.90
	Working	0	0	0	0	0	0	0	0

Post-neonatal Mortality in Kazakhstan

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	0.44	0.52	0.20	0.49	0.34	0.58	0.38	0.41
	Smaller than Average	1.10	0.27	-0.33	0.37	1.17	0.29	1.10	0.70
	Average or Larger	0	0	0	0	0	0	0	0
Age at Birth	<20	-0.97	1.08	-1.08	1.14	-1.06	1.10	-0.96	1.25
	20-29	0	0	0	0	0	0	0	0
	>30	-1.28	0.42	-1.30	0.41	-1.19	0.38	-1.28	1.05
Parity/Birth Interval	First Birth	-0.16	0.23	0.00	0.24	-0.01	0.25	-0.16	0.66
	2-3rd Bth/<24mnths	-1.16	0.19	-1.12	0.24	-1.19	0.21	-1.18	1.88
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	0.28	0.28	0.05	0.26	-0.10	0.20	0.29	0.70
	4+ Bth/>24mnths	0.58	0.40	0.62	0.33	0.46	0.40	0.54	1.15
Wealth Quintile	Lowest	1.22	0.96	1.05	0.88	1.20	1.03	1.20	1.32
	Below Average	1.87	0.57	1.87	0.53	1.67	0.55	1.86	1.26
	Average	1.21	1.00	1.25	0.91	1.11	1.04	1.20	1.25
	Above Average	-2.07	1.25	-2.10	1.27	-2.09	1.28	-2.06	1.09
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.77	0.41	0.76	0.40	0.83	0.42	0.78	0.51
	Female	0	0	0	0	0	0	0	0
Residence	Rural	-0.95	0.39	-0.85	0.31	-0.77	0.38	-0.93	0.62
	Urban	0	0	0	0	0	0	0	0
Marital Status	Formerly/Never Married	0.98	0.47	1.05	0.38	0.93	0.47	0.99	0.77
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	-0.63	0.19	-0.63	0.16	-0.62	0.18	-0.64	0.54
	Working	0	0	0	0	0	0	0	0

Early Neonatal Mortality in Malawi

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	-0.15	0.78	1.13	0.28	0.63	0.74	0.45	0.43
	Smaller than Average	0.27	0.49	0.19	0.27	0.47	0.33	-0.19	0.41
	Average	-0.48	0.42	-0.23	0.18	-0.04	0.29	0.05	0.64
	Larger than Average/Very Large	0	0	0	0	0	0	0	0
Age at Birth	<20	0.39	0.21	0.35	0.18	0.28	0.17	0.57	0.51
	20-29	0	0	0	0	0	0	0	0
	30-39	0.58	0.48	0.44	0.26	0.46	0.26	0.98	0.80
	>40	2.85	0.63	1.45	0.33	1.54	0.35	2.51	0.93
Parity/Birth Interval	First Birth	0.20	0.28	0.60	0.27	0.69	0.25	0.09	0.57
	2-3rd Bth/<24mnths	1.61	0.51	0.63	0.30	0.61	0.33	1.41	0.69
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	1.00	0.56	0.12	0.35	0.17	0.37	0.49	0.83
	4+ Bth/>24mnths	-0.68	0.76	-0.76	0.30	-0.73	0.30	-0.95	0.86
Maternal Education	None	0.02	0.87	0.97	0.64	1.00	0.66	0.25	0.73
	Primary	0.25	0.77	1.02	0.63	1.12	0.66	0.26	0.54
	Secondary+	0	0	0	0	0	0	0	0
Wealth Quintile	Lowest	0.35	0.61	0.17	0.20	0.03	0.20	-0.01	0.50
	Below Average	0.09	0.64	-0.10	0.24	-0.18	0.25	-0.04	0.53
	Average	-0.29	0.48	0.20	0.23	0.09	0.23	-0.21	0.70
	Above Average	-0.61	0.64	-0.28	0.25	-0.40	0.27	-0.32	0.73
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.10	0.27	0.45	0.15	0.41	0.14	0.13	0.39
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	0.21	0.44	0.50	0.12	0.57	0.12	0.61	0.70
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	-0.22	0.54	0.28	0.18	0.28	0.20	-0.20	0.51
	Urban	0	0	0	0	0	0	0	0
Marital Status	Never Married	-1.33	1.19	0.42	0.45	0.34	0.44	-1.47	0.47
	Formerly Married	-0.82	0.68	0.18	0.20	0.27	0.20	-0.78	0.87
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	-0.42	0.36	0.03	0.14	0.03	0.13	-0.43	0.40
	Working	0	0	0	0	0	0	0	0

Neonatal Mortality in Malawi

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small	1.27	1.34	0.91	0.27	0.79	0.80	1.09	0.95
	Smaller than Average	1.28	1.12	0.20	0.26	0.66	0.67	1.22	0.30
	Average	0.37	1.11	-0.45	0.20	0.06	0.62	0.41	0.28
	Larger than Average	0.41	1.20	-0.46	0.25	-0.07	0.71	0.19	0.51
	Very Large	0	0	0	0	0	0	0	0
Age at Birth	<20	0.24	0.29	0.25	0.17	0.19	0.18	0.53	0.46
	20-29	0	0	0	0	0	0	0	0
	30-39	0.72	0.35	0.41	0.24	0.44	0.24	0.93	0.50
	>40	1.99	0.46	1.12	0.33	1.23	0.34	1.84	0.66
Parity/Birth Interval	First Birth	0.60	0.36	0.77	0.21	0.84	0.21	0.31	0.52
	2-3rd Bth/<24mnths	1.60	0.45	0.78	0.28	0.78	0.30	1.42	0.60
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	1.17	0.54	0.39	0.33	0.42	0.34	0.72	0.60
	4+ Bth/>24mnths	0.01	0.52	-0.44	0.30	-0.43	0.29	-0.33	0.64
Maternal Education	None	-0.48	0.76	0.68	0.46	0.67	0.48	-0.37	0.66
	Primary	0.08	0.55	0.86	0.42	0.92	0.45	0.00	0.52
	Secondary+	0	0	0	0	0	0	0	0
Wealth Quintile	Lowest	0.69	0.43	0.19	0.23	0.10	0.20	0.61	0.47
	Below Average	0.49	0.52	-0.13	0.26	-0.16	0.25	0.37	0.50
	Average	0.14	0.39	0.17	0.22	0.10	0.21	0.21	0.52
	Above Average	-0.53	0.58	-0.27	0.24	-0.34	0.25	-0.22	0.65
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.08	0.26	0.46	0.12	0.41	0.11	0.04	0.31
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	-0.24	0.50	0.34	0.11	0.40	0.11	0.08	0.62
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	-0.19	0.42	0.27	0.20	0.30	0.22	-0.19	0.46
	Urban	0	0	0	0	0	0	0	0
Marital Status	Never Married	-1.75	1.01	0.12	0.44	0.01	0.44	-1.99	0.42
	Formerly Married	-0.96	0.58	0.09	0.19	0.17	0.18	-0.84	0.71
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	-0.07	0.26	0.12	0.13	0.12	0.13	-0.06	0.32
	Working	0	0	0	0	0	0	0	0

Post-neonatal Mortality in Malawi

		Complete Case		Mother's Perception		Multiple Imputation		Weighted Analysis	
		Parameter	S.E.	Parameter	S.E.	Parameter	S.E.	Parameter	S.E.
Birth weight	Very Small/Smaller than Average	-0.49	0.30	-0.01	0.24	-0.10	0.35	-0.68	0.50
	Average	-0.25	0.33	-0.14	0.20	-0.04	0.32	-0.46	0.47
	Larger than Average	-0.32	0.38	-0.18	0.24	-0.11	0.36	-0.61	0.50
	Very Large	0	0	0	0	0	0	0	0
Age at Birth	<20	-0.07	0.26	-0.11	0.17	-0.10	0.17	-0.15	0.24
	20-29	0	0	0	0	0	0	0	0
	30-39	0.17	0.36	0.01	0.14	0.03	0.14	0.09	0.32
	>40	0.79	0.30	0.38	0.23	0.38	0.23	0.53	0.49
Parity/Birth Interval	First Birth	0.58	0.22	0.67	0.11	0.62	0.12	0.56	0.25
	2-3rd Bth/<24mnths	0.64	0.34	0.46	0.15	0.40	0.15	0.33	0.39
	2-3rd Bth/>24mnths	0	0	0	0	0	0	0	0
	4+ Bth/<24mnths	-0.06	0.48	0.31	0.24	0.30	0.21	-0.16	0.45
	4+ Bth/>24mnths	-0.41	0.32	-0.26	0.20	-0.33	0.20	-0.42	0.31
Maternal Education	None	0.62	0.40	0.82	0.27	0.84	0.26	0.48	0.40
	Primary	0.88	0.32	0.90	0.24	0.89	0.24	0.77	0.37
	Secondary+	0	0	0	0	0	0	0	0
Wealth Quintile	Lowest	-0.08	0.23	0.01	0.20	0.01	0.20	0.02	0.27
	Below Average	-0.21	0.23	-0.25	0.16	-0.23	0.16	-0.19	0.27
	Average	0.01	0.25	0.09	0.19	0.10	0.18	-0.02	0.25
	Above Average	0.04	0.25	0.12	0.20	0.14	0.19	0.14	0.25
	Highest	0	0	0	0	0	0	0	0
Gender	Male	0.03	0.15	0.05	0.08	0.05	0.08	-0.01	0.18
	Female	0	0	0	0	0	0	0	0
Place of Delivery	Home	0.04	0.20	0.03	0.10	0.07	0.10	0.08	0.29
	Institution	0	0	0	0	0	0	0	0
Residence	Rural	1.00	0.32	0.74	0.28	0.74	0.28	0.94	0.26
	Urban	0	0	0	0	0	0	0	0
Marital Status	Never Married	-1.17	0.87	-2.08	0.94	-2.12	0.95	-1.32	0.24
	Formerly Married	0.36	0.22	0.16	0.12	0.17	0.12	0.42	0.22
	Currently Married	0	0	0	0	0	0	0	0
Working Status	Not Working	0.17	0.18	0.13	0.10	0.13	0.10	0.24	0.16
	Working	0	0	0	0	0	0	0	0

Appendix K

The simulation studying the accuracy of the multilevel multiple imputation technique found that covariate parameters in the mortality models were estimated with high accuracy, although the parameters for birth weight were not as accurate. It was hypothesised that the accuracy of the covariate parameters may be due to the parameters estimated simply using the reduced dataset are not biased in the first place. To test this hypothesis the mortality models were estimated using the reduced datasets, with either 5%, 10% or 25% of the birth weights simulated as missing. The parameter results for 10% missing data are presented in Table 8.12. This Appendix presents the parameter estimates for the mortality models and the differences in parameter estimates observed after using the multilevel multiple imputation simulation for 5% and 25% missing data compared to the complete case analysis, and also between the complete case analysis and when the dataset has 5% and 25% of the data simulated as missing.

5% Simulated Missing		Kazakhstan		Malawi		Cambodia	
		Difference MMI method to complete case	Difference no method to complete case	Difference MMI method to complete case	Difference no method to complete case	Difference MMI method to complete case	Difference no method to complete case
Birth weight	Very Light	-0.14	0.04	-0.04	0.00	0.07	0.06
	Lighter than Av	0.35	0.27	0.03	0.03	0.06	0.05
	Average	-	-	0.05	0.03	0.01	-0.01
	Heavier than Av	-	-	0.12	0.07	0.10	0.04
	Very Heavy (Ref)	-	-	-	-	-	-
Birth Order /Birth Interval	First Birth	0.05	0.03	0.04	-0.03	0.01	0.00
	2-3rd/<24months	-0.01	-0.62	0.01	0.05	0.00	0.07
	2-3rd/>24months (Ref)	-	-	-	-	-	-
	4th+/<24months	-0.24	0.14	0.03	0.04	0.03	-0.04
	4th+/>24months	-0.10	0.11	0.00	0.03	0.01	0.03
Wealth Quintile	Lowest	0.02	-0.08	0.03	0.04	0.02	-0.06
	Below Average	-0.03	-0.79	0.02	-0.06	0.00	-0.08
	Average	-0.11	-0.08	-0.01	0.00	-0.04	-0.06
	Above Average	-0.03	0.00	-0.02	0.00	0.03	-0.05
	Highest (Ref)	-	-	-	-	-	-
Gender	Male	0.00	0.33	0.00	0.04	-0.29	-0.31
	Female (Ref)	-	-	-	-	-	-
Place of Delivery	Home	0.00	-0.11	-0.03	0.03	0.04	0.01
	Institution (Ref)	-	-	-	-	-	-
Residence	Rural	0.05	0.03	-0.02	-0.04	-0.02	-0.02
	Urban (Ref)	-	-	-	-	-	-

25% Simulated Missing		Kazakhstan		Malawi		Cambodia	
		Difference MMI method to complete case	Difference no method to complete case	Difference MMI method to complete case	Difference no method to complete case	Difference MMI method to complete case	Difference no method to complete case
Birth weight	Very Light	0.28	0.57	-1.07	-2.27	-0.08	1.21
	Lighter than Av	-0.29	-0.33	-0.46	-0.58	0.31	0.09
	Average	-	-	-0.16	-0.64	-0.09	0.06
	Heavier than Av	-	-	-0.42	-0.87	-	-
	Very Heavy (Ref)	-	-	-	-	-	-
Birth Order /Birth Interval	First Birth	-0.12	0.49	0.11	-0.14	-0.14	1.22
	2-3rd/<24months	-0.08	0.17	0.08	0.44	-0.07	0.41
	2-3rd/>24months (Ref)	-	-	-	-	-	-
	4th+/<24months	0.26	0.91	0.04	0.82	0.02	1.28
	4th+/>24months	0.04	0.58	0.02	0.64	-0.17	-0.23
Wealth Quintile	Lowest	0.06	0.39	0.03	-0.17	-0.17	0.85
	Below Average	0.14	0.66	0.01	-0.51	0.00	-0.06
	Average	0.02	0.40	-0.02	-0.23	0.14	0.44
	Above Average	-0.06	0.28	-0.05	-0.75	0.08	0.51
	Highest (Ref)	-	-	-	-	-	-
Gender	Male	-0.04	-0.18	0.01	-0.28	0.04	-0.40
	Female (Ref)	-	-	-	-	-	-
Place of Delivery	Home	-0.25	-0.29	0.05	-0.90	-0.01	0.09
	Institution (Ref)	-	-	-	-	-	-
Residence	Rural	-0.08	-0.24	-0.01	0.21	0.11	0.68
	Urban (Ref)	-	-	-	-	-	-

Appendix L

Table 8.14 displayed the estimated parameter values for the determinants of NN mortality when using either birth weight or mother's perception of size for the same sample size, and the difference between these estimates. This was to assess the similarity in estimates when using actual birth weight and a proxy for birth weight. The results for the analysis of ENN and PNN mortality for Cambodia, Kazakhstan and Malawi are presented here. Each table will give the parameter estimates obtained when using birth weight and when using mother's perception of size. The difference between these estimates will also be shown.

Early Neonatal Mortality

		Cambodia			Kazakhstan			Malawi		
		Birth Weight	Mother's Perception	Diff	Birth Weight	Mother's Perception	Diff	Birth Weight	Mother's Perception	Diff
Birth weight	Very Light	5.58	3.18	*2.40*	19.16	11.82	*7.34*	0.86	2.15	*-1.28*
	Lighter than Av	0.24	0.17	*0.07*	3.91	5.00	*-1.09*	1.31	0.74	*0.57*
	Average	0.23	0.16	*0.07*				0.62	1.38	*-0.76*
	Heavier than Av	0.79	0.20	*0.59*	1.00	1.00	-	1.00	1.00	-
	Very Heavy (Ref)	1.00	1.00	-						
Birth Order /Birth Interval	First Birth	1.39	1.15	*0.24*	0.85	1.02	*-0.17*	1.22	1.24	*-0.03*
	2-3rd/<24months	3.24	3.32	*-0.08*	3.74	5.73	*-1.99*	5.02	5.38	*-0.36*
	2-3rd/>24months (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-
	4th+/<24months	1.11	0.84	*0.27*	2.89	3.55	*-0.66*	2.73	2.61	*0.12*
	4th+/>24months	0.60	0.55	*0.05*	1.54	1.83	*-0.29*	0.51	0.54	*-0.04*
Wealth Quintile	Lowest	0.26	0.70	*-0.43*	0.36	0.10	*0.26*	1.41	1.48	*-0.06*
	Below Average	1.20	1.38	*-0.18*	0.11	0.03	*0.08*	1.09	1.13	*-0.04*
	Average	1.16	1.53	*-0.37*	0.04	0.01	*0.03*	0.75	0.72	*0.03*
	Above Average	0.22	0.24	*-0.03*	0.12	0.07	*0.05*	0.54	0.53	*0.01*
	Highest (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-
Gender	Male	2.23	2.81	*-0.58*	3.61	3.92	*-0.31*	1.10	1.12	*-0.02*
	Female (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-
Place of Delivery	Home	0.04	0.04	*0.00*	-	-	-	1.23	1.29	*-0.06*
	Institution (Ref)	1.00	1.00	-	-	-	-	1.00	1.00	-
Residence	Rural	1.72	1.71	*0.01*	2.25	7.26	*-5.01*	0.80	0.88	*-0.08*
	Urban (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-

Post-neonatal Mortality

		Cambodia Birth Weight	Cambodia Mother's Perception	Cambodia Diff	Kazakhstan Birth Weight	Kazakhstan Mother's Perception	Kazakhstan Diff	Malawi Birth Weight	Malawi Mother's Perception	Malawi Diff
Birth weight	Very Light	9.30	1.61	*7.69*	1.54	1.27	*0.28*	0.61	0.53	*0.09*
	Lighter than Av	14.06	0.13	*13.92*	2.99	0.69	*2.30*			
	Average	3.87	0.67	*3.20*				0.78	0.68	*0.10*
	Heavier than Av	1.00	1.00	-	1.00	1.00	-	0.73	0.52	*0.21*
	Very Heavy (Ref)							1.00	1.00	-
Birth Order /Birth Interval	First Birth	3.39	3.59	*-0.20*	0.85	0.98	*-0.13*	1.78	1.76	*0.02*
	2-3rd/<24months	2.11	1.87	*0.24*	0.31	0.32	*-0.01*	1.90	1.89	*0.01*
	2-3rd/>24months (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-
	4th+/<24months	2.14	1.88	*0.26*	1.33	1.38	*-0.05*	0.94	0.95	*-0.01*
	4th+/>24months	0.82	0.74	*0.08*	1.78	2.02	*-0.24*	0.66	0.66	*0.01*
Wealth Quintile	Lowest	3.01	4.03	*-1.02*	3.39	3.09	*0.30*	0.92	0.93	*-0.01*
	Below Average	1.35	1.44	*-0.09*	6.46	6.88	*-0.42*	0.81	0.81	*0.00*
	Average	0.84	0.79	*0.05*	3.34	3.49	*-0.15*	1.01	1.02	*-0.01*
	Above Average	0.23	0.24	*-0.01*	0.13	0.12	*0.01*	1.04	1.03	*0.00*
	Highest (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-
Gender	Male	1.40	1.12	*0.28*	2.17	2.21	*-0.04*	1.03	1.03	*0.00*
	Female (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-
Place of Delivery	Home	1.60	1.18	*0.42*	-	-	-	1.04	1.04	*0.00*
	Institution (Ref)	1.00	1.00	-	-	-	-	1.00	1.00	-
Residence	Rural	1.82	1.76	*0.06*	0.39	0.39	*-0.01*	2.72	2.65	*0.07*
	Urban (Ref)	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-

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