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Neonatal Mortality in Developing Countries: an analysis of trends and determinants

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ABSTRACT

FACULTY OF LAW, ARTS AND SOCIAL SCIENCE

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Doctor of Philosophy

NEONATAL MORTALITY IN DEVELOPING COUNTRIES: AN ANALYSIS OF TRENDS AND DETERMINANTS

by Sarah Elizabeth Neal

There is limited understanding of how both trends and determinants of neonatal mortality vary from post-neonatal mortality, and more specifically how health care variables are associated with deaths in the first month of life. In particular the association between care at delivery and neonatal mortality is difficult to determine: in developing countries many women only seek skilled care once complications arise, making poor outcomes more probable. It is therefore inappropriate to directly compare outcomes from those who did and did not receive care at delivery due to this heterogeneity between the groups.

This three-paper PHD thesis attempts to address some of these issues. Chapter 1 provides an overview of what is known about the determinants of neonatal and child mortality, before developing a conceptual framework for the analysis of neonatal and post-neonatal deaths. Chapter 2 (paper 1) provides a comprehensive analysis of the quality of Demographic & Household Surveys (DHS) data, before describing how trends in neonatal mortality differ from post-neonatal mortality over the short- and medium- term. It then examines how the associations between gross domestic product and neonatal, post-neonatal and early childhood mortality at national level differ using both cross-sectional and longitudinal data.

Chapter 3 (paper 2) uses DHS data from Bangladesh to carry out bivariate and multivariate analysis to determine how the determinants of neonatal mortality vary from those of post-neonatal mortality. It also tries to identify groups of women who are at 'high' or 'low' risk from institutional deliveries and compares rates of neonatal mortality. The risk categories are based on socio-economic, maternal health and health care utilisation factors that influence whether or not they are likely to have planned their delivery care or sought hospital care only in the event of complications.

Chapter 4 (paper 3) furthers this work using Indian DHS data by examining how the association between health care determinants and neonatal mortality differ by asset quintile, mother's education and state-level access to professional attendant at delivery. In this chapter I also use instrumental variable methodology to overcome the problem of endogeneity between delivery care variables and neonatal mortality. This technique enables me to examine the association between professional assistance at delivery while adjusting for the heterogeneity between women who do and do not seek such care. Chapter 5 concludes with a summary of key findings, as well as outlining areas for further research in this area.

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DECLARATION OF AUTHORSHIP

I, Sarah Neal, declare that the thesis entitled *"Neonatal Mortality in Developing Countries: an analysis of trends and determinants"* and the work presented in the thesis are both my own, and have been generated by me as a result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this university;

- where I have consulted the published work of others, this is always clearly attributed;

- where I have quoted from the work of others the source is always given. With the exception of such quotations, this thesis is entirely my own work;

- I have acknowledged all main sources of help;

- part of this work has been published in WHO (2005) *The World Health Report 2005: Make every mother and child count.* WHO Geneva

Signed:

Date:

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ABBREVIATIONS

2SLS	Two-stage least squares (regression)
AMI	Acute myocardial infarction
ANC	Antenatal care
ANM	Auxiliary nurse midwife
AWW	Anganwadi worker
BIMARUO	Collective term for the Indian states of Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh and Orissa
CHC	Community health centre
CI	Confidence interval
DHS	Demographic and Household Survey(s)
ECMR	Early childhood mortality rate
FRU	First referral unit
GDP (PPP)	Gross domestic product (purchasing power parity)
HIV	Human immunodeficiency virus
ICDDR(B)	International Centre for Diarrhoeal Disease Research (Bangladesh)
IMR	Infant mortality rate
IV	Instrumental variable
MCH	Maternal and child health
MCH-FP	Maternal and child health - family planning
MMR	Maternal mortality ratio
NFHS	National Family and Household Survey (Indian DHS equivalent)
NMR	Neonatal mortality rate
OLS	Ordinary least squares
OR	Odds ratio
PHC	Primary health centre
PNMR	Post-neonatal mortality rate
PPP	Purchasing power parity
RCH II	Reproductive and Child Programme phase 2
SDP	State domestic product

SE	Standard error
SRS	Sample registration system (India)
TBA	Traditional birth attendant
TT	Tetanus toxoid
U5MR	Under 5 mortality rate
WFS	World Fertility Survey
WHO	World Health Organisation

CHAPTER 1: INTRODUCTION

1.0 Introduction

While significant progress has been made in reducing mortality in the post-neonatal and early childhood periods within the last few decades, progress in reducing neonatal mortality is less marked[1]. This has resulted in an increasing proportion of deaths in children under the age of five occurring in the first 28 days of life. It is estimated that, on a global scale, neonatal deaths now contribute to nearly 40% of all mortality in children under the age of five and around half of all children who die in their first year of life (based on figures from WHO 2006).

Despite the very high burden of mortality, the problem of neonatal mortality has received little attention until relatively recently. There is now a growing consensus within the international community that increased efforts are needed to reduce newborn deaths if further progress is to be made in reducing child mortality. In most countries the Millennium Development Goal to reduce child mortality by three-quarters by 2015 will not be achieved unless significant progress is made in reducing deaths within the first month of life.

1.1 The contribution of this thesis to knowledge on neonatal mortality

Attempts to address neonatal deaths need to be underpinned by a sound analysis of how trends in mortality reduction are different to those of older infants and children. Strategies also need to be based on evidence of factors that both impede and assist progress, and how these may differ in the neonatal and post-neonatal periods. Research in this area has been relatively limited. One of the defining characteristics of neonatal mortality is the intrinsic link with the health of the mother and the care she receives, and a clear understanding of the

[1] The neonatal mortality rate (NMR) is the number of deaths occurring in live-born infants before the 28th day of life per 1000 live births. The terms "neonate" and "newborn" are often used interchangeably.
Post-neonatal mortality rate (PNMR) is the number of deaths of children between 28 days and one year per thousand live births. DHS calculates this by subtracting NMR from the Infant mortality rate. Infant mortality rate (IMR) is the number of deaths in children before the age of one year per thousand live births. Early childhood mortality rate (ECMR) is the number of deaths in children over 12 months of age but less than five years of age per 1000 children reaching 12 months.

association between maternal health services and neonatal outcomes is essential. This thesis aims to examine some of these questions, and look at ways that they can be addressed through analysis of Demographic and Household Survey (DHS) data. The first study examines whether existing DHS data can be used to track changes in neonatal mortality over time at a national level, and compares trends in neonatal, post-neonatal and early childhood mortality over time both in the short- and medium-term. It then examines how differences in Gross Domestic Product (GDP) differentially influence neonatal mortality as opposed to deaths in older children. The subsequent papers build on this by examining the determinants of neonatal mortality using individual level data, with particular emphasis on health service variables.

In particular, the thesis addresses current gaps in knowledge under the following three themes:

1.1.1 Emphasis on examining how neonatal mortality varies from post-neonatal mortality

A greater understanding of how trends in, and determinants of, neonatal mortality differ from post neonatal mortality may shed light on why progress in reducing newborn deaths has been limited. The work on trends examines how reduction in child mortality varies from that in older children both on a country-by-country basis and over the short- and medium-term where patterns in overall child mortality have been quite different: progress in overall child mortality has decelerated in many countries since the mid 1980s/early 1990s, particularly in Sub-Saharan Africa. However, there is no evidence on whether rate of reduction for neonatal mortality has also slowed. Demographic and Household surveys (and the preceding World Fertility Surveys) offer the opportunity to examine more comprehensively how patterns in neonatal mortality differ from those in the post-natal period, and identify countries (or groups of countries) where patterns differ from the norm, and thus if lessons can be learnt from "atypical" examples.

While there is a significant body of information on the determinants of neonatal mortality, evidence is more limited on how they vary from those in the postnatal period. Nearly all available existing comparisons use bivariate data, which does not enable adjustment for confounding variables. This study develops comparable multivariate models which enables more direct comparison of both which variables are significant, and the size of the odds ratio for each variable. This study also uses population data to create a greater understanding on associations between mortality and gross domestic product between the age groups.

1.1.2 Health service determinants of neonatal mortality

The strength of the link between maternal and neonatal health is a factor that clearly differentiates newborns from older children, and the association between use of maternal health care services and neonatal mortality will be a key theme in the latter two papers. There is limited evidence on this, particularly the impact of skilled care during delivery at a population level. This is mainly because of methodological problems: while skilled care at delivery is generally believed to be the cornerstone of programmes to improve the survival of mother and babies, few studies have been able to demonstrate its impact. This is mostly because in developing countries most women only seek skilled care once they experience complications, so it is not possible to compare their outcomes with those of other women. This study attempts to identify groups of "lower risk women" who may have demonstrably lower rates of mortality when using skilled attendance because they are more likely to have planned their care rather than only use delivery services once complications are recognised. It also uses innovative instrumental methodology in an attempt to overcome the problem of endogeneity between place/type of delivery and outcome.

1.1.3 The potential for determinants to vary in impact across different population subgroups

This thesis is unusual as it raises the hypothesis that determinants of mortality may vary between different population groups. In particular it investigates whether maternal health care may have differing associations with outcome based on a mother's socio-economic group or access to health care. This is intuitively plausible: some interventions (*e.g.* tetanus toxoid immunisations) are specifically aimed at diseases associated with poverty and will therefore presumably mostly benefit the poorest, whereas conversely this group may gain less benefit from other types of provision (*e.g.* skilled care at delivery) because of barriers to access or poor quality services. The papers also emphasise the importance of identifying and exploring both inequities in use of services, and how different patterns of usage can lead to inequities in outcome.

1.2 Synopsis of main research questions for the three studies

The listing below provides a synopsis of the main research questions answered in the three studies that make up this thesis.

Study 1: Neonatal mortality in developing countries: quality of data, trends and relationship with GDP.

- How suitable is DHS data for analysing trends in neonatal mortality across time?
- How has neonatal mortality fallen over time? How has the pattern differed from post-neonatal and early childhood mortality? How do patterns differ over the short- and medium-term? Are there any countries that have been notably successful in reducing mortality in comparison with post-neonatal/early childhood mortality?
- Is increase in per capita GDP associated with a differential change in neonatal, post-neonatal and early child mortality at the national level?

Study 2: The Determinants of neonatal mortality in Bangladesh

- What are the associations between maternal health service variables (in particular professional attendance at delivery) and neonatal mortality in Bangladesh
- Do women who can be identified as "lower risk" (based on socio-economic, maternal health and health care utilisation characteristics that mean they are more likely to plan their care) have different outcomes from institutional deliveries than their higher risk counterparts?
- How do the determinants of neonatal mortality compare with post-neonatal mortality in Bangladesh?

Study 3: The impact of antenatal interventions and care at delivery in reducing neonatal mortality in India

- How does the association between health care determinants of neonatal mortality (antenatal care, tetanus toxoid immunization and professional attendant at birth) and outcome differ between socio-economic groups and populations with differing access to services in India?
- Can instrumental variable methodology be used to measure the impact of professional attendant at birth on neonatal mortality?

1.3 Structure of the chapter

This introductory chapter sets the scene and provides the background for the three papers. It initially highlights the importance of neonatal deaths by outlining the global burden of mortality. It also discusses the difficulties faced in effectively quantifying the problem. It then describes causes of mortality, with particular emphasis on indirect determinants (including health care determinants), as this will underpin much of the analysis and discussion in the research that follows. This chapter will then review the existing frameworks for analysing the determinants of childhood mortality, before developing a new one to be used in this thesis which more fully represents the specific factors affecting neonatal health and survival. In conclusion, the chapter will then briefly outline the content of the three papers that make up this PhD.

2.0 The global burden of newborn deaths

2.1 The scale of the problem

It is estimated that every year there are four million neonatal deaths, 98% of which occur in developing countries (WHO 2006). While rates are highest in Sub-Saharan Africa, the absolute burden of mortality is greatest in South East Asia, where 40% of global neonatal deaths occur (ibid). India alone experiences over a million deaths in this age group each year: approximately a quarter of all neonatal deaths (ibid). An estimated 1.2 million newborns die annually Africa (mostly in Sub-Saharan countries), with particularly high burdens of mortality in Nigeria, Ethiopia, the Sudan and the Democratic Republic of the Congo (ibid).

Globally, the neonatal mortality rate is estimated at 30 deaths per 1000 live births, but this masks vast differences between countries. While developed countries only experience an average NMR of 5 per 1000, in least developed countries the average rate rises to 42 per 1000 (WHO 2006). About 75% of newborn deaths occur in the first week of life (the early neonatal period) with the remaining 25% taking place in the late neonatal period (7-28 days).

Important inequalities exist even within countries. Poor women are more likely to experience a neonatal death than their wealthier counterparts (Lawn *et al* 2005), and these inequalities persist even as national rates of neonatal mortality drops: indeed a socio-economic gradient is evident even in developed countries (UK Office of National Statistics 1999). In developing countries that have achieved significant success in reducing neonatal mortality, a challenge often remains in reducing the inequities experienced by poor and disadvantaged communities (*e.g.* Vietnam) (Saving Newborn Lives 2003).

2.2 Neonatal morbidity

While the burden of mortality from neonatal deaths is very striking, this is in many ways only the tip of the iceberg as the conditions that contribute to mortality also cause severe and lifelong disability. For example, it is estimated that over 1 million children who survive birth asphyxia each year develop problems such as cerebral palsy, learning difficulties and other disabilities (JHPIEGO, undated). Low birth weight and pre-term infants are more vulnerable to illness in later childhood (*e.g.* Verhoeff *et al* 2004), and often experience impaired cognitive development affecting their long term opportunities and life-chances (Grantham McGregor and Lira 1998). There is also growing evidence that poor foetal growth during pregnancy has an impact on the development of chronic disease such as diabetes, high blood pressure and cardiovascular disease (Godfrey and Barker 2000). As these are essentially diseases which affect older people, they are becoming of increasing concern as some developing and transition nations face the challenge of growing ageing populations.

2.3 Neonatal mortality as a hidden problem

One reason why neonatal deaths have been neglected until recently is because the problem is to some extent "hidden" due to limited data. Many newborns in developing countries are born and die at home without contact with health care professionals. These deaths usually go unrecorded by any health information system. Most developing countries do not have effective vital registration systems, and therefore any estimate of the burden of mortality usually relies on community-based surveys such as the Demographic and Household Surveys

(DHS). However, these methods are also fraught with difficulties, which will be fully discussed in the next two papers.

3.0 <u>Why do newborns die?</u>

3.1 Direct causes

Data on the direct causes of neonatal mortality is sparse, because as previously discussed most deaths in developing countries occur at home with no contact with professional health care providers. Probably the best current global estimate is from a study by Lawn *et al* (2006) who modelled cause of death using multinomial regression techniques based on vital registration data (where available) and both published and unpublished studies. The study estimated that infections are responsible globally for 36% of all deaths (26% sepsis/pneumonia, 7% tetanus and 3% diarrhoea). A further 28% are caused by pre-term birth, 23% by asphyxia and a further 7% result from congenital abnormalities. The study does however suggest that there are significant variations in the distribution of cause of death between countries and regions and the study is also limited in that it cannot capture the multi-causal nature of many of these deaths. For instance, pre-term infants are more susceptible to infection, but the methodology used is unable to explore these interrelated factors.

3.2 The underlying determinants of neonatal mortality

While probably less is known about the determinants of neonatal mortality than those for older children, there is still a considerable body of evidence on a wide range of factors that affect newborn survival. This section reviews the existing literature on what is known about the different groups of determinants of neonatal mortality, and how they vary from determinants in older children. This review will provide a basis for further analysis carried out in the papers that follow.

3.2.1 Birth weight

As well being a direct cause of mortality, low birth weight (less than 2.5kg) is one of the most important underlying factors affecting neonatal mortality. It can be the result of pre-term birth (before 37 weeks), intrauterine growth restriction (IUGR) or a combination of the two, and leaves neonates predisposed to a number of other direct causes of mortality such as infection. Low birth weight infants are approximately 20 times more likely to die as heavier babies (Unicef 2004), as well as experiencing detrimental effects on health and wellbeing throughout childhood (*e.g.* Grantham McGregor and Lira 1998) and possibly into adult life (Godfrey and Barker, 2000). However, it is important to note that low birth weight is an outcome as well as a determinant: while low birth weight may, in some cases, be unrelated to intrinsic physiological factors, many of the socio-economic, biodemographic and maternal health factors discussed in this section also exert a strong influence on incidence.

3.2.2 Other biological and biodemographic determinants

In nearly all countries, males have higher mortality than females during infancy (United Nations Secretariat 1998). The male disadvantage is particularly marked in the neonatal period, primarily because of higher levels of deaths from perinatal conditions[2] and infection (Waldron 1998). Data from DHS from 56 countries found that boys were on average 28% more likely to die in the first month of life (Mahy 2003). This inequality generally resolves by one year, and beyond this age there is no significant difference between mortality rates for males and females (ibid.): indeed in some countries there is increased mortality among girls aged one to five as a result of discriminatory child care practices (United Nations Secretariat 1998).

Multiple births are also a major risk factor: twins and other higher multiple births are at greater risk of death due to higher rates of congenital abnormalities, low birth weight, pre-term labour and complications at delivery. Cultural taboos related to twins can also lead to neglect and higher mortality, as can competition for resources (Mahy 2003). While the increased risk associated with multiple births continues throughout childhood, it is most

[2] Perinatal conditions include conditions arising during pregnancy and labour and conditions specific to the newborn. They include birth trauma, asphyxia, prematurity, respiratory distress syndrome and neonatal tetanus.

marked in the neonatal period. A study of DHS data found that the relative risk for multiple births was 6 for neonatal mortality, and this dropped to 2.2 for post-neonatal mortality and 1.4 for early childhood mortality (ibid.).

Unequivocal evidence exists on the association between shorter birth intervals (less than two years) and increased child mortality, and the effect of this also appears to be strongest in the neonatal period (*e.g.* Mahy 2003). Birth order is also an important determinant for survival: first order births increase mortality within the neonatal period only, but increased risk from higher order births (after six births and above) continues throughout childhood (Mahy 2003). The relationship between fertility rate and mortality at the country level is somewhat difficult to interpret. While some studies show a relationship between parity and mortality, some of this effect may be the result of first births being more likely to occur to younger mothers, or higher order births having a higher chance of short birth intervals. While it could be hypothesised that reduced fertility would lower neonatal mortality rates, this does not appear always to be the case in practice. Andhra Pradesh can be used as an example, whereby the total fertility rate has declined significantly since the mid 1980s along with IMR, but neonatal mortality has remained almost stagnant (James *et al* 2000). There are two probable causes for this lack of association: firstly, in many countries increased use of contraception has resulted in reducing the number of overall births, rather than increasing birth intervals or increasing the age of mothers' first pregnancy. Both of the latter factors are thought to have much greater impacts on neonatal survival than late birth order (ibid.). Secondly, reducing the overall number of births will increase the proportion of first births, thus replacing one risk factor with another unless medical care is also improved (ibid.).

Maternal age is another well-known factor that affects child mortality. A number of studies have identified a U-shaped curve (*e.g.* James *et al* 2000), with children of both younger and older mothers experiencing higher mortality[3]. This is likely to be due to increased risk of birth complications and low birth weight, and, in the case of older mothers, congenital

[3] Other studies (*e.g.* Hobcraft *et al* 1985) have failed to identify increased mortality among older women.

abnormalities. Again, risks associated with both older and younger mothers are most marked in the neonatal period (Mahy 2003).

3.2.3 Socio-economic factors

It is well understood that there is a wealth gradient in child mortality. Extensive research has documented the association between GDP and national levels of child mortality, (*e.g.* Filmer and Pritchett 1997), but data has never been disaggregated to examine different age groups. Recent research using data at the family/individual level confirms a wealth gradient in mortality for newborns, with the poorest 20% of households experiencing consistently higher NMRs than the most wealthy 20% (Lawn *et al* 2005). However, there is some limited evidence that income may be of greater importance for older children than neonates. Lawn *et al* (ibid.) found that the differences in mortality between richest and poorest quintiles were generally greater for post-neonatal than neonatal deaths. Further evidence from UK historical data gathered from 1911 and 1932 in England and Wales demonstrates that while a class gradient did exist in neonatal mortality, it was considerably less steep than for infant mortality (Titmuss 1943, cited in Loudon 1992). As can be seen in Table 1, those in social class V (the poorest) suffered infant mortality rates of over twice that of their counterparts in social class I (the most wealthy), whereas the difference was much less marked when neonatal mortality alone was considered.

Maternal education has long been established as an important determinant of child mortality (*e.g.* Hobcraft *et al* 1984). However, once again, while data is currently fairly limited, several studies indicate that mother's education, as well as several other household-level socio-economic variables that impact on child mortality (*e.g.* urban/rural residence, father's occupation) may have a greater effect on early childhood mortality than during post-neonatal infancy or the neonatal period (*e.g.* Kost and Amin 1992, Bicego and Ahmad 1996, Mahy 2003).

Table 1: Infant and neonatal mortality rates according to Social Class, England and Wales, 1911 and 1932.

Social Class	1911	1930-2
Infant mortality		
All Classes	125	62
Class I	76	33
Class II	106	45
Class III	113	58
Class IV	122	67
Class V	153	77
Neonatal mortality		
All Classes	39	30
Class I	30	22
Class II	37	27
Class III	36	29
Class IV	39	32
Class V	43	33

Source: R. Titmuss, *Birth, Poverty and Wealth: A Study of Infant Mortality*, London 1943, cited in Loudon 1992, p 493.

3.2.4 Maternal health and nutrition

The health of the mother and newborn are intrinsically linked, and a number of maternal health problems have been shown to have a detrimental effect on newborn survival. Sexually transmitted diseases and infections of the reproductive tract (*e.g.* syphilis), HIV infection and malaria are all associated with increased neonatal mortality, as well as underlying causes such as pre-term birth (*e.g.* Child Health Research Project 1999). Complications of pregnancy also impact negatively on the newborn as well as the mother: studies suggest that between 5% and 24% of perinatal deaths[4] are a result of hypertensive disorders (WHO 2005a cited in Lincetto *et al* 2005, Kusiako *et al* 2000). Obstructed/prolonged labour and malpresentation were also found to be responsible for about 32% of perinatal deaths (Kusiako *et al* 2000). Maternal nutrition is another important factor in improving newborn survival: inadequate nutrition of female children can have long-lasting complications as the resulting stunting will affect birth outcomes and in

[4] While definitions vary, the *perinatal period* can be described as beginning at 22 completed weeks (154 days) of gestation (the time when birth weight is normally 500g), and ending seven completed days after birth. *Perinatal mortality* is death within this period which includes late pregnancy, birth and the first week of life (WHO 2007). It therefore included the early but not the late neonatal period.

particular increase the likelihood of obstructed labour (WHO/UNFPA/Unicef/World Bank 1999). Inadequate calorie intake results in poorer pregnancy outcomes, and supplementation to the mother with a number of micronutrients (*e.g.* iron, iodine and possibly Vitamin A) has been associated with increased neonatal survival (*e.g.* Caulfield 1999), although further research is needed in this area. A recent study where mothers were supplemented with multiple micronutrients found a reduction in early infant mortality (birth to three months) of 18%, and this rose to 25% for infants of malnourished or anaemic women (SUMMIT Study Group 2008).

3.2.5 Environmental factors

Environmental factors such as water and sanitation have long been known to impact on child health, although most studies focus on the incidence of diarrhoeal and other water-borne diseases as an outcome rather than mortality. It is generally understood that sanitation facilities and the quantity of water available (which directly impacts on hygiene practices such as handwashing) have a greater impact than the quality of drinking water (*e.g.* Esrey 1996). The specific impact on neonatal mortality is not clear, but it can be hypothesised that exclusive breastfeeding may to some extent protect the neonate. The estimated proportion of mortality for neonatal mortality caused by diarrhoea is only 3% (Lawn *et al* 2005) compared with an estimated 15% in children under five years (Boschi-Pinto and Velabit 2004), which again would support this argument.

Another key environmental factor is indoor air pollution caused by the use of coal and biomass fuels for heating and cooking. There is a strong association between indoor air pollution (IAP) and the incidence of acute respiratory tract infection, which is one of the major causes of death in children under the age of five years (Bruce *et al* 2000). The effect of this factor on morbidity and mortality is difficult to quantify as it is thought there is a dose–response relationship (*i.e.* risk rises with increased exposure, ibid), and again, no work has been carried out to suggest whether the impact differentially affects children at specific ages. If there is a dose–response mechanism, the outcome for the neonate is likely to be affected by family practices: *e.g.* if the infant is carried on the back of the mother while she cooks the exposure to particulates is likely to be very high. Some limited evidence also exists to show that IAP is associated with increased incidence of low birth weight (possibly due to increased maternal exposure to carbon monoxide), which will also impact on perinatal and neonatal mortality (Boy *et al* 2002).

3.2.6 Family care practices

The early care that children receive in the home has been shown to have an important impact on health outcomes. While this is often linked to preventive health service provision, it is also influenced by existing cultural and social norms. For the newborn, probably one of the most important behavioural factors is the initiation of optimal breastfeeding: *i.e.* exclusive breastfeeding initiated very shortly after birth. A review of existing literature by Darmstadt *et al* (2005) found that studies suggest optimal breastfeeding could reduce all-cause neonatal mortality by around 55-87%. A recent study in Ghana (Edmond *et al* 2006) using data on timing of breastfeeding initiation found a 2.5 fold reduction in risk of death among neonates who initiated breastfeeding on the first day of life (early initiation) compared to infants who initiated after the first day of life (late initiation). In addition, studies also suggest that 18%-42% deaths could be averted by the prevention of hypothermia (Darmstadt *et al* 2005), which in many cases can be done quite simply within the home.

3.3 Health care interventions as determinants of neonatal survival

There is a common misconception that neonatal mortality is difficult to prevent, and requires expensive interventions relying on advanced technology. As with older children, there are a large number of cost-effective, proven health care interventions that reduce neonatal mortality (see Fig. 1).

As can be seen from the table, these can be divided into antenatal (*e.g.* tetanus toxoid immunisation, diagnosis and treatment of reproductive tract infections during pregnancy and improved maternal nutrition); intrapartum (*e.g.* skilled care at delivery with prompt referral and management for obstetric emergencies) and postpartum interventions (*e.g.* early initiation of exclusive breastfeeding). Care of the sick newborn is also vital: prompt treatment of infections with antibiotics for neonatal infections is required. There is also much interest in simple, low technology approaches to managing low birth weight such as “kangaroo care”, whereby the baby is kept in skin-to skin-contact with the mother to stabilise body temperature, but the evidence of benefit is currently more limited (Conde-Agudelo *et al* 2004).

Figure 1: Summary of effective interventions for newborn health

ANTENATAL CARE: • Tetanus toxoid immunisation • Nutrition: iodine, iron, folate • Counselling on birth preparedness • Breastfeeding counselling • Treatment of syphilis/malaria • Identification of major risks of obstructed labour • Treatment of eclampsia • Voluntary Counselling and testing for HIV*
INTRAPARTUM/IMMEDIATE NEWBORN CARE: • Clean delivery • Antibiotics for premature rupture of membranes • Emergency obstetric care • Prevention of mother to child transmission of HIV* • Neonatal resuscitation • Prevention of hypothermia: *e.g.* drying and warming • Immediate breastfeeding • Eye care** • Management of sick/premature/low birth weight newborn
POSTPARTUM NEWBORN CARE • Exclusive breastfeeding • Maintenance of temperature • Cord care and hygiene • Special care for low birth weight baby • Prevention of mother to child transmission of HIV* • Care seeking for signs of illness • Management of infections and other complications

* Will not directly affect neonatal mortality, but will impact on infant/child mortality
** Will affect morbidity rather than mortality

3.3.1 Maternal health services

The key channel for delivery of these interventions is maternal health services. In total, it has been estimated that nearly three-quarters of all neonatal deaths could be prevented if women were adequately nourished and received appropriate care during pregnancy, delivery and the postnatal period (Tinker 1997). In most countries maternal health care is currently focussed on the provision of skilled attendance at delivery, and to a lesser extent, antenatal care (although there is growing awareness of the importance of the need to develop effective postpartum care for both mother and baby). While the efficacy of many individual interventions is well known, the actual impact of antenatal and skilled care at delivery is more difficult to quantify, partly because quality and content of services vary greatly between countries (or indeed districts and individual facilities). In addition, unequivocal data on the impact of maternal health care services on neonatal mortality would probably require the use of randomised controlled trials, which would be considered unethical.

DHS data suggests that neonatal mortality is lower among children of women who received care during pregnancy and childbirth (WHO 2005), but these figures need to be interpreted with caution. Firstly, they are not adjusted for factors such as wealth and maternal education, which have been shown to influence care seeking behaviour (Paul and Rumsey, 2002). Secondly, by combining data on antenatal care and care at delivery rather than examining the two elements separately, it is impossible to discern which of the two is making the larger contribution, or, indeed whether the impact of both aspects of care are positive: an earlier study of DHS data found that in some countries mortality rates were higher in neonates born in institutions, probably because they were much more likely to be the result of complicated pregnancies or deliveries (Govindasamy *et al* 1993). Methodological difficulties make it extremely difficult to evaluate differences in outcome between deliveries in institutions (or at home with skilled attendants) or at home without professional assistance. Some less rigorous evidence of benefits does exist: a study based on national level data found that countries with higher levels of neonatal mortality tended to have lower levels of skilled attendance (Lawn *et al* 2005), but again this is not adjusted for confounding factors such as gross domestic product or female education. An evaluation of a project to improve access to skilled attendance in Indonesia appears to have shown some downward trend in perinatal mortality, but data was only collected over a short period of time, and some of the improvement could be due to exogenous factors (Alisjabana *et al* 1995). This issue will be discussed in more detail in Chapter 4.

The literature on the impact of antenatal care is also somewhat uncertain: a number of studies have found higher rates of perinatal or neonatal mortality in infants born to women who have not received antenatal care even when adjusted for relevant socioeconomic factors (*e.g.* Kavoo-Linge 1992) but in other studies the findings have been less clear. This issue will also be discussed more fully in Chapter 4.

While some countries have made some progress in improving access to maternal health services, for much of the developing world coverage remains extremely low. Globally, only around 68% of women receive antenatal care (WHO/Unicef 2004) and 53% are delivered by a skilled attendant (Unicef 2001). Even when services do exist quality is often poor, or social and financial barriers prevent women from making use of them (Adamu and Salihu 2000). In most countries postnatal care is extremely underdeveloped for both mothers and their babies, and neonates are often unable to access facility-based services as cultural norms confine to the home for a period after birth. Even when they are able to access primary care facilities, many health staff lack confidence or skills in treating newborns.

3.3.2 Family practices

The importance of family practices, as well as the difficulty in ensuring neonates have access to existing health care services, has led to growing interest in the potential role of community-based interventions as a strategy for reducing neonatal mortality. One recent randomised controlled study investigated the potential impact of using women's groups to identify problems in newborn care within a community and develop locally appropriate solutions. It achieved a statistically significant reduction in neonatal mortality of nearly 30% in the intervention area (Manandhar *et al* 2004). Another study used lay workers to attend births and visit regularly in the postnatal period to both offer advice on issues such as breastfeeding and management of low birth weight infants and provide interventions such as resuscitation of asphyxiated newborns and treatment of sepsis with injectable antibiotics.

This study showed a reduction in neonatal mortality of 62% over a three year period (Bang *et al* 1999).

3.4 Gaps in knowledge on determinants of neonatal mortality

While there is clearly a body of evidence on the determinants of neonatal mortality, important gaps still exist. These include:

- *Gaps in knowledge of the impact of maternal health care at the population level.* While at an individual level the interventions that can save the life of a newborn are well known, there is little evidence of the degree to which access to maternal health services, and in particular delivery care, actually reduces mortality at a population level in practice. This is mostly due to methodological difficulties.

- *Limited knowledge as to how neonatal and post-neonatal determinants vary.* While there is some evidence of how the importance of particular variables differ between neonatal and post-neonatal mortality, it is nearly all based on bivariate analysis[5]. As many determinants are correlated, this could result in confounding. Multivariate analysis could present a clearer picture of these differences, by showing how models of determinants vary, rather than just individual determinants. There are also some specific gaps in knowledge: *e.g.* on the role of environmental variables at different ages and whether GDP has differing effects at national level on neonatal, post-neonatal and early childhood mortality.

- *No relevant model for analysing the determinants of neonatal mortality.* A number of conceptual frameworks have been developed in order to assist in the analysis of the determinants of child mortality. However, none of these fully captures the specific nature of the determinants of neonatal mortality, and in particular the link

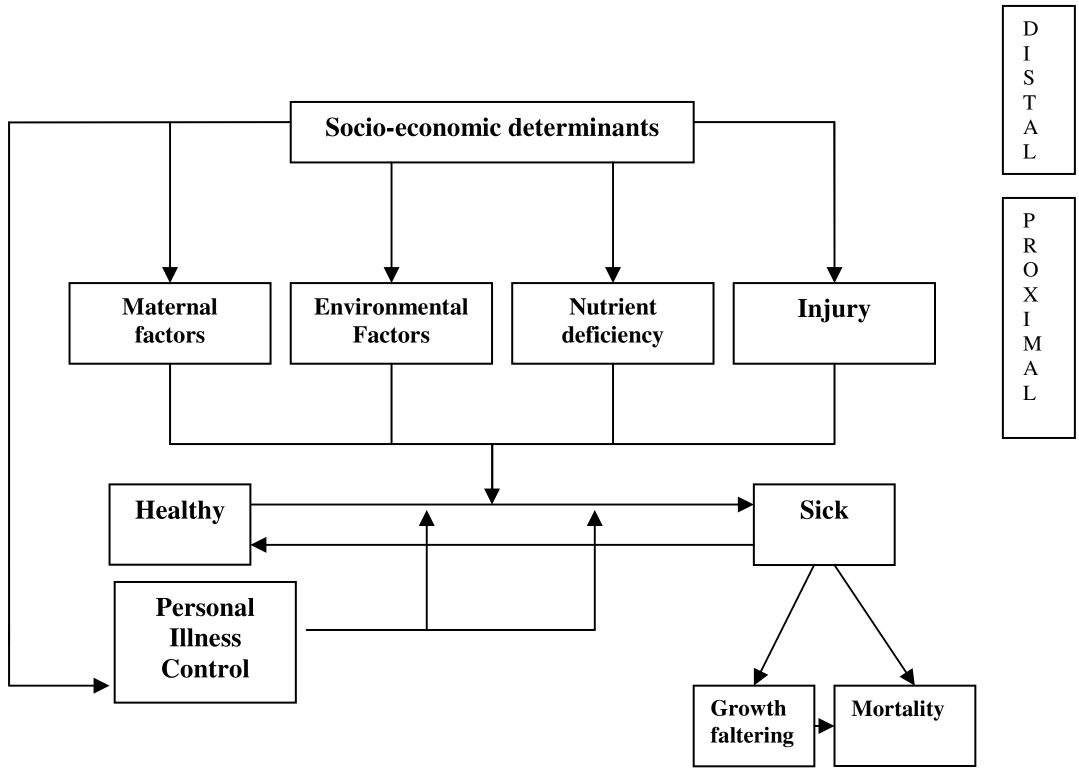
[5] The only previous study that uses multivariate analysis is an interesting but somewhat limited study by Kost and Amin (1992). It uses a small, geographically-localised dataset, and has a relatively limited list of sometimes context-specific variables. It does include biodemographic and some socio-economic variables, but, for instance only includes a few health variables based on access to local health care programmes, rather than specific health care interventions.

with maternal health. The next section examines the existing frameworks and develops a new one to encompass the determinants of both neonatal and post-neonatal mortality. This will then be used as a basis for analysis in Chapters 3 and 4.

4.0 Frameworks for analysing the determinants of neonatal, post-neonatal and early child mortality

In 1984 Mosley and Chen produced a seminal paper describing a framework for the analysis of child mortality in developing countries (see Figure 2). They identified a series of proximal determinants (*e.g.* environmental and maternal factors) which directly impact on mortality and morbidity, as well as a further group of distal determinants (*i.e.* socio-economic factors such as education and income). These distal variables only exert influence on child health outcomes through their impact on the proximal variables: for instance, increased economic status may affect child survival through improved water, sanitation and housing (*e.g.* environmental variables), greater access to a range of nutritious food or increased use of health care services. A concept that Mosley and Chen call “Personal Illness Control” (which does not appear to be classified as either a distal or proximal determinate), affects both the number of children who become sick through preventive care, and the proportion of illnesses resulting in death through curative treatment. Illness could result in death or return to health or lead to a “vicious cycle” of malnutrition, growth faltering and long-term ill-health which may precipitate death at a later stage.

Figure 2: Mosley and Chen's framework for the study of child survival



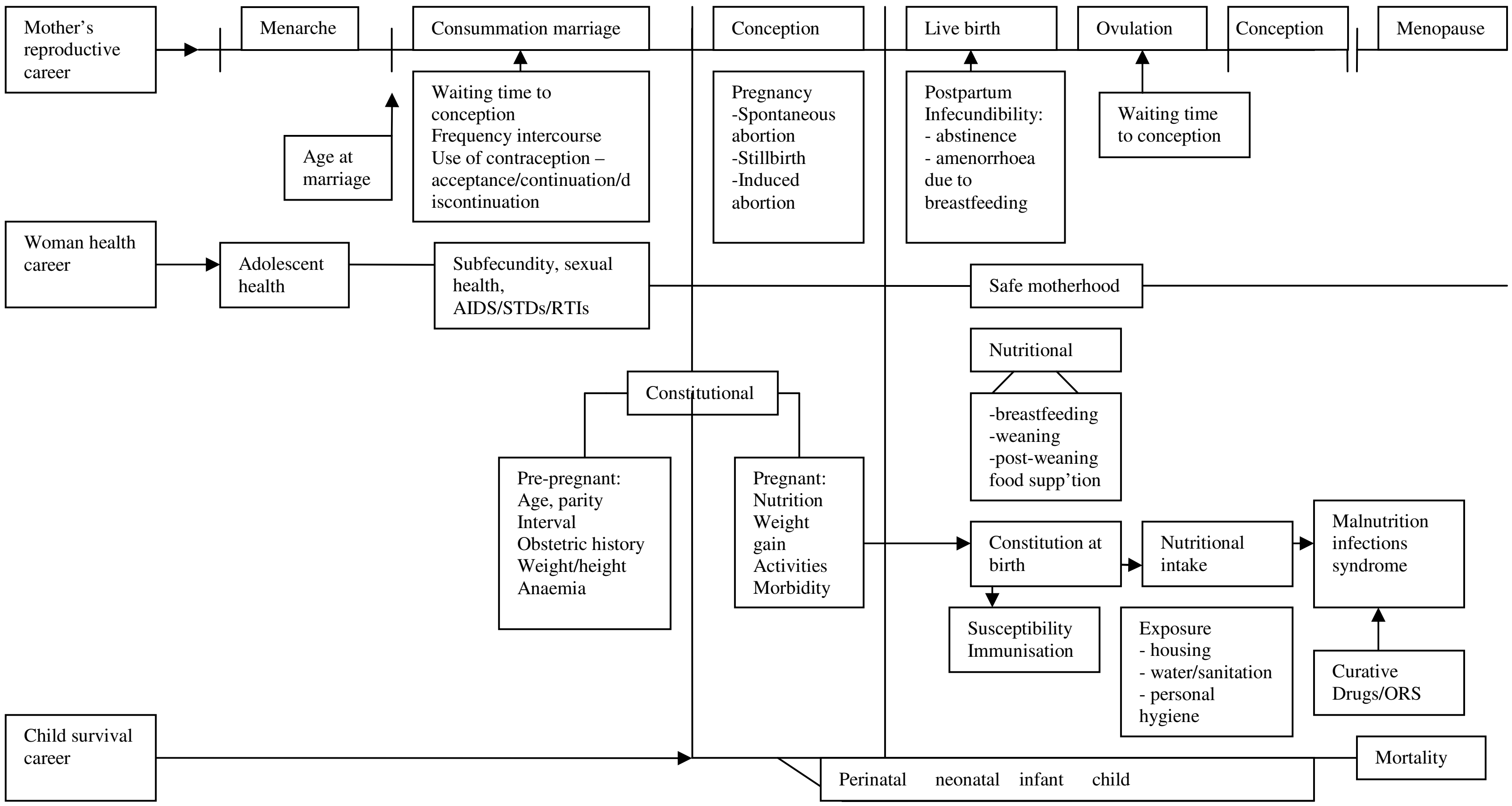
Source: Mosley W.H and Chen L. An Analytic Framework for the Study of Child Survival in Developing Countries. *Population and Development Review* 1984; 10 Suppl 25-45.

While this model has been highly influential in providing an explanation for the mechanism by which distal variables impact on survival, it has a number of limitations, particularly when applied to the neonate. Firstly it assumes that impact only flows in one direction, whereas in reality many of the proximal variables may exert horizontal influence on other variables, or indeed the outcome of illness may exert an influence on distal variables through increased poverty as a result of health care spending by the family or withdrawal from paid employment by carers. The inclusion of injury as a proximal variable within the neonatal context is also probably unhelpful: neonatal injury normally refers to damage sustained during the birth process and is probably more appropriately viewed as an outcome, as its occurrence depends on a number of maternal and health care factors. Indeed injury at any age is strongly influenced by proximal variables such as maternal factors and environment, and could be considered part of the "vicious cycle" within Moseley and Chen's model, the effect of which can be mitigated by personal illness control.

In addition, the concept of a “vicious cycle” of repeated illness and malnutrition often preceding death is less relevant to the newborn, as many neonates die very quickly. A final point is that the model fails to identify how certain variables may exert their influence on infant health outcomes through the mother as well as directly to the child, and, with the exception of nutrition, there is little clarity on the role of family practices.

Further work has been carried out to extend and develop this model. In particular Hutter (1998, cited in Den Draak 2003) has drawn on both Mosley and Chen’s model and Bongaarts’ (1978) work on the determinants of fertility to produce an integrated model of a mother’s reproductive and child’s survival career (see Figure 3). This provides a comprehensive framework for examining the links between a wide range of maternal factors and child health outcomes, making it extremely relevant to the neonatal period. The disadvantage for use within this study is that it uses the mother’s reproductive and health career as a starting point, and does not relate these to underlying socio-economic conditions. In addition, its detail and complexity make it somewhat difficult to use as an operational model.

Figure 3: Integrated model of mother's reproductive career and child's survival career



Source: Hutter (1998) cited in den Draak (2003) p47

Magadi *et al* (2003) used graphical chain models to comprehensively identify both the socio-economic and biodemographic and maternal health determinants of unfavourable birth outcomes, but as they confine their outcomes to low birth weight, premature delivery and Caesarean section it does not include some of the postnatal factors that affect the survival of both neonates and older children. Mohamed *et al* (1998) also used graphical chain modelling, and arranged their variables to create a model based on temporal sequence. They address the problem of association between determinants by creating "sub-blocks" within blocks of variables to denote when groups of determinants have an association.

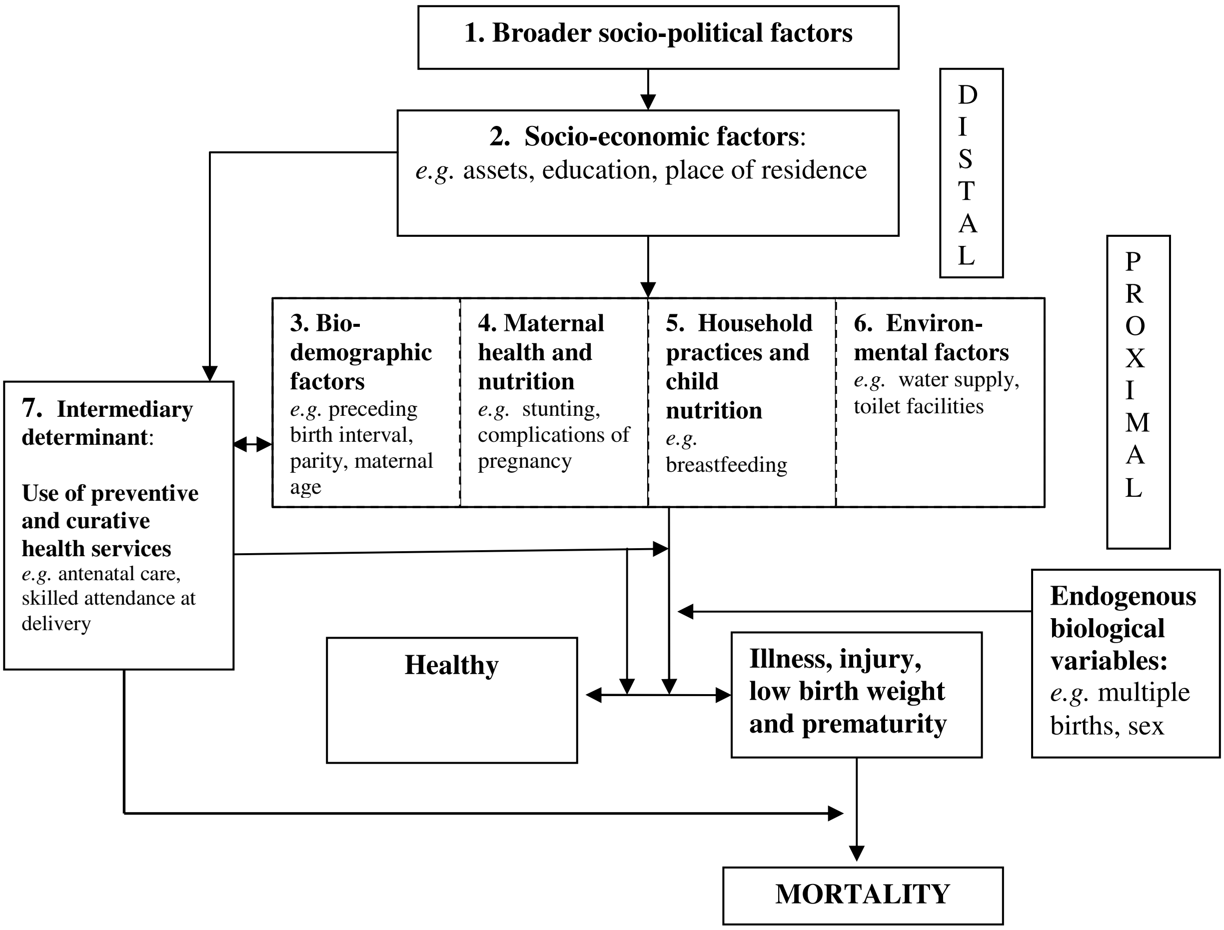
4.1 Developing a relevant conceptual framework for this study

As this study seeks to compare the determinants of neonatal mortality with those of older children, it needs to be based on a model that identifies the determinants of child health generally but also ensures that those specific to neonatal mortality are well represented. The model in Figure 4 draws heavily on the Mosley and Chen framework, and shows a somewhat simplified schema for the determinants of neonatal and post-neonatal mortality. Like the Mosley and Chen model, it is structured using a series of distal and proximal determinants. The distal variables are now divided into wider socio-political factors (Box 1, *e.g.* political context, existence of conflict *etc.*, national economic performance), which then feeds into the individual level socio-economic factors such as wealth and education (Box 2). Instead of having separately defined proximal determinants, this model uses a wider "block" of determinants divided into four "sub-blocks" similar to the Mohammed model separated by dotted lines to imply that they are not completely independent and may influence each other. The contents of the proximal variable "sub-blocks" are similar to Mosley and Chen's, but, with the exception of environmental factors (Box 6), the groupings are different to better reflect the influences affecting the newborn. Box 3 includes biodemographic variables, such as parity, preceding birth interval and mother's age. This has a clear link with maternal health and nutrition (Box 4), which will include such factors as complications of pregnancy, stunting and micronutrient deficiencies and infections such as malaria and sexually transmitted infections.

Boxes 3 and 4 were combined in the Mosley and Chen model under "maternal factors", but in the interests of clarity and to emphasise their importance to neonatal mortality, they have been separated in this model. Household practices and child nutrition (Box 5) include such factors as breastfeeding, weaning and hygiene (which are obviously influenced by environmental factors). This group is not included in the Chen and Mosley model, though many of the factors are implicitly included in the determinants "nutritional deficiency" and "personal illness control". This model highlights them more clearly as a result of growing understanding of their importance in neonatal, as well as post-neonatal, survival.

In this model the "outcome" has been simplified so that the child no long enters the "vicious cycle" of illness and malnutrition identified by Mosley and Chen. Instead, the child can move between illness and health, or can alternatively proceed from ill-health to mortality.

Figure 4: Framework for the analysis of neonatal and post-neonatal mortality



Use of preventive and curative health services (Box 7) corresponds broadly to Mosley and Chen's determinant of "personal illness control", but is somewhat more narrowly defined. This will include health care delivered both to the mother during her pregnancy and delivery (*e.g.* antenatal care, skilled care at delivery) and also care provided to a sick or low birth weight infant. While it is undoubtedly influenced by the distal variables (both through broader political factors such as prevailing ethos on health care financing, and at the individual socio-economic level), it has not been included as a proximal variable. Instead it has been labelled as an "intermediary variable", because it has a role in mitigating the impact of other variables. Three potential points of impact are identified: firstly it can influence the proximal variables themselves (*e.g.* through providing the necessary contraception to practice birth spacing, rectifying micronutrient deficiencies before or during pregnancy or treating malaria and sexually transmitted diseases before they have an adverse effect on the foetus). Secondly, it can mitigate the negative impacts of some of the proximal variables (*i.e.* if a mother who has experienced complications of pregnancy receives appropriate care to avert a negative outcome, or tetanus toxoid is administered to protect an infant who may be subjected to unhygienic cord care practices). Thirdly, health services can influence whether a sick or low birth weight infant or child proceeds down the pathway to health or mortality. There is obviously a clear two-way link between this determinant and household practices (Box 5). Household practices may well be influenced by information provided through health services, but will also influence the use of these services.

The model also draws on the Hutter model in its inclusion of biological factors, which are of particular importance in the neonatal period. Biological factors (Box 8) are also not considered proximal variables. While some factors that could be viewed as biological (*e.g.* low birth weight) are influenced by both proximal and distal determinants, for the purposes of this model biological variables are viewed solely as those which are independent of external influences *e.g.* gender and multiple births. The externally influenced component is captured through the causal pathway linked to the proximal variables that leads to mortality.

This model will be used as the basis for developing a logistic regression analysis to identify key determinants of neonatal and post-neonatal mortality. Groups of proximal variables will be progressively added to distal variables. As it is assumed that the influence of distal determinants is directed through the proximal determinants it would be expected that the coefficients for socio-economic variables will decrease as groups of proximal variables are progressively added.

5.0 Outline of the three papers

5.1 Data used in the studies

All three papers use Demographic and Household Survey (DHS) data. These are relatively large, representative surveys which are comparable across time and place. The proliferation of these studies since the late 1980s offers opportunities for both examining trends over time, and carrying out cross-national comparisons. While they are usually the most reliable national-level data available in developing countries, these surveys have a number of inherent problems. The studies clearly acknowledge and describe these problems in detail, while asserting that, even though imperfect, this source of data has an important role in enabling the development of a greater understanding of both trends and determinants of neonatal mortality.

5.2 Chapter 2: Using DHS data to examine neonatal mortality in developing countries: reliability, trends and association with GDP

This study explores the potential contribution of DHS data in improving knowledge of trends in neonatal mortality in developing countries. It outlines the causes and possible consequences of sampling and non-sampling error in survey data, before using DHS and World Fertility Survey (an earlier set of surveys comparable with DHS) estimates to describe apparent trends in neonatal mortality over the last few decades and compare them with those for post-neonatal and early childhood mortality. In particular it examines how patterns differ over the short- and medium term. While it is well documented that progress in child mortality has declined in many countries in more recent years, it is not known if this pattern is the same for neonates. It also examines the association between neonatal mortality and per capita gross domestic product (GDP) at national level. The study draws out how both patterns of progress and relationship with GDP differ markedly in the neonatal period from the post-neonatal infancy and early childhood periods. The discussion summarises the potential limitations in using DHS estimates for NMR, as well as outlining potential factors underlying the relatively poor progress being made in reducing neonatal deaths.

5.3 Chapter 3: The determinants of neonatal mortality in Bangladesh

This paper draws on DHS data from Bangladesh to establish the determinants of newborn survival. It uses both bivariate and multivariate analysis to examine a range of factors including socio-economic, biodemographic, environmental, family practices, health service usage and maternal health and nutrition. In particular it will focus on maternal health care determinants, and a feature of the study will be a systematic comparison of findings for determinants of neonatal mortality with post-neonatal mortality.

Another focus of this study is to explore the association between neonatal mortality and institutional delivery for different groups of women. Demonstrating the impact of services such as skilled attendance at birth is notoriously difficult in developing countries as women who use such services are much more likely to have experienced complications; therefore it is inappropriate to directly compare outcomes with women who did not. This study cannot overcome this methodological problem, but it takes a novel approach by attempting to differentiate women who are likely to be using the service as a response to complications and therefore be "high risk" (based on socio-economic, maternal health and care utilisation factors), and those who are more likely to use them as routine planned care with an associated lower risk. It then analyses how outcomes between these groups differ.

5.4 Chapter 4: The impact of antenatal interventions and care at delivery in reducing neonatal mortality in India

The final paper will build on the work developed in paper 2 on how outcomes from health care variables differ between different groups of women. The study investigates how the impact of health care variables differs between women based on their socio-economic status and access to services by running individual regressions based on these different sample groups. I also use Instrumental Variable (IV) methodology in an attempt to address the problem of endogeneity in establishing the association between skilled attendants at delivery and neonatal outcomes. Distance from the health facility is used as an instrumental variable based on the hypothesis that it is correlated with the endogenous variable (*i.e.* use of professional care at attendance) but not with the outcome (neonatal mortality or survival).

CHAPTER 2 : USING DHS DATA TO EXAMINE NEONATAL MORTALITY IN DEVELOPING COUNTRIES: RELIABILITY, TRENDS AND ASSOCIATION WITH GDP

1.0 Introduction

While the last few decades have seen a significant decrease in child mortality within developing countries, the decline in neonatal mortality (NMR) has been less marked. Previous analysis (*e.g.* Hill and Pande 1997) has demonstrated that in many countries neonatal mortality has fallen more slowly than post-neonatal infant mortality (PNMR) or early childhood mortality (ECMR). Although this general pattern has been relatively well documented in recent years, further cross-national analysis is needed in order to develop a clearer picture of how mortality rates and progress vary both between countries and regions, and over time. No study has clearly ascertained whether the trend of slower reductions in NMR is universal, or if patterns differ in some countries. In addition, there is little understanding of how recent trends in neonatal mortality have changed in the light of stagnation and reversal of gains in child health, particularly in Sub-Saharan Africa.

The proliferation of Demographic and Household Surveys (DHS) throughout the 1990s, as well as the availability of earlier comparable surveys, offers opportunities to carry out cross-national analysis of trends in neonatal mortality for a larger number of countries to address these issues. However, limitations within the quality and scope of DHS data need to be considered. Previous studies have highlighted specific sampling or non-sampling errors. This study will undertake a comprehensive review of data quality and apply a number of internal validity tests to the data and I will bring the findings together and discuss the implications.

If mortality is slower to decline in the neonatal age group, it begs the question why this is the case. One factor that is believed to have driven down child mortality rates in the last few decades is increase in GDP and the concurrent improvements in standard of living which accompanies this. This study aims to shed some light on how economic growth may differentially affect child mortality in different age groups. It is well documented that national levels of child mortality are strongly correlated to per capita Gross Domestic Product (GDP) (*e.g.* Pritchett and Summers 1996) and there has been ongoing debate as to the extent to which reduction in child mortality has been driven by overall improvements in standards of living (*e.g.* Rutstein 2000). While there is some limited evidence that neonatal mortality may be less affected by wealth than PNMR or ECMR, no studies have tried to quantify how income may differentially affect this age group. If the association between neonatal mortality and GDP is weaker than in the post-natal period, this may offer some explanation for the relatively poor progress made in reducing deaths in this age group, as well as having implications for future progress.

1.1 Structure of the chapter

This chapter is divided into three distinct strands:

- Reliability of NMR estimates with particular relation to DHS data
- Trends in neonatal mortality and
- The relationship between neonatal mortality and GDP.

Section two addresses the first theme of data reliability. It outlines some of the problems in measuring neonatal mortality, before carrying out a comprehensive assessment of the quality of DHS data used later in this study. In particular it addresses two main questions:

- Is there evidence that the omission of neonatal deaths is a problem?
- How large are standard errors for NMR, and how will this affect analysis using DHS data?

The first question is addressed using both a review of existing studies and data and also through carrying out a number of internal validity checks. The second question is mainly answered through a review of available data.

Section three looks at trends in neonatal mortality. As well as describing overall trends in NMR it will be addressing two questions:

- To what extent is slower progress in reducing NMR than PNMR, ECMR universal among countries with differing overall levels of child mortality?

- Is there evidence to suggest that progress in NMR has slowed in more recent years (*i.e.* since the mid/late 1980s), particularly in Sub-Saharan Africa?

The section starts by reviewing what is already known about this issue before discussing methodology used. I then present empirical analysis examining trends in neonatal mortality with particular emphasis on how they differ from PNMR and ECMR. I will also focus on how trends have changed in more recent years when there has been a documented reduction in progress to reduce overall child mortality, and even stagnation and reversal of gains in some countries.

Section four addresses the relationship between neonatal mortality and GDP. It initially reviews previous studies that examine the association between income and child mortality. I then use regression analysis to examine the association between per capita Gross Domestic Product (GDP) and NMR, and analyses how this relationship differs from that between GDP and PNMR/ECMR. The calculation of elasticities for the different age groups allows direct comparison.

Section five finishes by discussing the reliability and value of DHS estimates, and how they may be improved. It will also discuss the observed patterns of progress and suggests possible causes for the differential rates of change between regions and age groups, as well as the policy implications that arise from this.

1.2 Data used for this study

The empirical analysis in this chapter mostly uses data from Demographic and Household Surveys (DHS) which are a series of large, nationally representative and comparable surveys that have been carried out since 1984 in many developing countries. Some of the trend analysis also uses data from World Fertility Surveys (an earlier series of 41 surveys carried out in the 1970s and 1980s) which provide comparable estimates for neonatal mortality. DHS data is taken from the online Statcompiler[6] facility provided by Macro International.

[6] http://www.statcompiler.com

A total of 57 countries are included in the study. Of these, 30 are in Sub-Saharan Africa, with the remaining countries in: North Africa and Western Asia (six countries), Central Asia (four countries), South and South East Asia (eight countries) and Latin American and the Caribbean (nine countries). For analysis requiring only one estimate per country, data is taken from the most recent survey[7], in this case carried out between 1990 and 2002. Of the group, one country (Gabon) is classified by the World Bank as "upper middle income", 17 are classified as "lower middle income", and the remaining 39 are "low income" countries[8]. DHS estimates for rates of neonatal mortality for all countries range from 14 per 1000 (Colombia) to 68 per 1000 (Cote d'Ivoire). The highest estimated rates are found in Sub-Saharan Africa (mean rate 39.6 per 1000) and lowest in Latin America and the Caribbean (mean rate 21.3 per 1000).

The work on trends uses a smaller sub-sample of 34 countries where more than one survey has been carried out. For 17 of these countries only recent short term data is available (defined as data collected from 1990 onwards covering periods of 4-12 years). For 16 countries both recent short- and medium- term data is also analysed (using estimates from the World Fertility Surveys collected between 1975-82 as the baseline, and data from DHS III and Plus gathered between 1997-2002 for follow-up and covering periods of 18-24 years). For one country (Mauritania) only medium-term data is available.

2.0 Measurement of neonatal mortality and reliability of DHS data

This section initially outlines some of the problems in measuring neonatal mortality in developing countries. I then provide a comprehensive analysis of the quality of DHS data for measuring neonatal mortality. The first section examines non-sampling error, with particular focus on the problem of possible omissions. It draws on existing literature to discuss what is known about omission and biases in collecting data on NMR, before discussing the problem of heaping. I will also be reviewing the extent of heaping at seven days for data used in this study both by drawing on the work of Hill and Choi (2006). I will then be carrying out some original analysis to try to ascertain the degree of heaping at one month. No previous study

[7] This refers to the most recent survey when this study commenced (1990-2001). A number of DHS datasets have since been published.
[8] Based on World Bank Classifications: http://www.worldbank.org/data/countryclass/countryclass.html

has attempted this, and it is an important omission as heaping, either at 28 days or one month, could indicate under-reporting of neonatal mortality.

This section will then examine the internal consistency of neonatal mortality data. While some types of error are difficult to detect, previous studies have shown that neonatal mortality generally conforms to a number of accepted patterns. One relationship that has been previously documented is the correlation between the proportion of child deaths occurring in the neonatal period and the overall under five and infant mortality rate. Because neonatal deaths tend to be the most persistent, as overall child mortality rates decrease the proportion of deaths occurring in the neonatal period increases. The degree to which DHS data conforms to these patterns may provide some (albeit approximate) indication of quality, and I examine this using the data on which this study is based. Further analysis is also carried out to see the ratio of early to late neonatal deaths conforms to expected patterns.

Finally, because DHS collect data on child mortality in five year periods up to 25 years prior to the survey, it offers an opportunity to compare data from different surveys covering the same time period (*i.e.* by using differing periods of time prior to data collections for surveys from the same country but different years) as a further method for evaluating accuracy. Curtis (1995) carried out this comparison for a relatively small number of DHS surveys, but this study offers more extensive opportunities for analysis.

The questions addressed and the methods used to answer them are summarised overleaf:

Research questions	Methods used to address question
Non-sampling errors: is omission of neonatal deaths a major problem?	• Review of existing studies • Analysis of relationship between NMR and IMR/U5MR • Analysis of heaping at 7 days • Analysis of heaping at one month/28 days • Comparison of data from different surveys covering the same time periods
How large are standard errors for NMR estimates?	• Review of existing data and analyses

2.1 The measurement of neonatal mortality in developing countries

The accurate measurement of neonatal mortality in developing countries presents a number of challenges, and limited data has probably contributed to the lack of focus given to this area in the past (Lawn *et al* 2001) . In most developing countries vital registration is incomplete or non-existent, and since many neonatal deaths occur within the home without any contact with medical services they are not recorded by health information systems. Even where institutional delivery is common, varying policies for classification of neonatal deaths and stillbirths can result in measurement discrepancies (Aleshina and Redmond 2005). There is also some evidence that within certain health systems there are incentives for staff to misreport neonatal deaths as stillbirths in order to avoid audit or improve hospital ratings when NMR is used as an indicator of quality (ibid.).

The development of effective and comprehensive vital registration systems are unlikely to be achieved in the near future by many countries. There are currently almost no countries with both child mortality rates of over 25 per 1000 live births and complete coverage of vital registration (classified as 95% of all deaths recorded) (Morris *et al* 2003). The development of ongoing retrospective surveys or sample registration systems, such as those developed in

China and India, are another option. The Indian Sample Registration Survey (SRS) actually uses dual methods to gather data: births and deaths are continuously enumerated in a sample of areas by a part-time worker and six monthly retrospective studies are also carried out. However, it would appear that even the dual methods used by the SRS produce underestimations of mortality (Bhatt 2002).

2.2 Demographic and Household Surveys

The only feasible method of collecting reliable national-level direct estimates on neonatal death rates in many developing countries is through large surveys such as the DHS. These are nationally representative surveys with sample sizes of about 5,000 households providing data on a wide range of indicators in the areas of population, health and nutrition. Full birth histories are collected from women aged 15-49 years in sampled households, and data is comparable both over time and between countries. The women are asked a series of questions about each birth they have experienced, including month and year of the infant's birth, and, if no longer living, age at death (in days if under a month old). Children who were born or died during the month prior to the interview are excluded.

The estimates used are based on maternal recall of deaths occurring in the five years preceding the survey data, but in some cases data from earlier recall periods (5-9 years and 10–14 years) are also used to cross-check apparent trends. Data from the World Fertility Surveys were taken from the WFS Comparative Study of Infant and Child Mortality (Rutstein 1983).

The mortality estimates for both WFS and DHS are calculated according to the conventional life table approach. Deaths and exposure in any calendar period are first tabulated by age intervals in months of 0, 1-2, 3-5, 6-11, 12-23, 24-35, 36-47 and 48-59. Age-interval-specific probabilities of survival are then calculated, and probabilities for larger age segments are calculated by multiplying the relevant age interval survival probabilities together and subtracting the result from one (Rutstein 1983).

2.3 Non-sampling error in DHS data: omission of deaths

Even a relatively large scale survey of this type may experience a number of potential problems that compromise the accuracy of the data collected. Probably the greatest risk from non-sampling errors is omission of child deaths, which is a problem thought to be most prevalent in the neonatal period (Curtis 1995). Although mothers are asked to recall all infants born alive who later died,[9] neonatal deaths may be misclassified as stillbirths, either in genuine error or because of cultural beliefs and practices. The problem is compounded by very limited DHS data on stillbirths, so it is not possible to jointly review trends in the two rates in order to provide a more comprehensive picture. There is some evidence from earlier WFS data that these omitted deaths are concentrated amongst the most socially and economically disadvantaged (Hobcraft *et al* 1984), which may result in the introduction of important biases.

While it is difficult to estimate the degree of under-reporting, a study in the Indian state of Maharashtra (Bang *et al* 2002) found an NMR nearly 20 points higher (51.2 deaths per 1000 as opposed to 32 deaths per 1000) than that recorded in the 1998 Indian National Family and Household Survey for this state (NFHS, a DHS equivalent). However Bang *et al* (2002) acknowledge that at least some of this difference may be explained by selection bias in the study population, which contained a much higher proportion of tribal people than the NFHS survey (ibid.). In addition Hill and Choi (2006) suggest that further error could have been introduced by paying informants to report deaths. They also point out that the ratios of neonatal to infant deaths are similar in both the study and NFHS data. While this in no way demonstrates that the NFHS did not under-report neonatal deaths, it does indicate that NMR is not differentially under-reported when compared to post-neonatal mortality.

2.3.1 Sampling bias

Sampling bias will be an issue if certain sectors of the population are under-represented in the survey. A potential cause of bias is that DHS use women of reproductive age as the basic sampling unit, so children without living mothers are excluded from the survey. Studies in

[9] The interviewers also use a probe which asks whether the mother had “any baby who cried or showed signs of life but did not survive”, DHS 2003),

resource-poor countries suggest that death of the mother commonly results in death of the child, and this risk is particularly strong for the newborn. A study of maternal mortality in the Jamalpur district of Bangladesh found that of the 21 babies live-born to women who subsequently died, all were dead by 28 days (Khan *et al* 1986). Another larger study also in Bangladesh (Matlab district) showed less dramatic results, but still found that only 65% of infants born alive to mothers who died survived until one month, compared with 94.4% who survived in the control group of infants with living mothers (Koenig *et al* 1988)[10]. This link may lead to an under-reporting of newborn deaths, particularly in countries where maternal mortality is high. A study by Artzrouni and Zaba (2003 cited in Mahy 2003(a)) which examined the bias produced by AIDS when using direct estimation techniques for child mortality suggests that while there is likelihood of under-reporting, it is only of a magnitude of 5-7% at most. However, further work would be useful to ascertain if there is any specific bias in NMR data caused by maternal death, and particularly whether estimates in countries that have extremely high all-cause maternal mortality may be more severely affected.

2.3.2 Data heaping

A further potential problem is that of data "heaping", *i.e.* the preference for reporting deaths at a particular day, week or month. Hill and Choi (2006) carried out some analysis to establish the degree to which heaping occurs at seven days and found that, in 40% of the DHS surveys they examined, one half or more of all deaths occurring between four and nine days were reported at seven days. This could be important as it means that a number of deaths occurring in the early neonatal period will actually be recorded as late neonatal deaths, but it is of little relevance in studies such as this which do not seek to differentiate between early and late deaths. The possibility of heaping at 28/30 days or one month is of much more importance to this study as this would lead to under-reporting of neonatal deaths. There appears to be a very small amount of heaping at 30 days in all regions (and also at 28 and 31 days in some regions) which might lead to slight underestimations of NMR, but for most regions this would be negligible (see Appendix 1 for graphs showing reporting of deaths by day for each region).

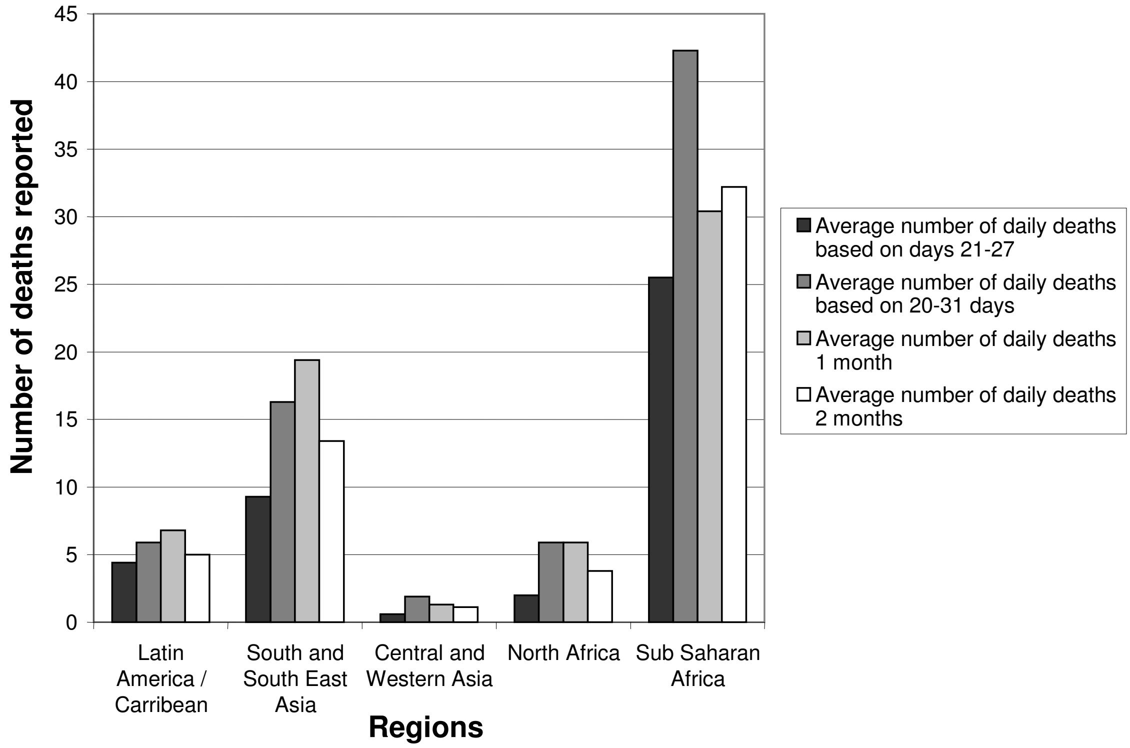
[10] The differences in these studies may at least be partly due to variation in overall NMR between the two study areas.

Unfortunately, it is more difficult to ascertain whether some late neonatal deaths are being misreported at one month of age as, after 31 days, the age of death is recorded by month only, and no previous studies have attempted to examine this issue. It could be hypothesised that if large numbers of neonatal deaths were displaced into the one month age group it would be expected that this would affect the pattern of mortality for 1-12 months. This is difficult to verify: while a model has been established of expected distribution of mortality by month (Bourgeois-Pichat 1952, cited in Galley and Woods, 1999), more recent work has found the pattern to vary considerably between time and place, and there is no single fixed relationship (Galley and Woods 1999). It is therefore not possible to compare DHS infant mortality data distributed by month of death with a model to ascertain with any certainty whether deaths at one month appear overrepresented.

While no model is available, it can certainly be assumed that as infant deaths become less frequent with increasing age, the number of deaths at one month should be markedly less than in deaths occurring in the first 28 days of life. Appendix 2 shows infant mortality bar graphs for the five regions by month of death. In all regions the numbers of deaths recorded at one month are only a fraction of those recorded for less than one month: the percentage ranges from 9% in Sub-Saharan Africa to 17% in Latin America and the Caribbean. There is also no evidence that reported mortality in month one is markedly higher than in months two and three. Even if it were assumed that the number of deaths at one month should be no greater than the number of deaths in months two and three (which may well be an underestimation as infant mortality usually decreases with increasing age) the reassignment of estimated excess deaths would only lead to an increase in deaths before one month of less than 7% for North Africa and Central Asia, Latin America and the Caribbean and South and South East Asia. In Sub-Saharan Africa and Central Asia the number of deaths recorded at one month is actually lower than the two subsequent months. This analysis would suggest heaping is not a major problem.

However, neonatal mortality is extremely high in the first week, and then falls sharply. Probably a better way of comparing neonatal mortality with rates in months one and two is not to look at overall deaths in the first month of life, but rates at the end of the neonatal period. It could be assumed that the average daily number of deaths recorded by surveys for infants one and two months old should be less (or at least the same as) the average daily number of deaths in the later part of the neonatal period. Figure 5 shows the average daily number of deaths for each region reported from 21-27 days (the last week of the neonatal period), compared with average daily figures for one and two months (calculated on a 30 day month).

Figure 5: Average number of daily deaths based on estimates on two different time periods in the first, second and third months of life



Source: Data is from DHS surveys 1990-2002.

Daily rates of mortality in the later neonatal period will vary greatly depending on the period chosen because of heaping of data. Daily average rates have therefore been calculated for two time periods: the "true" final week of the neonatal period from 21-27 days, and a longer period (20-31 days), which strictly speaking exceeds the neonatal period, but includes heaped deaths at 20 days (as well as more modest heaping at 28 and 30 days). It can be seen that all regions have a lower number of daily average deaths recorded in the surveys in the last week of the "true" neonatal period than for one month. The second column shows the daily average calculated from 20-31 days. Even using this estimate, South and South East Asia and Latin America and the Caribbean still have a higher recorded number of average daily deaths at one month (though I do not test to see if these differences are statistically significant), suggesting that some deaths that should have been recorded as occurring before one month may have been displaced. It is impossible to draw any firm conclusions from this very cursory analysis and SEs may be large. However, as the probable actual daily number of deaths occurring in the later part of the first month of life probably lies somewhere between these two estimates displacement may be a problem in some surveys, causing NMR to be under-reported. Further, more detailed analysis would be worthwhile in order to develop stronger evidence on this issue as this is obviously a potentially major error in the data.

2.3.3 Correlation between proportion of child deaths occurring in the neonatal period and overall under five and infant mortality

As previously discussed, one way of examining the potential accuracy of DHS neonatal mortality rates is to see whether there is a negative correlation between the proportion of deaths occurring in the neonatal period and the overall child mortality rate. A number of studies, including Hill and Pande (1997) have demonstrated that, as child mortality falls, the proportion of deaths occurring in the neonatal period rises. If the proportion of neonatal deaths is lower than expected, this could suggest omission of deaths.

In order to examine these patterns for the study data, the relationship between overall child mortality and NMR is explored using scatterplots, which provide a visual representation of the relationship between two continuous variables, and Ordinary Least Squares (OLS) regression. OLS is used because the dependent variable (proportion of child deaths in the neonatal period) is continuous. Dummy variables were also added to the OLS regressions to investigate the effect of different regions on proportion of deaths in the neonatal period. This gives the equation:

$$Y = a + B_1 X_1 + B_2 X_2 + e$$

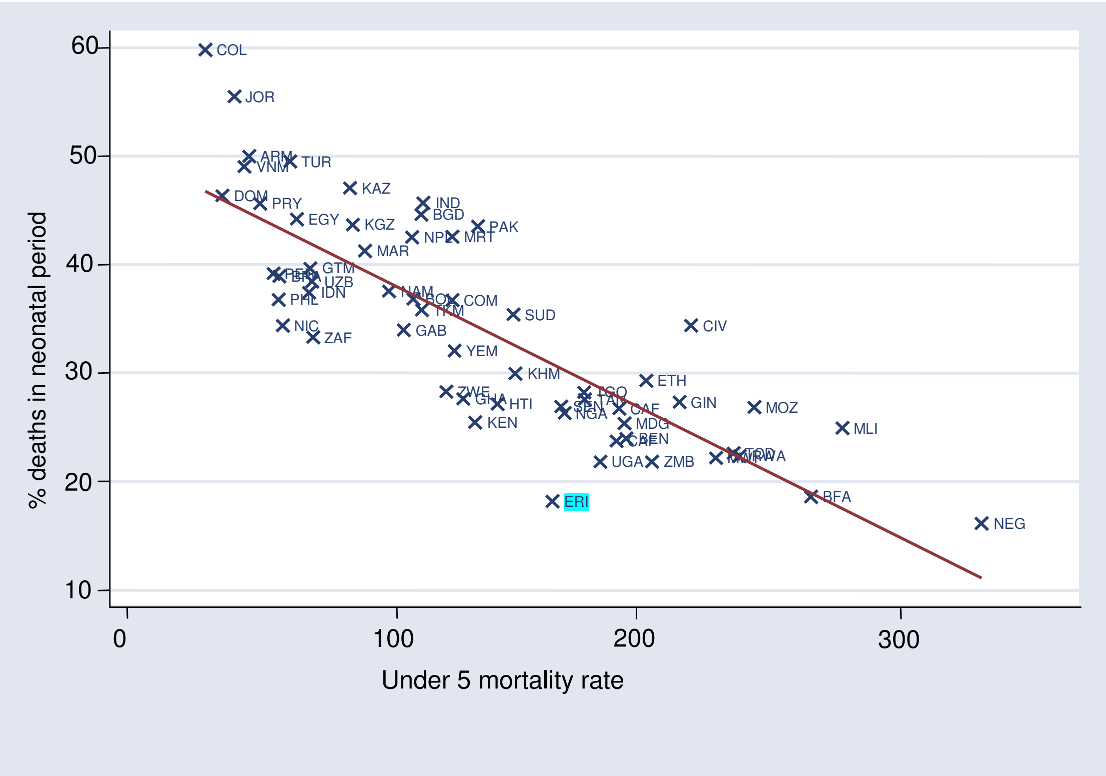
when:

Y = proportion of under five deaths occurring in neonatal mortality; a = constant

X_1 = Overall U5MR; X_2 = Region (dummy); e = error

The scattergram in Figure 6 shows the relationship between the percentage of child deaths occurring within the neonatal period and overall child mortality rates. It broadly concurs with previous well-documented evidence that the proportion of under five mortality in the neonatal period neonatal increases as under five mortality decreases. A few countries, *e.g.* Eritrea (ERI, highlighted) appear to have a lower proportion than may be expected which may indicate under-reporting of neonatal deaths. An OLS regression using percentage of under five deaths occurring in the neonatal period as the dependent variables and under five mortality rate as the independent variable with dummy variables added for region produces the results in Table 2.

Figure 6: Scatterplot showing percentage of deaths in children under five years occurring in the neonatal age group with under 5 mortality rate



* Percentage of all deaths in children under 5 occurring in the neonatal period
Data is from DHS surveys 1990-2002
Note: International Organisation for Standardisation country name abbreviations have been used, and can be found at http://www.un.org/Depts/Cartographic/english/geoinfo/geoname.pdf

Table 2: Results of OLS regression using U5MR and region as independent variables and % of under 5 deaths occurring in the neonatal period as dependent variable

	Unstandardised coefficients		**Significance**
	B	Std. Error	
(Constant)	49.8	2.41	<0.001
Under 5 mortality rate	-0.11	0.019	<0.001
North Africa/Western Asia	2.08	2.76	0.45
Central Asia	0.01	2.89	0.99
Latin America/Caribbean	-2.8	2.61	0.45
Sub-Saharan Africa	-6.25	2.43	0.01

57 observations. Adjusted $r^2 = 0.71$ Reference category is South and South East Asia.

The results in Table 2 imply that Sub-Saharan Africa has a percentage of child deaths occurring in the neonatal period approximately six percentage points lower than South and South East Asia (the reference category) when adjusted for under five mortality rate (though the confidence interval is quite wide). Other regions do not vary significantly from the reference category. If the natural log of both the NMR and U5MR are used, the adjusted r^2 is increased to 0.82 as the data is non-linear.

There is also a strong correlation between infant and neonatal mortality rates ($r^2 = 0.80$) and this association increases further if the natural log of both IMR and NMR is used ($r^2 = 0.86$). An OLS regression using the natural log of NMR as the dependent variable and natural log of IMR and dummy variables for region as the independent variables produce the results found in Table 3:

Table 3: Results of OLS regression using natural log of IMR and region as independent variables and natural log NMR as dependent variable

	Unstandardised coefficients		Significance
	B	Std. Error	
(Constant)	0.41	0.24	0.1
Log of IMR	0.75	0.06	<.001
North Africa/Western Asia	-0.04	0.07	0.62
Central Asia	0.09	0.07	0.2
Latin America/Caribbean	-0.14	0.06	0.04
Sub-Saharan Africa	-0.08	0.07	0.2

57 observations. Adjusted $r^2 = 0.86$ Reference category is South and South East Asia.

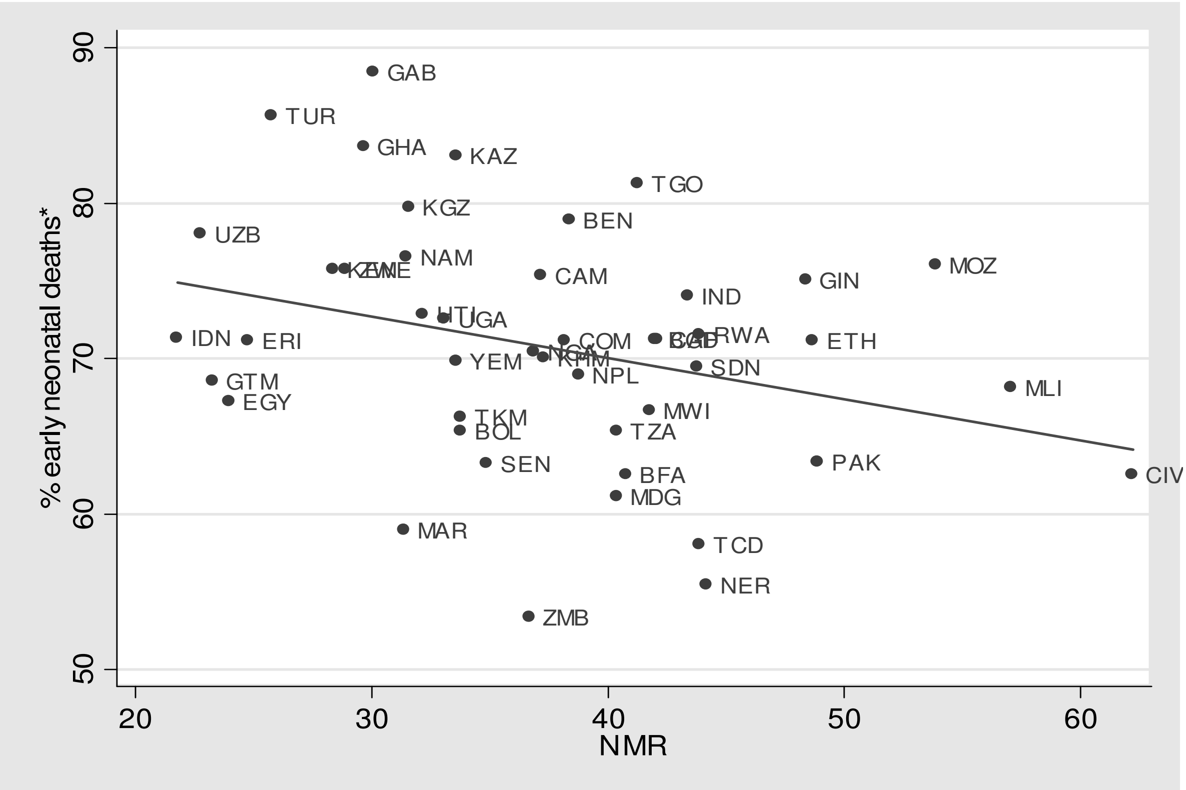
This implies that for every 10% decrease in IMR, NMR will on average decrease by about 7.5%. Latin America and the Caribbean have a significantly lower rate of NMR to IMR from the reference category (South and South East Asia).

2.3.4 Proportion of early to late neonatal deaths

Boerma (1988, cited in Curtis 1995) suggested that at an NMR of 20 per 1000 or more, approximately 70% of neonatal deaths occur in the first six days, and an unexpected low proportion of early neonatal deaths could be a result of under-reporting deaths in this age group. This would be expected as deaths in the later neonatal period tend to decline earlier than those in the first week of life (Curtis 1995). Hill and Choi (2006) plotted the ratio of early to late NMR in 108 DHS against IMR and compared them with a reference line developed using data from England and Wales 1905-1997[11]. They found that data points for Asia, North Africa and Latin America and the Caribbean were broadly scattered around the historic reference line. In Sub-Saharan African countries there was a higher rate of early than late neonatal deaths than within the model, and there was no apparent relationship with IMR changes. Hill and Choi concluded from this that there is no evidence for substantial omission of early neonatal deaths, but the lack of pattern in some parts of Sub-Saharan Africa may be explained by a high degree of random error in the reporting of age of death in days.

[11] It is worth noting that Hill and Choi smoothed their data to account for the high levels of heaping at seven days before carrying out their analysis.

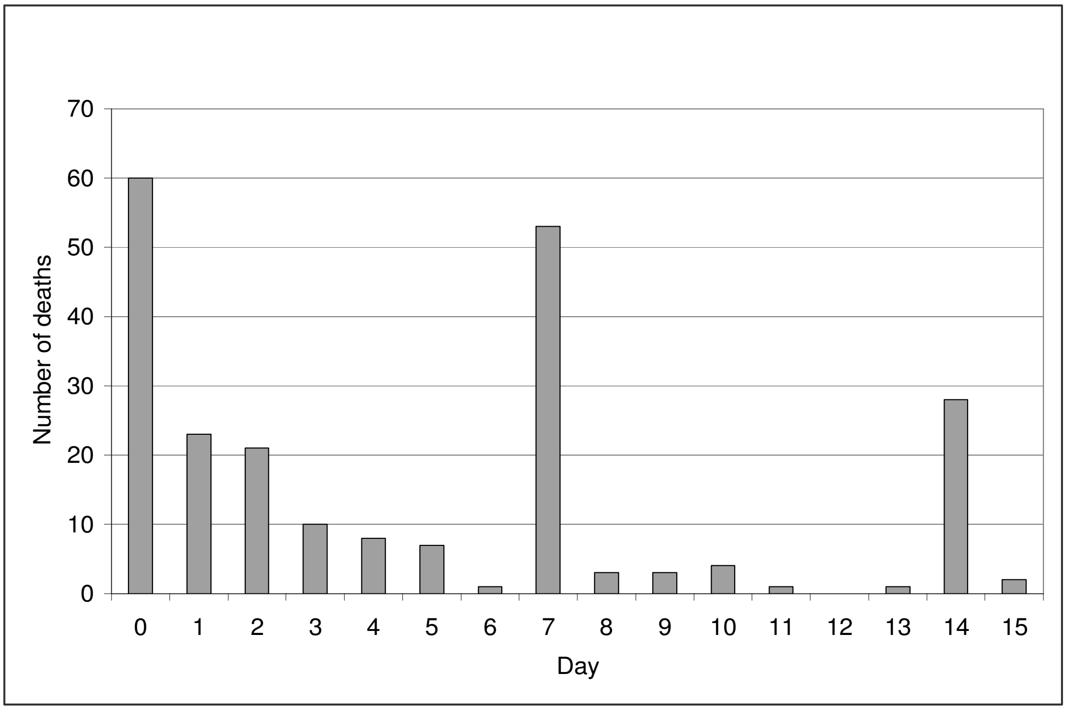
Figure 7: Scattergram showing percentage of neonatal deaths occurring in the early neonatal period against overall neonatal mortality (with regression line)



*Percentage of all neonatal deaths occurring between 0-6 days.
Data is from DHS surveys 1990-2002.
Note: International Organisation for Standardisation country name abbreviations have been used, and can be found at http://www.un.org/Depts/Cartographic/english/geoinfo/geoname.pdf

In order to examine the relationship between early and late neonatal mortality for the data used in this study, I created a scattergram of percentage early neonatal mortality plotted against neonatal mortality rate for 46 countries with NMR estimates of 20 or more (Figure 7). The scattergram shows a negative correlation (r^2 = -0.31) between overall neonatal mortality and proportion of deaths occurring in the early neonatal period. The mean proportion of deaths occurring in the first week in the 46 countries with an NMR of 20 or above was 71.1, which would fit with Boerma's analysis. However, this masks significant variation between countries, and the range for percentage of neonatal deaths occurring in the early period ranged from 53.3% to 88.2%. Niger, Chad, Zambia and Morocco (NER, TCD, ZMB, MAR) appear to have levels of early neonatal deaths lower than may be expected. However, a closer examination of the mortality data by day of death suggests it is likely to be as a result of age heaping as described by Hill and Choi (2006). All four countries show marked heaping at day seven, which will result in a higher proportion of deaths recorded in the late neonatal period. This pattern is particularly striking in Zambia, as illustrated in Figure 8.

Figure 8: Distribution of deaths from 0-14 days by day of death: Zambia DHS 2001/2



A number of other countries such as Gabon, Ghana, Togo, Kazakhstan and Turkey (GAB, GHA, TOG, KAZ, TUR) have higher rates of early neonatal deaths than might be expected. This could be a real reflection of local epidemiological conditions or may result from poor differentiation between early and late neonatal deaths. Alternatively it could indicate either a tendency for stillbirths to be reported as neonatal deaths (resulting in an overestimation of early neonatal deaths) or late neonatal deaths being misclassified as post-neonatal deaths (resulting in an underestimation of late neonatal deaths). However the percentage in the majority of countries falls between about 60% and 80%, suggesting there is no evidence of widespread under-reporting of early neonatal deaths.

2.3.5 *Comparison of recall data from 5-9 years with 0-4 year recall from earlier surveys in corresponding time period*

Opportunities for external validation of the DHS data is extremely limited as few other comparable national direct estimates of neonatal mortality exist. However, as each survey records data on deaths up to 25 years before the date of the survey divided into five-year time periods, data can be compared from different surveys covering the same time period.

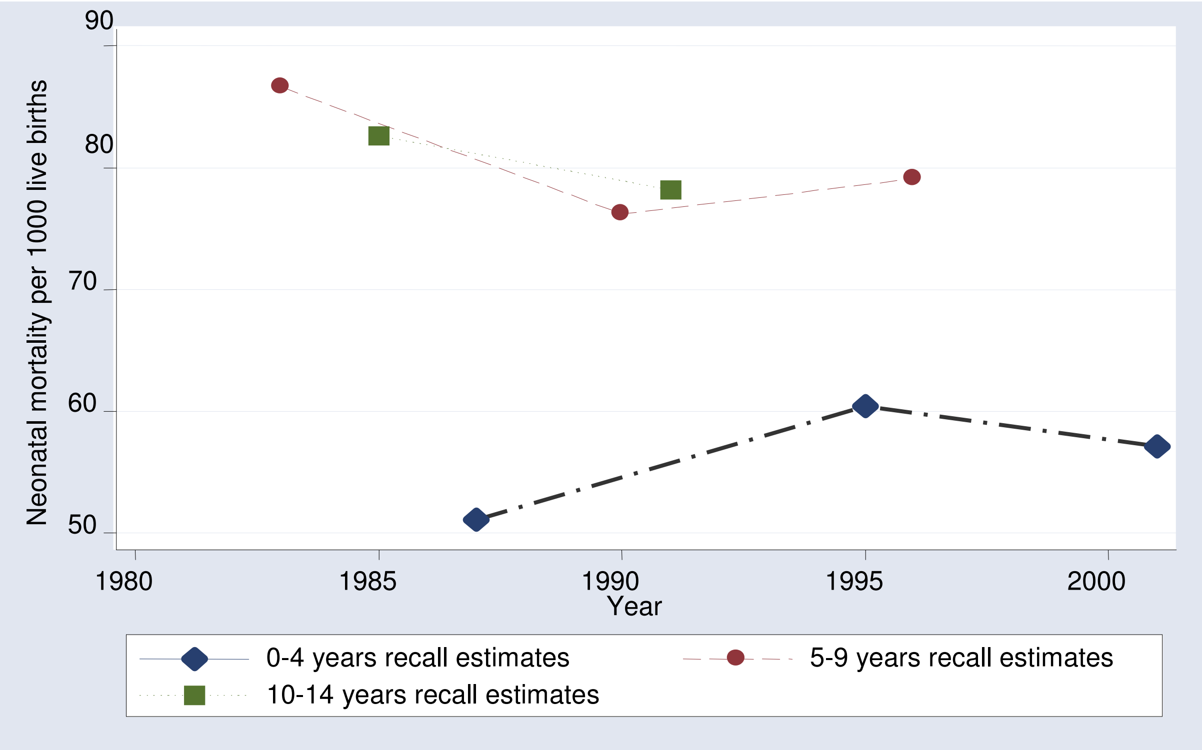
Table 4 shows 5-9 year recall data from the most recent surveys (1990-2002) from 18 countries, along with 0-4 year recall data from preceding surveys undertaken exactly five years previously, and therefore covering a corresponding period. The difference between the two rates is also given.

Table 4: Comparison of recall data from 5-9 years prior to most recent national studies and data from 0-4 years recall from earlier surveys in corresponding time period

Country	Year of first survey	Year of second survey	Recall data from 5-9 years prior to second survey	Data from 0-4 years from earlier survey in correspond-ing time period	Actual difference in rates (0-4 year recall estimate minus 5-9 year recall estimate)	% difference in rates (actual difference as % of 0-4 year recall estimates)
Morocco	1987	1992	36.5	41.5	5.0	12.0
Egypt	1995	2000	34.0	30.4	-3.6	-11.8
Turkey	1993	1998	30.1	29.2	-0.9	-3.1
Yemen	1991/2	1997	47.8	40.9	-6.9	-17.0
Nepal	1996	2001	56.5	49.9	-6.6	-13.2
Philippines	1993	1998	20.7	17.7	-3.0	-16.9
Colombia	1995	2000	17.8	18.7	0.9	4.8
Haiti	1994/5	2000	39.9	31.2	-8.7	-27.9
Benin	1996	2001	44.7	38.2	-6.5	-17.0
Cote d'Ivoire	1994	1998/9	48.7	42	-6.7	-16.0
Ghana	1993	1998	35.1	40.9	5.8	14.2
Kenya	1993	1998	25.5	25.7	0.2	0.7
Madagascar	1992	1997	40.7	39.2	-1.5	-3.8
Mali	1995/6	2001	79.3	60.4	-18.9	-31.3
Senegal	1992/3	1997	38.5	34.9	-3.6	-10.3
Uganda	1995	2000/1	37.1	27	-10.1	-37.4
Zambia	1996	2001/2	29.4	35.4	6.0	16.9
Zimbabwe	1994	1999	23.3	24.4	1.1	4.5

The relatively large standard errors in NMR make comparisons somewhat difficult: assuming the standard errors are similar for DHS data series across time, sampling error could probably not be ruled out as an explanation of differences in any of the countries. However, particular observed patterns suggest that this is not the full explanation for some of the larger differences. The rates recorded in the 5-9 year recall period are higher than those from the 0-4 year period of the earlier study for 12 out of 18 countries (see Figure 9 for the difference in trends based on 0-4, 5-9 and 10-14 year recall data in Mali). This pattern is particularly marked for countries with marked differences in rate: only one of the eight countries with a difference in rates over 15% has a larger estimate from 0-4 year than 5-9 year recall data. The opposite may have been expected, as it has been suggested that event omission is more common when the deaths occurred further back in time, which would lead to lower estimates for the 5-9 year recall period (Curtis 1995). A probable explanation for the observed pattern of higher estimates for 5-9 year recall is the phenomenon of displacing births in time in order for interviewers to avoid asking the extensive series of questions required for children born within five years of the survey. Arnold and Blanc (1990) found strong evidence of this occurrence in Sub-Saharan Africa, which could lead to underestimation of mortality rates. This is very concerning as it suggests that rates of neonatal mortality in these countries may be even higher than current estimates. It also raises doubts about the reliability of using recall data from different periods to establish trends when more than one survey is not available.

Figure 9: Data from DHS surveys 1987, 1995/6 and 2001 in Mali, showing difference in trends based on estimates from 0-4 year, 5-9 year and 10-14 year recall.



2.4 Sampling errors

Sampling error is also a problem leading to confidence intervals that are often quite wide. Standard errors are usually relatively higher than those for infant or child mortality as the actual number of deaths are lower (Curtis 1995), and in surveys with low neonatal mortality rates and relatively small sample sizes, the standard errors can be very high. A study by Korenromp *et al* (2004) assessed whether DHS from Sub-Saharan African countries were suitable for establishing whether the Millennium Development Goals for the reduction of child mortality were being met. The median relative standard error[12] for national mortality rates was 4.4% for all under-five mortality, and 5.6% for infant mortality (relative SEs were not calculated for neonatal mortality). They established that for all under-five deaths DHS from Sub-Saharan Africa could effectively detect changes of 15% or more between subsequent surveys: any smaller changes could be the result of standard error. However, this

[12] The relative standard error of an estimate is obtained by dividing the standard error of the estimate by the estimate itself. This quantity is expressed as a percentage of the estimate.

will obviously be greater for neonatal mortality. The average mortality and fertility rates in Sub-Saharan Africa are also greater than in most parts of the world, and as relative standard errors increase as these decrease, it is probable that differences in surveys would need to be greater to ensure significance in other regions.

Appendix 3 shows the NMR and estimations of standard error for 17 DHS II Surveys as reported by Curtis (1995). The relative standard errors are particularly large for some of the countries in Latin America, where NMR and numbers of births recorded by the survey are relatively low. For example, the 95% confidence intervals for the Dominican Republic (estimated NMR 23.7 per 1000 live births) from 16.3-31.2. In some cases, the relative standard errors for neonatal mortality are more than twice that found for the U5MR: For Burkina Faso and Zambia the relative standard errors for under five mortality rates are 0.033 and 0.036, whereas for NMR they are 0.081 and 0.068 respectively (Curtis 1995). This raises real issues about the accuracy of estimating rates of change or comparisons between countries from DHS data, and relatively small observed changes over time could actually be the result of sampling error rather than real progress.

In addition sampling error makes comparisons of NMR between sub-samples extremely difficult as standard errors will be further increased within the subgroups and only very large differences will be statistically significant.

3.0 Trends in neonatal mortality

The last decade has seen several studies published which examine trends in neonatal mortality. One of the first studies on trends in neonatal mortality was carried out by Hill and Pande (1997) who examined 12 developing countries in Sub-Saharan Africa, Asia, North Africa and Latin America using World Fertility Survey (WFS) and DHS data from the mid 1970s to early 1990s. They found that the neonatal mortality rate fell at a slower rate than IMR or under five mortality rate (U5MR), resulting in the proportion of deaths occurring in the neonatal period being inversely proportional to the infant and under five mortality rate (ibid.). Obviously this study uses a very small sample size, and no other study has systematically examined how trends differ between deaths in the neonatal period and older age groups (although several studies *e.g.* Black *et al* 2003, confirm that as child mortality falls, the concentration of deaths in infants under one month increases as a general rule).

Since I began work on this thesis, Hill and Choi (2006) have published a study examining trends in NMR using data for a total of 31 countries which have more than one DHS dataset ranging from the 1980s until the early 2000s. It found an annual rate of decline of 1.9% for all countries. Declines in the Latin America and the Caribbean and North Africa and the Middle East regions were greater with rates of over 3% per annum. Declines in the other regions (East and Southern Africa, Central and West Africa, South and South East Asia and Western Pacific) are extremely small. The study provides limited comparison with infant mortality trends: global rates of decline in infant mortality were found to be slightly greater than neonatal at 2.1% per annum[13]. It also found that declines in early neonatal mortality were consistently poorer than late neonatal mortality[14].

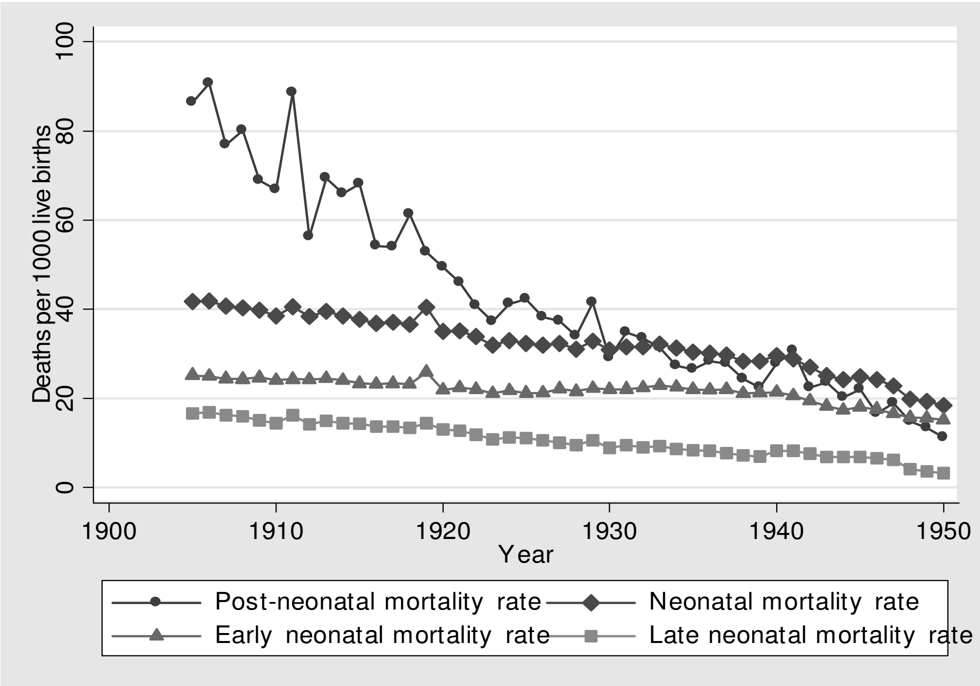
These findings mirror the pattern demonstrated historically in many developed countries. In the US, for instance, the proportion of infant deaths occurring in the neonatal period increased as mortality rates fell between 1915 and 1970 (Hill and Pande, 1997). Studies from developed countries suggest that this trend continues until the IMR is around 20, when NMR is about three quarters of IMR. This pattern has resulted in marked differences between the developed and developing world in the proportion of child deaths occurring in the neonatal period. In Western Europe, neonatal mortality rates are very low (usually around 3-5 deaths per 1000 live births) (Save the Children 2001), but contribute to around three quarters of all deaths in children under five years. In contrast, many countries in Sub-Saharan Africa with extremely high under five mortality rates have estimated neonatal rates of over 40 deaths per 1000 live births (*e.g.* Mozambique, Chad, Malawi) (Save the Children 2001) but they may make up less than one quarter of all child deaths.

[13] Comparison between neonatal and infant mortality rates are of somewhat limited value as they will also include neonatal mortality.
[14] The early neonatal period is from birth until 6 days. The late neonatal period is from 7-27 days.

Studies of historical data also suggest that in addition to declining more slowly, neonatal mortality in many developed countries did not begin to fall substantially until some years after a decline in post-neonatal and childhood mortality had been achieved. When decline did occur, it was initially in the late rather than early neonatal period. For instance in Sweden, Austria, Hungary and Belgium, a marked reduction in post-neonatal mortality could be detected from the beginning of the 20th century (Masuy-Stroobant 1997). However, neonatal deaths in all four countries did not begin to decline significantly until around 1925. Early neonatal deaths did not decline until even later: around the time of the Second World War in Sweden, Austria and Belgium and the mid-1970s in Hungary (ibid). In the UK infant and child mortality was also declining steadily from the turn of the century. A slow and not particularly consistent decline in late neonatal deaths can be detected from around the time of the First World War but progress was limited, particularly when compared with post-neonatal mortality (see Figure 10). Average annual percentage rate of decline for overall NMR was around 1.3% from 1911 to 1920, 1.2% from 1921 to 1930 and fell still further to around 0.6% in the 1930s[15]. Progress did not accelerate until the 1940s (when early neonatal mortality also began to reduce), when the average rate of decline rose to about 3.6% per annum (Macfarlane 2000). However, comparisons between modern developing countries and historical trends need to be treated with some caution: while strategies to reduce maternal and neonatal mortality in developing countries are currently well known, historical data reflects a period when evidence of effective responses was much less prevalent. This could lead to different patterns emerging due to different health care policies or family practices.

[15] The exception to this poor progress in the 1930s was among illegitimate births, where NMR fell precipitously from about 58 to 41 per 1000 live births between 1932 and 1938 (Winter 1979).

Figure 10: Trends in neonatal and post-neonatal mortality rates in England and Wales: 1905-1950



Source: Macfarlane A, (2000) *Birth Counts: Statistics of Pregnancy and Childbirth*, The Stationery Office, London (Dataset A3.3.1).

3.1 Gaps in knowledge on trends in neonatal mortality

3.1.1 Comparative changes in NMR, PNMR and ECMR

Within recent years some progress has been made in effectively documenting trends in neonatal mortality. However a number of important omissions remain: no study has systematically compared changes in NMR with PNMR or ECMR at country or regional level for a large sample size. This is important in ascertaining whether patterns of slower reduction in NMR are universal or if some countries appear to have reversed this trend. It is of particular interest to examine whether countries with a lower overall U5MR are still experiencing markedly lower rates of NMR reduction, as it is probable that the rates of PNMR, and particularly ECMR, will be very low in these groups.

3.1.2 Recent trends in neonatal mortality

It has been well documented that progress in child mortality has slowed since the late 1980s. In developing countries significant gains in child survival were not evident until after the

Second World War. Initially these declines were dramatic: annual rates of decline in the developing world as a whole accelerated between 1960 and 1980 and more than doubled from a rate of 2% in 1960-5 to about 5% by 1980 (Hill and Amouzou in Jamison *et al* 2006). However, by the mid 1980s, stagnation was beginning to set in within Sub-Saharan Africa and progress was also slowing in some countries and regions (*e.g.* India and the Western Pacific/Eastern Mediterranean regions[16]) (WHO 2005, Claeson *et al* 1999). Between 1970 and 1990 the U5MR dropped by an average of 20% per decade, whereas between 1990 and 2000 it dropped to only 12% (WHO 2005). In Sub-Saharan Africa rates of decline averaged about 2% per annum between 1970 and 1985, but fell back to about 1% between 1985 and 1990 and less than 1% during the 1990s (Hill and Amouzou in Jamison *et al*. 2006). No previous study has ascertained whether the pattern has been similar for NMR and there is no information on how recent trends in neonatal mortality (*i.e.* since the late 1980s/1990s) have changed from the rates of change in the medium term (*i.e.* since the mid-1970s)[17]. On the one hand it could be assumed that as many of the determinants are the same for all age groups, then progress in reducing neonatal mortality is also likely to have declined. However, as neonatal mortality failed to decline as rapidly as older age groups in the 1970s-early 1980s, it could be argued that there are still some "easy wins" which could have enabled progress to continue undiminished. In addition, some regions experienced modest but steady increases in skilled attendants at delivery throughout the 1990s (*e.g.* Asia, Middle East and North Africa) (AbouZahr and Wardlaw 2001), which could have promoted sustained mortality reduction in newborns. This study addresses both of these gaps, as well as providing more detailed information on changes at individual country level than any of the existing studies.

[16] Countries in the Western Pacific Region include China, Malaysia, Cambodia and the Philippines. Countries in the Eastern Mediterranean region include Pakistan, Iran, Iraq, Morocco, Sudan and Jordan.

[17] Obviously the deceleration in decline in child mortality did not occur at exactly the same time in all countries. For the purpose of this study, the year 1990 was used as the earliest year for which base data for examining recent trends was used. This is because it will capture deaths from the mid-late 1980s onwards (i.e. occurring five years before the date of the survey), which is when serious stagnation is first noted in Sub-Saharan Africa. In some other countries deceleration was not noted until a few years later, so it is possible that this cut-off may include a period before the reduction in downward trend. However, in reality most of the surveys used as baseline are actually from 1992 (up until 1996), so the vast majority of deaths in the short term analysis will have occurred from 1987 onwards, and probably the majority since 1990.

3.2 *Methodology for analysing trends*

In order to examine trends in neonatal mortality, data were analysed for neonatal, post-neonatal and early childhood mortality for 33 countries where more than one survey was available. Medium-term data comes from World Fertility Surveys collected between 1975 and 1982 as the baseline, and data gathered between 1997 and 2002 for follow up. The data covers periods ranging from 18 to 24 years. Short-term, recent trend data is taken from DHS surveys from 1990 onwards, and covered periods of 4 to 12 years. This time period was chosen in order offer some insights into patterns of change since the mid 1980s, when reduction in child mortality began to slow in some countries.

Average annual percentage rates of change were calculated to enable cross-national comparison for the trend data using the formula:

$$\frac{r_1 - r_2}{r_1 \times t} \times 100$$

Where:

r_1 = mortality rate for the year of the survey used as the baseline

r_2 = mortality rate in the year of the final survey

t = number of years between the first and second survey.

This formula does not allow for compounding. It is a measure of relative change, so countries with already low mortality can exhibit impressive rates of percentage reduction with relatively small absolute reduction in the mortality rate, whereas for countries with high rates of mortality the converse is true: high rates of percentage reduction can only be achieved through significant reductions in overall rate. Use of percentage changes may obscure patterns in the absolute rate of change, so average rates of absolute change are also given for comparative purposes. Where data was available for years between the baseline and final years, this was not included in the calculation of rate, but this more detailed trend data was used for individual country examples and graphs.

While regional averages have been used here it must be recognised that DHS data cannot be considered representative of a region. DHS surveys are normally only carried out in countries where vital registration and other health service data is incomplete or unreliable, so tend to focus on countries where relatively limited progress has been made in establishing effective health systems. The regional averages are not weighted by population.

In general, deaths within the first day of life are most difficult to prevent, and are the hardest to reduce. It was therefore hypothesised that any downward trend would be accompanied by an increase in the proportion of neonatal deaths occurring in the first day. Analysis was carried out on changes in proportion over time for the short term data as a way of triangulating changes in rate (information is not available on the proportion of deaths occurring in the first day from WFS data, so the exercise could not be carried out for medium-term trends).

3.3 Management of standard errors when comparing rates for trend data

The issue of standard errors will be discussed in greater depth in the next section, but wide confidence intervals (CIs) will make any analysis of trend difficult. CIs are not available for WFS data and for many DHS datasets.[18] One option would be to calculate CIs for all DHS survey data (datasets for WFS are not readily available) but this would be extremely time-consuming and complex: due to the structure of DHS datasets a jackknife methodology is required. It has therefore been decided that for the purposes of this study rough estimates will be made based on the standard errors given for DHS II surveys in Appendix 3. Based on these calculations, percentage differences between the two groups of figures of up to about 40% could be expected as a result of sampling error for countries outside Latin America and the Caribbean, and up to 60% for Latin American and Caribbean Countries[19]. These may be

[18] Sampling errors are published as annexes for most DHS II and Plus studies. However, in many cases they are calculated on data up to nine years prior to the survey, and are therefore of little use in examining trends.

[19] Nearly all countries outside Latin America and the Caribbean (LAC) have relative standard errors between 0.069 and 0.10 (although one outlier, Cameroon, has a considerably higher relative standard error of 0.127). Assuming that standard errors for DHS II and DHS Plus are similar, this would suggest that CIs for most countries would lie between ±13.3% and 19.4% of the estimated rate (calculated by multiplying standard errors as percentage of estimate x 1.94). Relative SEs for LAC lie between 0.069 and 0.158, producing confidence intervals of ±13.3%-29.8%. However, it should be remembered that when comparing two consecutive estimates you would need to have a difference of 2 x CI to be absolutely certain that a change is not the result of sampling error (i.e. ±26.6%-38.8% for countries outside LAC and 26.6% - 59.6% for countries within LAC). In the absence of more recent data it would appear to be reasonable to assume the relative SEs have not changed

fairly conservative estimates for later surveys, which tend to have larger sample sizes, but conversely in many countries both mortality and fertility has fallen, which will counteract this. For a few countries standard errors for five year neonatal mortality rates have been published, and where adequate data can confirm whether differences over time are significant, this is stated.

3.4 Trends in DHS NMR estimates

This section analyses the contribution of mortality to overall child mortality in the different regions, before examining trends in neonatal mortality over time, and comparing them with trends in post-neonatal and early childhood groups. The full data used for initial cross-sectional analysis can be found in Appendix 4, and the data used for the longitudinal studies is found in Appendices 5 and 6.

3.4.1 The contribution of neonatal mortality to overall deaths in children under five years of age

A graph showing mortality rates by region for NMR, PNMR and ECMR can be seen in Figure 11. To determine the proportion of child deaths occurring in the neonatal period data, NMR as a percentage of U5MR was calculated for 57 countries. The percentages for each country can be found in the table in Appendix 4, and are also displayed in Figure 12. Sub-Saharan Africa has a far higher rate of child mortality, but the proportion (approximately 27%) occurring in the neonatal period is much less than in other regions. The other regions all have fairly similar proportions of child deaths occurring in the neonatal period (ranging from 40% to 46%). Sub-Saharan Africa also has the lowest percentage of infant deaths occurring in the neonatal period (46.5%), whereas North Africa and Western Asia and South and South East Asia have the highest percentage (55.9%).

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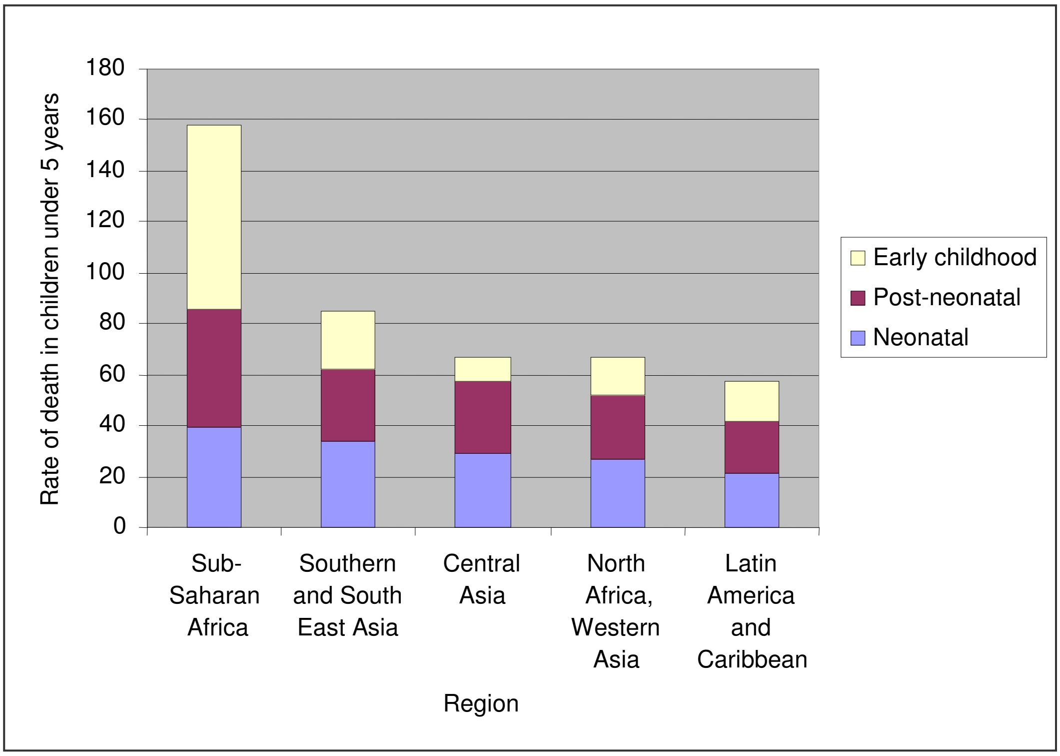
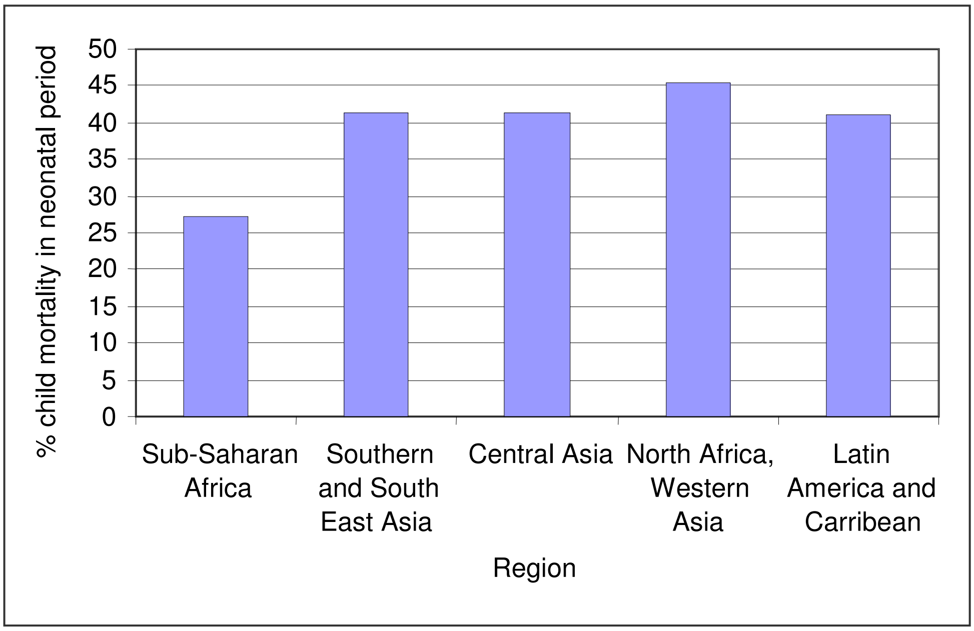
greatly between surveys, as while in some countries the NMR rate may have reduced (which may increase the relative SE), most later surveys have used larger sample sizes.

Figure 11: Bar graphs showing total child deaths by region disaggregated by NMR, PNMR and ECMR



Data refers to DHS estimates carried out between 1990 and 2002

Figure 12: Percentage of under 5 mortality occurring in the neonatal period by region



3.4.2 Trends in neonatal mortality over time

Table 5 presents both the estimated annual percentage rate of change and the annual actual rate of change for 17 countries over the medium term (18-24 years) for the neonatal, post-neonatal and early childhood periods. Table 6 shows the short term data (4-12 years since 1990) for 33 countries. Any annual rate of change calculated on a difference of more than 40% between the two survey estimates is marked with an asterisk, as this is unlikely to be purely the result of sampling error (though particularly in the Latin America and the Caribbean this possibility cannot be ruled out). An annual change based on a difference of less than 20% between survey estimates has been placed in italics within the tables to indicate that calculated annual rates of change are based on a relatively small overall change (Footnote 9 already explains the rationale for this). The data upon which these calculations are based can be found in Appendices 5 and 6. Standard errors for NMRs are available for some countries with short term data (see Appendix 6), and where it is possible to ascertain whether a difference is significant or non-significant, this is marked.

Table 5: Average annual rate of change calculated using medium term data

Country	Average annual % change in neonatal mortality rate	Average actual annual change in neonatal mortality rate	Average % annual change in post-neonatal mortality rate (PNMR)	Average actual change in post-neonatal mortality rate	Average annual % change in early childhood mortality (ECMR)	Average actual change in ECMR
Sub-Saharan Africa						
Benin	-1.2	-0.6	*-0.6*	*-0.4*	-1.5	-1.7
Cote d'Ivoire	*0.8*	*0.5*	*-0.9*	*-0.5*	2.2*	1.2*
Ghana	-1.1	-0.4	-1.2	-0.4	*-0.5*	*-0.3*
Kenya	-1.3	-0.5	*-0.3*	*-0.2*	-1.6	-1.0
Mauritania	*-0.4*	*-0.2*	-2.0	-0.8	-3.5	-4.1
Nigeria	*-1.0*	*-0.5*	*-0.8*	*-0.4*	*-0.9*	*-0.8*
Senegal	-1.3	-0.6	-2.7*	-1.7*	-3.0*	-5.3*
Average	**-0.8**	**-0.3**	**-1.2**	**-0.6**	**-1.3**	**-1.7**
North Africa/Western Asia						
Egypt	-3.0*	-1.7*	-3.7*	-2.7*	-4.2*	-2.9*
Jordan	-1.5	-0.4	-3.6*	-1.4*	-2.9*	-0.4*
Turkey	-3.0*	-1.9*	-3.8*	-2.6*	-3.7*	-1.4*
Yemen	-2.4*	-1.4*	-3.3*	-3.4*	-3.6*	-3.3*
Average	**-2.4**	**-1.3**	**-3.6**	**-2.5**	**-3.6**	**-2.0**
South/South East Asia						
Bangladesh	-1.8*	-1.3*	-2.5*	-1.5*	-3.0*	-3.0*
Indonesia	-2.6*	-1.2*	-2.4*	-1.1*	-3.9	-2.8*
Nepal	-1.9*	-1.5*	-2.5*	-1.7*	-3.0*	-3.3*
Philippines	-1.4	-0.3	-2.4*	-0.8*	-3.1*	-1.2*
Average	**-1.9**	**-1.0**	**-2.4**	**-1.3**	**-3.2**	**-2.6**
Latin America/Caribbean						
Colombia	-2.3*	-0.8*	-3.4*	-1.2*	-3.8*	-1.6*
Peru	-2.5*	-1.1*	-3.1*	-1.6*	-3.3*	-2.0*
Average	**-2.4**	**-0.9**	**-3.3**	**-1.4**	**-3.6**	**-1.8**

Data sources: World Fertility surveys (1977–1982) and Demographic and Household Surveys (1997–2001)
Time period over which medium term data was collected ranges from 1977 to 2001, and covers periods of between 18 and 20 years.
Italics denote calculation of annual rate of change based on a difference between two survey estimates of less than 20%
* Denotes calculation of annual rate of change based on a difference between two survey estimates of greater than 40%

Table 6: Average annual rate of change calculated using Recent Short Term Data

Country	Average annual % change in neonatal mortality rate	Average annual actual change in NMR	Average annual % change in post neonatal mortality rate (PNMR)	Average annual actual change in post neonatal mortality rate (PNMR)	Average annual % change in early childhood mortality (ECMR)	Average annual actual change in ECMR
Sub-Saharan Africa						
Benin	*0.1†*	*0.0†*	*-1.8*	*-1.0*	*-0.6*	*-0.4*
Burkina Faso	*-0.9*	*-0.4*	4.7	2.4	3.7	4.0
Cameroon	*1.9*	*0.6*	3.8	1.2	3.2	2.1
Cote d'Ivoire	9.6*	4.0*	*1.5*	*0.7*	*3.1*	*2.1*
Ghana	-3.5	-2.2	*1.1*	*0.3*	*-1.0*	*-0.6*
Kenya	*2.1*	*0.5*	5.2	1.9	*2.2*	*0.8*
Madagascar	*0.6†*	*0.2†*	*0.7*	*0.4*	*-1.9*	*-1.5*
Malawi	*0.2†*	*0.1†*	-4.2	-3.9	*-2.2*	*-2.5*
Mali	*-0.9†*	*-0.5†*	*1.5*	*-1.0*	*-0.5*	*-0.1*
Niger	*1.4†*	*0.6†*	*-0.7*	*-0.6*	-3.8	-8.5
Nigeria	*-1.4†*	*-0.6†*	*-1.7*	*-0.8*	-4.3	-5.0
Rwanda	*1.7†*	*0.7†*	4.6	2.2	4.6	3.4
Senegal	*1.4†*	*0.5†*	*-1.8*	*-0.6*	*2.4*	*1.7*
Tanzania	*0.9†*	*0.4†*	*1.3*	*0.7*	*-0.4*	*-0.2*
Togo	*0.4*	*0.6*	*0.2*	*0.1*	*-1.4*	*-1.2*
Uganda	4.5†	1.2†	*0.4*	*0.2*	*-0.8*	*-0.5*
Zambia	*-1.6†*	*-0.6†*	*-1.1*	*-0.7*	*-1.6*	*-1.5*
Zimbabwe	*3.7†*	*0.9†*	5.5	1.6	8.2*	2.8*
Average	**1.1**	**0.3**	**1.1**	**0.2**	**0.0**	**-0.3**
North Africa/Western Asia						
Egypt	-3.4	-1.1	-4.0*	-1.1*	-6.6*	-1.6*
Jordan	*-1.6†*	*-0.3†*	-3.2	-0.4	*2.2*	*0.1*
Turkey	*-2.3†*	-0.7†	-5.6	-1.3	*2.3*	*0.2*
Yemen	-3.2	-1.3	*-0.8*	*-0.3*	-3.6	-1.5
Average	**-2.6**	**-0.9**	**-3.4**	**-0.8**	**-1.4**	**-0.7**
Central Asia						
Kazakhstan	18.1*	3.5*	10.2*	2.1*	14.0*	1.0*
South/South East Asia						
Bangladesh	*-3.3*	*-1.7*	-5.1	-1.8	-6.8*	-3.4*
India	*-1.8††*	*-0.9††*	-3.2	-1.0	*-2.1*	*-0.7*
Indonesia	-5.2	-1.7	-5.6	-2.0	-9.8*	-3.1*
Nepal	-4.4	-2.2	*-2.1*	*-0.6*	-6.8	-2.9
Philippines	*0.1†*	*0.0†*	*1.8*	*0.3*	-7.2	-1.5
Average	**-2.9**	**-1.3**	**-2.9**	**-1.0**	**-6.5**	**-2.3**

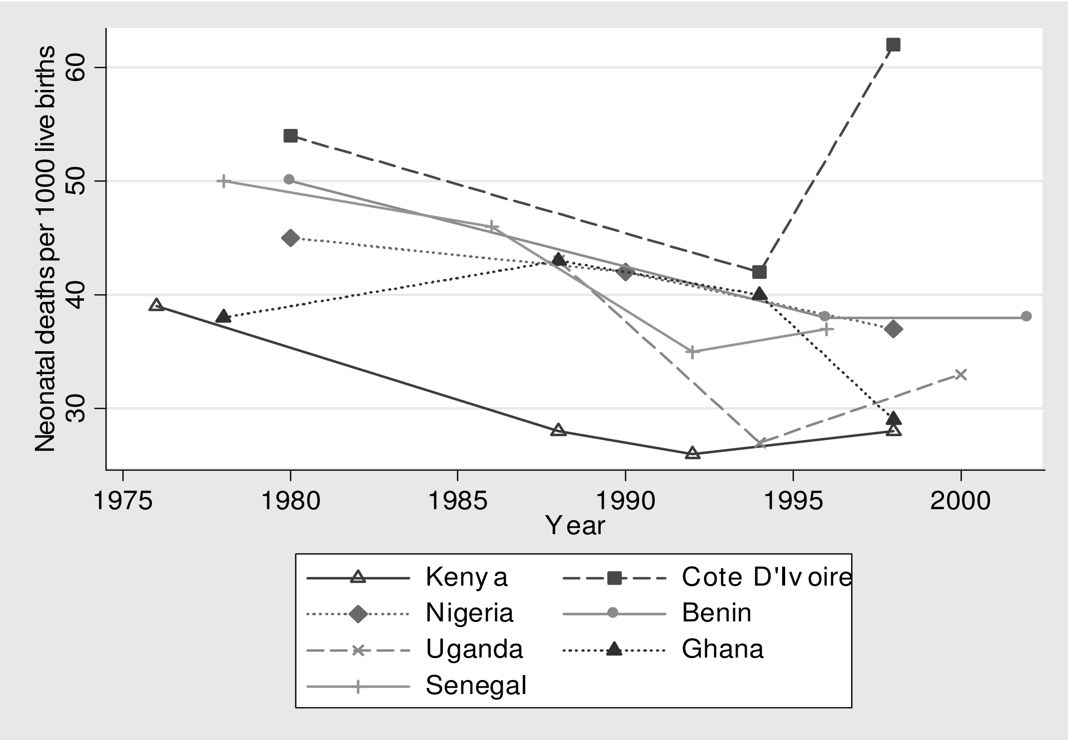
Country	Average annual % change in neonatal mortality rate	Average annual actual change in NMR	Average annual % change in post neonatal mortality rate (PNMR)	Average annual actual change in post neonatal mortality rate (PNMR)	Average annual % change in early childhood mortality (ECMR)	Average annual actual change in ECMR
Latin America/Caribbean						
Bolivia	*-1.7*	*-0.6*	*-3.5*	*-1.4*	-9.9	-4.3
Colombia	4.6*	0.5*	*0.5*	*0.0*	-4.4*	-0.3*
Dominican Republic	-5.0*	-1.2*	-7.2*	-1.4*	-6.4*	-1.1*
Haiti	*0.5†*	*0.2†*	*2.1*	*0.9*	-5.3	-3.3
Peru	-3.5††	-0.9††	-6.1*	-1.8*	-5.4*	-1.3*
Average	**-1.1**	**-0.4**	**-2.8**	**-0.7**	**-6.2**	**-2.1**

Data sources: Demographic and Household Surveys from 1990 onwards covering periods of 4 to 12 years.
Italics denote calculation of annual rate of change based on difference between two survey estimates less than 20%
* Denotes calculation of annual rate of change based on difference between two survey estimates greater than 40%
† Denotes differences between first and second NMR not significant at the 5% level based on available standard errors (N.B. in some cases this may be based on the existence of one SE only).
†† Denotes differences between first and second NMR are significant at 5% level based on available standard errors.

3.4.3 Sub-Saharan Africa

Sub-Saharan Africa appears to have been the poorest performing region over the medium term period, both in terms of percentage annual reduction and actual annual reduction. While all countries except Cote D'Ivoire have shown some reduction in neonatal mortality, progress in all age groups has mostly been very limited, and the average annual percentage rate of change based on the available data for countries in this region over the medium term has been only -0.8% per annum (or an annual change in NMR of -0.3 neonatal deaths per 1000 live births each year). The only two countries that appear to have made significant progress in reducing PNMR and ECMR over the medium term (Mauritania and Senegal) have made much less progress in reducing neonatal deaths.

Figure 13: Trends in neonatal mortality in Sub-Saharan Africa



While the recent short-term data should be interpreted with particular caution because changes could be the result of sampling error, it suggests an even bleaker picture of stagnation or even reversal of gains in Sub-Saharan Africa. Only one country (Ghana) has shown a marked decrease in NMR. Overall the NMR has actually increased for this region by an average of 1.1% per annum. Two countries in particular (Cote D'Ivoire and Uganda) have demonstrated marked increases in NMR estimates (the increase in Uganda narrowly misses being significant at the 5% level)[20]. Figure 13 shows the trend over estimated NMR for seven countries where several consecutive surveys are available and a number of these countries appear to be demonstrating marked stagnation and reversal from the early 1990s. Progress within the other age groups is also extremely poor, and marked increases can be noted in ECMR for several countries.

[20] This could reflect data anomalies, either resulting from an underestimation of deaths in the earlier survey, or an overestimation in the later survey. An examination of recall data for both countries 5-10 years before the final survey suggests that underestimation of the rate in the earlier period is not the reason for the apparent increase in deaths in Cote D'Ivoire, but may possibly contribute towards it in Uganda.

3.4.4 Trends in North Africa and Western Asia

Countries within the North Africa and Western Asia region, by contrast, appear to have made sustained progress across all three age groups over the medium term (though progress in Jordan would seem to be poorer than others within the group). Turkey, Egypt and Yemen all had extremely high levels of neonatal mortality in the mid-1970s (58-63 deaths per 1000 live births), and have markedly reduced their estimated rates to between 24 and 34 deaths per 1000 live births in recent years. With the possible exception of Jordan, countries within the North Africa and Western Asia region appear to have continued to make sustained progress across all three age groups in the recent short term (though data needs to be interpreted with caution), and the regional average percentage rate of progress is similar for the two periods.

3.4.5 Trends in countries in Latin America/Caribbean

Available medium-term data for the two countries within the Latin America/Caribbean region shows a very similar pattern to those in North Africa. However, estimates for recent short term progress within South America show a very mixed picture, and overall average rate of progress has slowed. The Dominican Republic has produced one of the greatest percentage rates of change of all countries within this study, whereas Haiti has demonstrated no change. Peru has also demonstrated a marked reduction in neonatal mortality, which is significant at the 5% level. Colombia appears to have experienced a sharp rise in neonatal and under five mortality from 1990 to 2000. However, examination of recall data suggests that the 1990 DHS may have produced an underestimation of the death rate which produces a false impression of an increase (although this would still indicate there has been no improvement in neonatal mortality in the last 10 years).

3.4.6 South and South East Asia

The figures available for countries in South and South East Asia also indicate progress over both the short- and medium-term in all age groups (with the exception of the Philippines which shows no short term reduction in neonatal or post-neonatal mortality rates). A number of countries (*e.g.* Bangladesh, Indonesia and Nepal) suggest that reduction in NMR is greater over the recent short term than over the medium, and this positive trend is reflected in the regional average (-1.92% average reduction per annum over the medium term, compared with -2.95% over the recent short term). Though this data should once again be interpreted with caution, they are supported by patterns observed when examining the 5-9 and 10-14 year recall figures from the most recently available survey. India shows less short-term progress than other countries within the sub-continent, and this relatively poor progress is supported by available government figures (Natarajan 2003). This is particularly concerning because of the large proportion of deaths globally that occur within this country. However, probably because of the very large sample sizes in these Indian DHS surveys, these modest differences are significant at the 5% level.

3.4.7 Trends in Central Asia

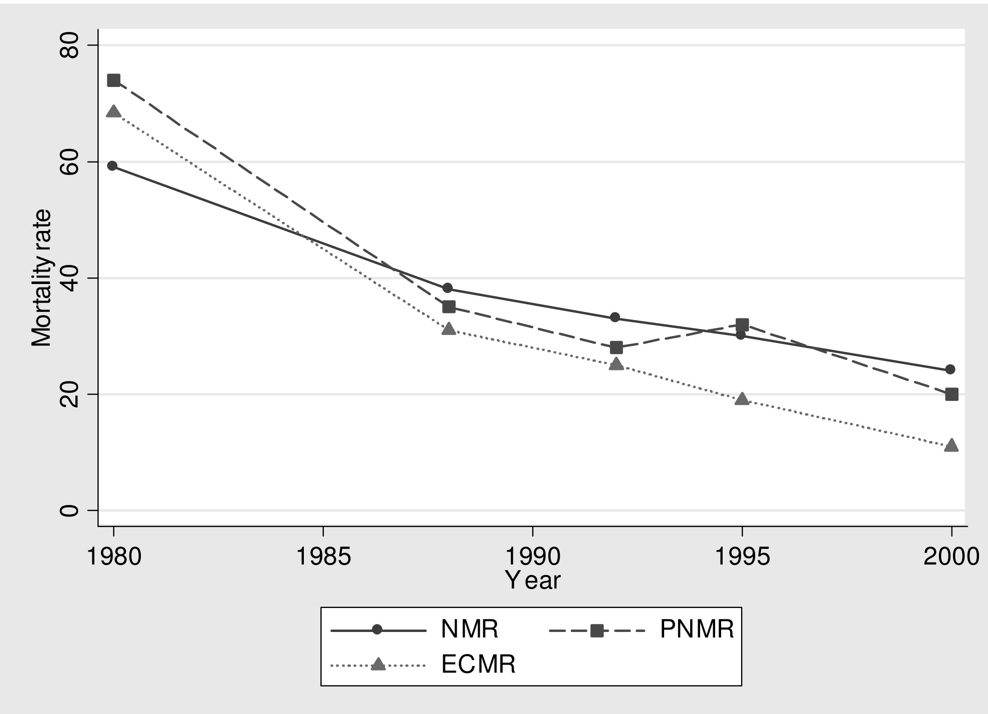
Trend data is only available for one country in Central Asia: Kazakhstan. The data only covers a period of four years (1995-1999) and shows a huge increase in deaths in all age groups, but greatest in the neonatal period. Such a huge increase may well raise questions about data quality, although examination of recall data would indicate underestimation of baseline NMR is not the cause. Another possible explanation would be a change in the definition of stillbirths and neonatal deaths: around this time Kazakhstan moved to the WHO definition of neonatal deaths, which could result explain the sudden increases as deaths that may have previously been categorised as stillbirths would now be included.

3.5 How does rate of progress for NMR compare with that of PNMR and ECMR?

Over the medium term for all regions, the average percentage rate of change in reduction of NMR (and average actual rate of change) is lower for NMR than either PNMR or ECMR (see Table 5). The total average annual percentage change for all countries where there is medium-term DHS data is -1.3% compared to 3% for both PNMR and ECMR. This difference is not unexpected, as there has long been concern that NMR is reducing at a slower rate than other age groups. However, what is quite remarkable and previously undemonstrated is how uniform this pattern is: indeed, outside Sub-Saharan Africa there are no countries where average annual rate of progress is greater or the same in the neonatal period as in early childhood, and only Indonesia demonstrates a marginally greater rate of progress in neonatal than post-neonatal mortality.

The data for recent short-term trends is fairly similar. While short-term data within South and South East Asia shows encouraging signs of accelerating progress in NMR, the difference in progress appears to have increased between NMR and ECMR with an average annual rate of change for NMR being -3.0%, and for ECMR -6.5% (compared with -1.92% and -3.24% for medium-term data). The regional average for Latin America and the Caribbean also has very marked differences in the recent short term between progress in NMR and ECMR. Most countries outside Sub-Saharan Africa appear to be following a pattern similar to that illustrated by the graph showing trends in Egypt (Figure 14), whereby neonatal mortality follows the overall sustained downward trend in child mortality, but at a lower rate than that seen in older age groups. Sub-Saharan Africa shows a much more confused picture, and it is difficult to generalise about differential rates of progress between age groups. The only region where NMR appears to be reducing faster than ECMR is North Africa and Western Asia. This is driven by the fact that two countries (Turkey and Jordan) actually appear to have experienced increases in ECMR.

Figure 14: Trends in under 5 mortality in Egypt disaggregated by age-group



3.6 How does the short-term progress in NMR compare with medium-term progress?

In Sub-Saharan Africa there is evidence that even the limited progress made over the medium term has slowed over the short term, and in some cases countries have demonstrated marked increases in neonatal mortality. However, despite possible deceleration or reversal of gains in a few isolated countries, there is little evidence of widespread stagnation outside the Sub-Saharan African region. Indeed, progress in the North Africa and South and South East Asia regions appears to have continued unabated and indeed in some countries accelerated. The picture is extremely mixed for Latin America and the Caribbean, but comparisons between short and medium term are somewhat complicated by the fact there are only two countries with medium-term data. It is also heartening to note that in most countries outside Sub-Saharan Africa there is little or no evidence of widespread reduction in progress for any age-group in the recent short term (with the possible exception of North Africa, where lower rates in progress for early child mortality and post-neonatal mortality over the short term has contributed to an overall deceleration in progress for under five mortality from 3.2% to 2.9% per annum). It is also obviously possible that the deceleration noted in previous studies is being partially driven by change in age composition: *i.e.* as more early childhood deaths are prevented, child mortality is increasingly occurring in the neonatal and post-neonatal periods. As these age groups have lower rates of reduction, overall mortality reduction will slow.

3.7 Changes in percentage of neonatal deaths occurring on the first day of life

As neonatal deaths in the first day are the most difficult to reduce, reduction in neonatal mortality would normally be accompanied by an increase in the percentage of neonatal deaths that occur in the first 24 hours of life. I hypothesise that an analysis of changes in the percentage of deaths occurring in the first day (in this study defined as those reported on day 0 or 1) may provide important information to support or raise queries on the accuracy of trends in rate, although this data will also be prone to similar sampling and non-sampling errors as NMR estimates. This has never been considered by previous studies and if found to be effective may assist in triangulating data on trends. Table 7 shows the percentage of neonatal deaths occurring on day 1 for both the baseline data and the follow-up data for the recent short term. It also provides the difference in these two figures.

For all countries outside Sub-Saharan Africa where a decrease in neonatal mortality is suggested by short-term trend data, there is also an increase in the percentage of deaths occurring in the first day as would be expected (though in some instances these are small). However, Kazakhstan, which shows an apparent sharp increase in neonatal mortality also shows an increase in deaths in the first day of life, which suggest that there may be some data anomalies. This may support the idea that the rise in NMR in Kazakhstan is at least partly due to changing definitions of neonatal deaths and stillbirths (although the fact that other age groups have also experienced a rise may reflect a real trend of increasing mortality).

Table 7: Changes in % neonatal deaths in the first 24 hours of life (short term data)

	% NMR in first 24 hours (1st survey)	% NMR in first 24 hours (2nd survey)	Difference % NMR between first and second surveys
Sub-Saharan Africa			
Benin	46.2	50.7	4.5
Burkina Faso	30.2	37.7	7.5
Cameroon	39.3	49.0	9.7
Cote d'Ivoire	42.9	31.1	-11.8
Ghana	51.7	57.0	5.3
Kenya	48.9	56.2	7.3
Madagascar	34.4	41.8	7.4
Malawi	38.5	41.9	3.4
Mali	42.4	44.9	2.5
Niger	29.6	28.7	-0.9
Nigeria	42.6	42.3	-0.3
Rwanda	26.2	49.0	22.8
Senegal	31.9	31.4	-0.5
Tanzania	40.3	50.4	10.1
Togo	49.6	58.8	9.2
Uganda	43.3	54.1	10.8
Zambia	39.3	34.2	-5.1
Zimbabwe	55.7	60.2	4.5
North Africa/Western Asia			
Egypt	31.3	36.4	5.1
Jordan	41.1	45.8	4.7
Morocco	26.9	32.7	5.8
Turkey	47.2	44.8	-2.4
Yemen	45.6	42.1	-3.5
Central Asia			
Kazakhstan	26.9	48.9	22.0
South/South-East Asia			
Bangladesh	38.4	44.9	6.5
India	40.4	43.5	3.1
Indonesia	40.7	53.4	12.7
Nepal	36.1	43.3	7.2
Philippines	47.4	44.9	-2.5
Latin America/Caribbean			
Bolivia	42.3	41.5	-0.8
Colombia	55.0	60.3	5.3
Dominican Republic	51.7	75.0	23.3
Guatemala	60.8	60.0	-0.8
Haiti	27.9	33.7	5.8
Peru	43.1	46.7	3.6

Data source: Demographic and Household Surveys from 1990 onwards covering periods 4-2 years.

4.0 **<u>The relationship between child mortality and income</u>**

It has long been recognised that there is a strong relationship between economic growth and child mortality, and a number of studies have tried to quantify the relationship at a cross-national level (using per capita GDP as a measure of income). One of the most frequently cited studies is Pritchett and Summers' (1996) analysis, which estimates the effect of wealth on infant and child mortality using regression methodology based on cross-country time series data. A particular feature of this study is that is uses instrumental variables to establish a causal link between increased income and reduced child mortality: other studies have been unable to rule out the possibility of reverse causation (*i.e.* improved child mortality leads to increased GDP), or incidental association. The study concludes that in 1990 alone over 0.5 million child deaths in developing countries could be attributed to poor economic performance during the 1980s. A recent study by Bhalotra (2008), which examines the association between change in GDP and child mortality over time using data from 15 Indian states found that the composition of GDP growth is also important: growth within the non-agricultural sector has a greater impact on mortality. Both of these studies also introduce a number of control variables into the equation (*e.g.* women's education), which tend to reduce the size of the elasticity for GDP.

Both of these studies (and a number of others) have used a double-log design, which produces elasticities (*i.e.* the ratio of the incremental percentage change in one variable with an incremental percentage change in another). Methodological differences make it extremely difficult to effectively compare the elasticities calculated in these panel data studies, but estimates from Pritchett and Summers' analysis study are comparatively low (between -0.2 and -0.4 for infant and child mortality: *i.e.* for every increase in GDP of 10%, infant and child mortality reduces from between 2% and 4%). Bhalotra's estimate for India is higher for child mortality (-0.71), with state level estimates ranging from -0.4 to -1.7. Several studies which used cross-sectional rather than time data trends have produced similar elasticity estimates for child mortality of around -0.6 to -0.7 (*e.g.* Tandon 2005, Filmer and Pritchett 1997).

Relatively little work has been carried out to estimate the extent to which economic growth has driven progress in child health over the last few decades. Filmer and Pritchett (1997) carried out a study using regression methodology on a cross-sectional sample of countries to ascertain which factors best explain variation in under-five mortality. It concludes that the differences in infant and child mortality rates between countries can be overwhelmingly explained by a relatively small group of economic and social factors, with very little variation explained by public spending and health policy. Rutstein (2000) carried out a study to examine the extent to which potential explanatory variables had changed over time in countries where child mortality had reduced. His work, and a similar study by Cornia and Mwabu (1997), suggests that there has been no "magic bullet" in the reduction of child mortality, but both suggest that socio-economic factors such as women's education and literacy; improved real average per capita household income; and environmental conditions (safe water supply sanitation and housing) have all played a part in reducing child mortality, as well as improvements in health services and child nutrition.

Further recent studies have estimated whether economic growth alone will enable the Millennium Development Goal for child health (to reduce child mortality by two thirds between 1990 and 2015) to be attained (*e.g.* Bhalotra 2008, Tandon 2005). Both suggest that, while GDP can contribute to decline, it is not realistic to hope it can be wholly responsible for achieving the target: Bhalotra's study estimated that a rate of decline in childhood mortality adequate to reach the MDG would only be achieved through an annual increase in GDP of 14.1% within India (far higher than the actual rate of 3.1%). Tandon's study, which is based on cross-sectional data from number of Asian countries, estimates that over 6% annual growth in GDP is needed, which, while considerably lower, is still considered unrealistic.

As previously discussed in the introductory chapter, socio-economic factors, including wealth are thought to possibly have a lesser effect on reducing neonatal mortality. Comparisons of mortality across centiles for different age groups (Lawn *et al* 2005) and historical data from the UK both suggest that while there is a proven relationship between neonatal mortality and wealth, it is much weaker than during the post-neonatal period. A broader study by Matthews *et al* (2005, cited in WHO 2005) using principal component analysis suggests that contextual factors (income, female literacy, sanitation and access to clean water) explain less of the variation between country mortality rates for neonatal mortality than for post-neonatal and early child mortality. However, no previous study has ascertained whether the GDP elasticities for neonatal mortality are lower than for post-neonatal or early childhood mortality. This is a question of great interest for policy makers: if gains in neonatal mortality are less marked from socio-economic development, the importance of effective strategies to reduce deaths in this age group becomes even more vital. Countries that have already made gains in reducing post-neonatal and early childhood mortality may well experience stagnation as neonatal mortality becomes a higher proportion of all child deaths if there is over-reliance on the role of economic growth alone.

4.1 Methodology for examining the association between GDP and NMR, PNMR and ECMR

In addition to scattergrams, ordinary least squares (OLS) regression was used to capture the association between mortality rates and GDP per capita using cross-sectional data from 56 countries. The analysis uses simple regression with one independent variable (natural log of GDP per capita) and natural log of mortality rate as the dependent variable, creating the equation:

$$LnY = a + B\,LnX + e$$

Where

LnY = log of the mortality rate; a = constant; LnX = Log of GDP per capita and

e = error

A double log model was used as the data is non-linear and this provided the best fit. An advantage of the double log model is that the slope coefficient measures the average percentage reduction in mortality that is associated with a percentage increase in national income, thus making interpretation easier. GDP purchasing power parity (PPP) was used as this is the most effective economic tool for comparing the relative value of different currencies.

The examination of the relationship between GDP and mortality using cross sectional data has the disadvantage that it cannot allow for country-specific factors that may affect the association. In order to address this, the study also examines the relationship between the change in mortality and the change in GDP for 27 countries where trend data is available for a period ranging from 8 to 25 years. Again, a double log model is used.

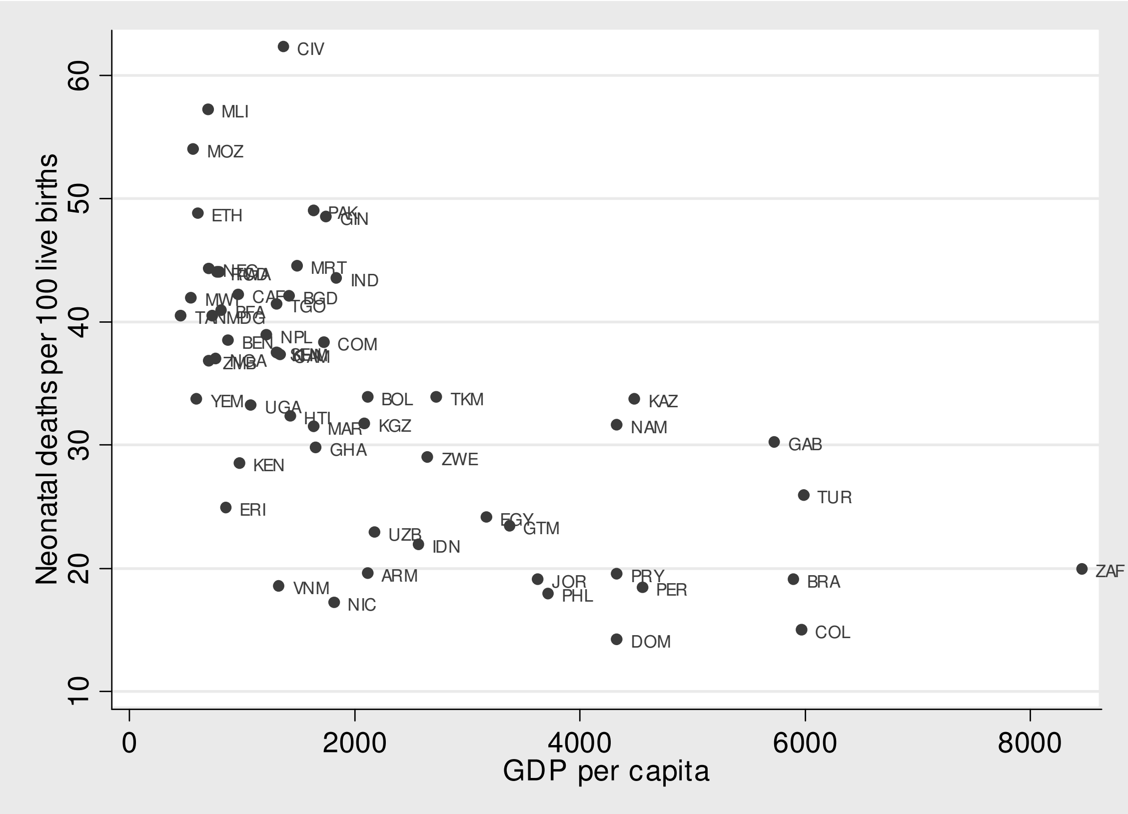
The limitations of GDP as a measure of living standards are fully accepted: in particular it is not able to capture national fractionalisation or inequalities, and may be particularly inaccurate in countries where the informal economy or non-monetised sectors are important. However, as the focus of this chapter is income rather than broader socio-economic wellbeing, it was decided that this would be preferable over some of the broader composite indices such as the Human Development Index. It is also fully recognised that a number of other socio-economic factors such as education and public spending also impact on child mortality, but it was not thought that these could be effectively addressed within the remit of this study (or, indeed within the limitations of the data). It is, however, acknowledged that a number of other socio-economic indicators will be strongly correlated with GDP.

4.2 The relationship between neonatal mortality and GDP

The scattergram in Figure 15 shows a curvilinear relationship between NMR and GDP per capita[21]. However, it is interesting to note the wide variations in NMR for countries with similar levels of GDP, particularly amongst the poorer countries. For instance, Guinea (GIN) and Nicaragua (NIC) have relatively similar levels of GDP per capita but estimates for NMRs are 48.4 and 17.1 per 1000 live births, respectively. Even within regions marked differences can be seen between countries with similar GDPs, such as Eritrea and Ethiopia (ERI and ETH).

[21] Estimates for GDP per capita based on World Bank figures (taken from the World Bank Development Indicators CD Rom) for purchasing power parity (PPP) per capita for the mid year of the 5 year period covered by the survey.

Figure 15: Scattergram showing association between neonatal mortality rates and annual PPP per capita GDP



A series of OLS regressions on data from 56 countries where GDP per capita income is available using the natural log of GDP per capita as the independent variable and the natural log of NMR, PNMR, ECMR, IMR and U5MR as dependent variables produces the following results in Table 8:

Table 8: Results for OLS regression using natural log of GDP per capita as independent variable and natural log of NMR, PNMR, IMR, ECMR and U5MR as dependent variable

	Dependent variable				
	Nat. log. NMR	**Nat. log. PNMR**	**Nat. log. IMR**	**Nat. log. ECMR**	**Nat. log. U5MR**
Constant	5.95 *(-0.37)*	7.85 *(0.51)*	7.60 *(0.40)*	10.84 *(0.88)*	9.20 *(0.49)*
Natural log GDP per capita	-0.34 *(0.05)*	-0.60 *(0.07)*	-0.46 *(0.05)*	-1.00 *(0.12)*	-0.62 *(0.07)*
r^2	0.47	0.57	0.58	0.56	0.62
Significance	<0.001	<0.001	<0.001	<0.001	<0.001
Number of observations	56	56	56	56	56

As can be seen, the r^2 values suggest that the degree of variation which can be attributed to GDP per capita is slightly greater for PNMR and ECMR than NMR. However, there is a very marked difference in the elasticities: a 10% increase in GDP per capita is associated with a 3.4% decrease in NMR, a 6% decrease in PNMR and a 10% decrease in ECMR. This is illustrated in Figure 16 by separate regression lines for each age group. Testing using seemingly unrelated regression (SUREG) shows that the difference between the coefficients of the log of GDP per capita for NMR and PNMR, and PNMR and ECMR are statistically significant at the 5% level. The results also demonstrate how focus on the relationship between GDP and IMR or U5MR mask differences in the component rates.

In addition regressions were run using the log of change in GDP over time as the independent variable and the log of the change in NNMR, PNMR and ECMR as dependant variables. A total of 27 countries were included in the equation where trend data was available for periods ranging from 8 to 25 years. The results (see Table 9) showed higher elasticities for post-neonatal and early childhood mortality than for neonatal mortality: a 10% increase in GDP over time is associated with decreases of 7.2%, 9.5% and 15.6% in NMR, PNMR and ECMR, respectively. Again a SUREG test showed the differences in coefficients to be significant, but this time at the 1% level. It can be noted that changes in GDP over time appear to have a greater impact on mortality than differences in GDP between countries at the same point in time, although the confidence intervals are wide.

Figure 16: Scattergram showing relationship between log of NMR, PNMR and ECMR and PPP per capita GDP, with fitted regression lines for each age group.

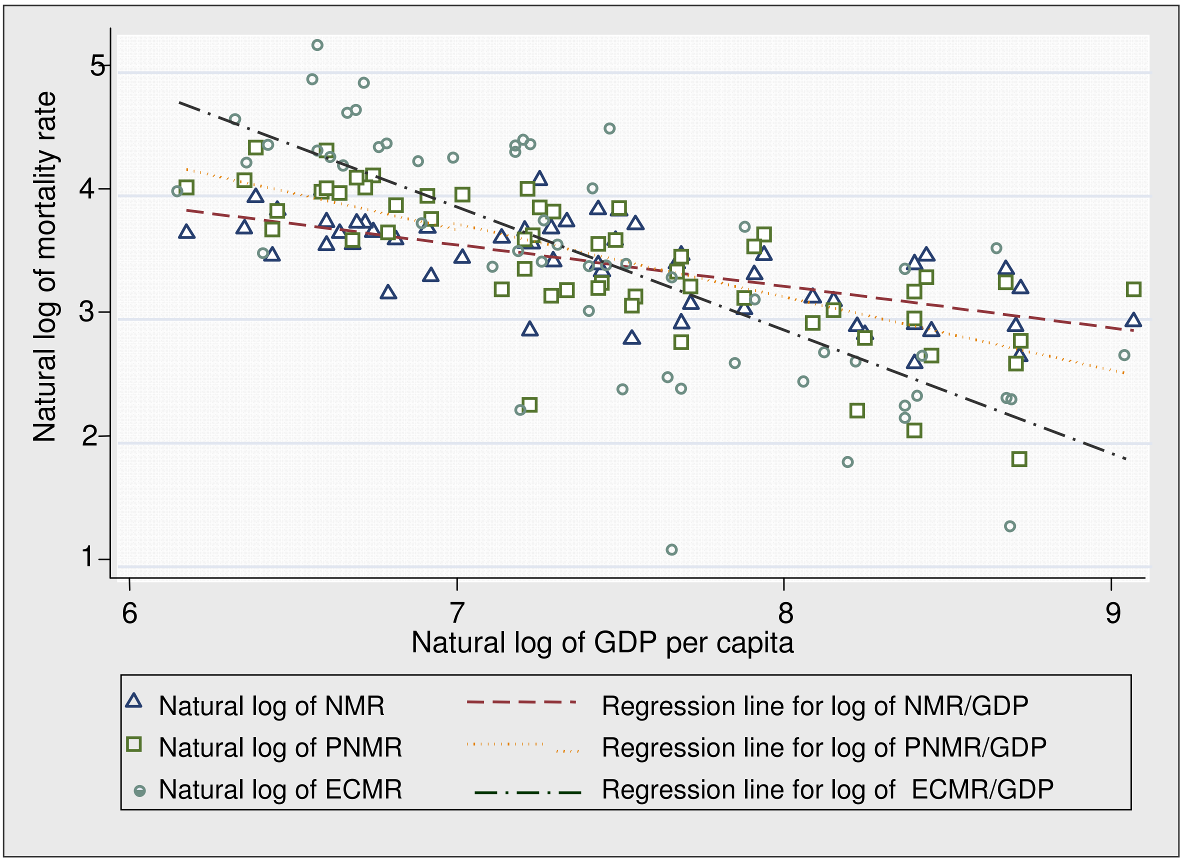


Table 9: Results of OLS using log of change in GDP over time as the independent variable and the log of the change in NNMR, PNMR and ECMR as dependant variables.

	Dependent variable				
	Nat. log. difference in NMR	**Nat. log. difference in PNMR**	**Nat. log IMR**	**Nat. log. ECMR**	**Nat log U5MR**
Constant	-0.26 (0.06)	-0.42 *(0.11)*	-0.36 *(0.08)*	-0.49 *(0.12)*	-0.39 *(0.08)*
Natural log difference in GDP per capita	-0.72 *(0.18)*	-0.95 *(0.42)*	-0.78 *(0.24)*	-1.56 *(0.50)*	-0.99 *(0.24)*
r^2	0.38	0.25	0.30	0.40	0.40
Significance	0.001	0.01	<0.001	<0.001	<0.001
Number of observations	27	27	27	27	27

The elasticity for under-five mortality of -0.99 found in this study is generally larger than that found in other studies using panel data (although as previously mentioned, methodological differences make direct comparison problematic). This could just be a result of large standard errors, but part of the reason for the high elasticity could relate to the country profile used in this analysis, which includes three countries which have actually experienced a rise in child mortality and fall in GDP. If these countries are removed from the analysis, the elasticity reduces (-0.66 for IMR and -0.84 for U5MR), although they are still relatively high. This may suggest that a drop in GDP is associated with a greater rise in mortality than when rising GDP results in falling mortality. This makes some sense, as falling GDP is likely to signal a complex deterioration of socio-economic conditions and national infrastructure, which would affect child health through a number of channels.

5.0 <u>Discussion and Policy Implications</u>

5.1 How reliable are DHS estimates for neonatal mortality?

Accuracy of estimated neonatal mortality rates from the DHS, particularly in the absence of other national level surveys to provide external validation, are difficult to determine with any certainty. Probably one of the greatest limitations for DHS data is the wide confidence intervals. This makes it difficult to use DHS data to detect relatively small changes over time, and means that any estimation of rate of change or comparison between countries needs to be interpreted with caution. One possible way of reducing confidence intervals for DHS would be to increase the sample size. However, this would have serious financial and practical considerations, and increasing sample size to a degree which would significantly reduce standard errors is probably unlikely. Korenromp *et al* (2004) suggest that one possible solution would be to have an additional shortened survey identifying child mortality, which could be administered to a greater number of clusters.

There is some evidence that a proportion of neonatal deaths may be omitted in some countries. Probably the two most concerning non-sampling errors identified are possible back-dating of deaths which lead to underestimation of deaths, and possible age heaping at one month (though further analysis of this potential problem is required). Both of these problems could at least partially be reduced by improved training and supervision of survey staff. In recent years interviewers have been trained to probe for the child's exact age of death if the death occurs at one year to avoid heaping at this age (Mahy 2003), and a similar approach could be used to reduce heaping of deaths reported at seven days or one month.

Analysis of change in the proportion of deaths occurring at one day produced ambiguous results. In general countries that had experienced a marked fall in mortality did experience the expected increase in proportion of mortality in day one. However, the findings for Sub-Saharan Africa were more conflicting. This may be because the changes in rate were too small to be reflected in corresponding changes in proportion, or reflect data inaccuracies. However, it must be remembered that the causes underlying the increases in mortality in many countries within this region are not fully explained, and patterns may not be conforming to what is expected: *i.e.* a higher proportion of the excess deaths could be occurring in the very early neonatal period. More analysis should be carried out on this before it is used as a tool for verifying change.

In the medium term it may also be necessary to rely on process indicators for monitoring short-term changes brought about through national programmes. Calculations of these rates from survey data have much greater levels of precision than relatively “rare” events such as child deaths. A number of indicators have been identified, including antenatal attendance, skilled attendance at delivery, tetanus toxoid vaccination, postnatal care and breastfeeding rates. While all these interventions or packages of intervention have strong evidence of impact on neonatal mortality, further research is needed to quantify the level of potential impact of some of these in practice, and how this will vary in different settings and scenarios.

5.2 What progress is being made in reducing neonatal mortality?

This study demonstrates that across all regions and in almost all countries neonatal mortality is declining at a slower rate than deaths in other age groups. It is particularly noteworthy that this pattern continues even when countries have made huge strides in reducing deaths in older age groups, resulting in a high proportion of child deaths occurring in the neonatal period. Central Asia, North Africa and Latin America all have low rates of deaths occurring in the early childhood period, but the reduction of neonatal mortality still lags behind. It is likely that further progress in reducing child mortality will rely on gains in the neonatal and post-neonatal period for these countries. In most Sub-Saharan African countries there is still major scope for reducing the high number of early childhood deaths. However, even within this region up to 42% of all childhood deaths occur in the neonatal period (*e.g.* Mauritania) suggesting that, in many countries, action to reduce deaths in the first month of life is vital to ensure rapid and sustained progress in reducing child mortality. The low proportion of NMR in relation to overall child mortality identified in Sub-Saharan Africa is likely to be a result of an unusually high proportion of early childhood mortality in this region: a phenomenon described elsewhere (*e.g.* Bicego and Ahmad 1996) which may be partly due to the high incidence of malaria.

It must be acknowledged that a higher proportion of neonatal mortality is intractable than for older age groups, and a further proportion requires very high quality care to avert mortality. Transitional countries that have reduced their ECMR to 3 or less deaths per 1000 may still have NMRs as high as 8 per 1000 (*e.g.* Mexico, Romania). It is difficult to ascertain what level of NMR is achievable in resource-poor settings where investment in expensive technology and neonatal intensive care services is unfeasible. Success stories among developing countries may suggest what can be achieved: Vietnam and Nicaragua have total per capita health expenditure of only \$21 and \$52[22], respectively, which is much lower than many of the other countries in this study. However, they have reduced their NMR to 12.2 and 17.1 per 1000, respectively[23]. Evidence can also be taken from historical data. Within the UK, access to even the most basic neonatal intensive care services did not become available until the late 1960s and early 1970s. However, by 1960 the NMR in England and Wales had dropped to 13 deaths per 1000 (Macfarlane 2000). This suggests that nearly all the countries in this study can plausibly still make progress without unrealistic major investment in neonatal care technology.

Relatively little attention has been paid to how countries with somewhat more developed health systems can effectively address the needs of the neonate or infant, and this is an important future area of policy development. One study, however, presents a cautionary picture of how the increased medicalisation of childbirth that often accompanies improved access to maternal health services can halt progress in mortality reduction. A cohort study in Pelotas, Brazil found NMR had remained unchanged between 1990 and 2004, despite a marked drop in gestational age-specific mortality. This was because of a marked increase in preterm births, which are believed to be mostly as a result of early induction of labour or Caesarean section where gestation had been erroneously calculated by ultrasound scan (Barros *et al* 2005).

[22] Total health expenditure is the sum of public and private health expenditures as a ratio of total population. It covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation. Figures are from World Development Indicators, 2000. The WDIs are from the World Bank, and accessed through Economic and Social Data Service www.esds.ac.uk

[23] The Vietnam rate is based on the 2002 DHS, which was published after analysis for this chapter was completed.

While progress is slower than for older age groups, there is little evidence of widespread stagnation in neonatal mortality outside Sub-Saharan Africa. However, there appears to be considerable heterogeneity of progress. While there is a strong correlation between NMR and national per capita GDP, there are examples of good and poor progress among both the wealthier and the poorer countries within the sample group. Of particular interest are the group of countries that have achieved impressively low rates of neonatal mortality despite very limited resources. While obviously much of this success may be influenced by broader socio-economic factors such as high maternal literacy and levels of female empowerment, these countries establish the possibility of reaching relatively low levels of NMR with limited resources and provide interesting opportunities for health policy case studies.

The reversal of gains in neonatal health in sub-Saharan Africa is both concerning and unusual. While long-term patterns in child mortality have often historically been adversely affected by reversals within Europe, these have mostly affected older age groups (Reher and Perez-Moreda 1997). Neonatal mortality, while declining more slowly, has been resistant to adverse change and reversals have been modest. This is possibly because many of the sharp, short-term increases in child mortality are the result of epidemics of infectious diseases which have little impact on very young infants. The causes behind the poor progress in reducing both neonatal and later childhood deaths in Sub-Saharan Africa are likely to be many and complex. Economic decline and conflict are likely to have played a significant role, as is the increasing failure of heath systems and reduced access to quality services (Hanmer and White 1999, Simms *et al* 1998, both cited in Costello and White 2001). The impact of the HIV/AIDS epidemic on post-neonatal mortality is well established, but is less certain for the neonatal period. A systematic review and meta-analysis on the impact of HIV on perinatal outcomes (Brocklehurst and French 1998) found an increased risk of perinatal mortality. However, this seems to be mostly related to stillbirths and the slight increase detected in neonatal deaths was not statistically significant, possibly because of the small number of studies available. Ticconi *et al*. (2003) found infants of HIV-positive mothers were more likely to experience pre-term delivery, low and very low birth weight and low APGAR scores[24], all of which are

[24] An APGAR score is a summary measure of the condition of the newborn infant based on heart rate, respiratory effort, muscle tone, reflex irritability and colour. Each factor is given a score of 0, 1, or 2; the sum of these five values is the APGAR score, ranging from 0 to 10.

important underlying causes of neonatal mortality. There is also strong research to suggest that co-infection of HIV and malaria increases the risk of adverse pregnancy outcomes (ibid). Mahy (2003) also suggests that HIV can have indirect adverse impacts on child health though diverting scarce resources away from maternal and child health services and further weakening health systems. The impact of HIV on neonatal mortality is one which requires more research both in terms of the degree to which it increases neonatal deaths, and also the degree to which high prevalence of HIV may bring about changes in established patterns (*i.e.* affect the ratio of early to late neonatal deaths, or the ratio of stillbirths to early neonatal deaths).

5.3 Why is progress poorer in the neonatal period?

5.3.1 The role of economic growth

While improved child health services have undoubtedly contributed to the reduction of child mortality in some countries (*e.g.* Victora 2000), as previously discussed, studies suggest that socio-economic factors, including improvements in GDP have been important drivers of mortality reduction over the last few decades. If, as this study suggests, changes in GDP have less impact on neonatal than post-neonatal and early childhood mortality, this may partly explain why progress has been slower.

Further support for this hypothesis can be gained from the examination of historical data. As mentioned earlier, post-neonatal mortality in Europe fell steadily from the late 19th century (Sweden and the Netherlands) and from the early 20th century (Britain). There is little evidence that reductions in mortality during the first few decades of the 20th century in the UK were fuelled by improvements in health care provision, and most studies suggest that they resulted from a number of factors including rising standards of living and nutrition, reduced fertility and environmental health reform, such as provision of safe water and sanitation and improved housing (*e.g.* Loudon 1992, Werner and Sanders 1997). As mentioned previously, neonatal mortality started declining later, and progress did not accelerate until around the time of the Second World War. This coincided with greater use of antenatal care and wider access to, and improved quality of, professional midwifery services. These services had first been developed in the 1920s, but coverage was initially very poor: in 1930 only 27% of pregnant women in England and Wales attended antenatal clinic, though by 1938 this figure had risen to 61% (Winter 1979). The mid to late 1930s and early 1940s also brought improvements in the provision and training of midwives, quality of antenatal care, emergency obstetric and tertiary level care and access to antibiotics. While there is no evidence of a causative link, this pattern may suggest that the early decline often attributed to socio-economic improvements had a limited impact on neonatal mortality, and progress did not accelerate (particularly during the early neonatal period) until maternal health care services were implemented. Parallels could be drawn between UK historical data and current data from developing countries to suggest a similar phenomenon: neonatal mortality in many countries will continue to lag behind that of post-neonatal and early childhood mortality until appropriate and accessible health care is widely available.

If neonatal mortality is less affected by changes in GDP, it has implications for the extent to which increased wealth will reduce child mortality in different countries. For countries with lower overall child mortality, and therefore a higher proportion of neonatal deaths, the impact may be less than for countries with high overall mortality. Further study of these issues would be of value.

5.3.2 The role of healthcare in reducing neonatal mortality

If socio-economic factors are likely to have a lesser impact on reducing neonatal mortality than for older age groups, reducing deaths in newborns will be even more reliant on the development of effective health care services. However, there is widespread evidence that health services have failed to meet the need of the newborn. Bhutta (2000) argues that in South Asia most of the progress in reducing child mortality has been the result of global initiatives and vertical programmes, which fail to meet the needs of infants in the first month of life. Even child health strategies aimed at conditions that also affect the neonatal period may be limited in their impact because the method of delivery is inappropriate. One leading cause of death common in both neonatal and post-neonatal age groups is pneumonia and respiratory tract infections, but traditional, facility-based services may be inaccessible to the newborn as many cultures confine mother and baby to the home for 40 days after delivery. Health staff also often lack confidence or have been inadequately trained to treat very young babies.

As previously mentioned, the key channel for improving neonatal mortality is maternal health services, but the development of effective care in many parts of the world has to date often been hampered by limited resources, lack of political will and, until recent years, poorly defined strategies (Inter-Agency Group on Safe Motherhood 1997). Coverage for basic obstetric services remains a problem: in developing countries only 68% of women received any antenatal care[25] (WHO/Unicef 2004), and only 53% have their babies delivered by a skilled attendant (Unicef 2001). Even when services do exist quality is often poor, or social and financial barriers prevent women from making use of them (Adamu and Salihu 2000). AbouZahr and Wardlow (2001) found that while some countries had made significant progress in increasing the level of skilled attendance within the last decade, improvements tend to be greatest in countries that had initially high levels of coverage. While a few countries within this study's sample have shown impressive progress (*e.g.* Bolivia, Egypt, Indonesia, and Togo) (ibid.), the general picture is less positive. Within Sub-Saharan Africa few countries have made significant progress, and indeed some have shown decreasing coverage (*e.g.* Kenya, Madagascar, Tanzania, Mali and Zambia). Progress within India, Bangladesh, Philippines, Nepal, Pakistan and Haiti has been extremely poor or non-existent. While data is limited, there is also evidence to suggest that Caesarean section rates have changed little over the last decade, particularly where rates are lowest, and therefore presumably the need is greatest[26]. It is interesting to note that a number of the countries which appear to have made the most rapid progress in increasing coverage of skilled attendance at delivery are also those that have continued to make good progress in reducing neonatal mortality in the short term (*e.g.* Indonesia, Dominican Republic and Egypt). For others, however (*e.g.* Togo), reductions in neonatal mortality is less impressive. While a number of studies have examined the relationship between neonatal mortality and skilled attendance using cross-sectional data, none have used longitudinal data, and this would be an interesting study for the future. In particular it would be interesting to study whether the correlation between reduction in neonatal mortality and skilled attendance becomes stronger once skilled attendance reaches a particular level. It might be hypothesised that

[25] Defined as a least one visit with a skilled provider.
[26] This indicator is used as a proxy for the extent to which health facilities provide – and women can gain access to – emergency obstetric care. The indicator is somewhat controversial as Caesarean sections can sometimes be used without medical necessity. Unicef, WHO and UNFPA guidelines suggest 5% of deliveries are likely to medically require a caesarean section, but study of rates obviously cannot indicate whether those performed were carried out on women who needed them.

improvements from a very low baseline may still fail to reach the women who really need it, so impact is only seen once a particular level of access is reached.

In countries where efforts have been made to improve services, there has sometimes been a failure to capitalise on the possible synergies between maternal and neonatal health in service delivery. In some resource-poor countries there is a tendency to focus attention on skilled attendance and emergency obstetric care at delivery, which is believed to have the greatest impact on reducing maternal mortality (MacDonagh 2003). While this is vital to newborn health, impact would be greatest if maternal health services provided an evidence-based package of ante- and postnatal as well as intrapartum care. If synergies are to be maximised between maternal and neonatal health services a broader approach which addressed the mother's health and nutritional needs should be adopted rather than a narrow focus on maternal mortality reduction. Adequate attention should also be given to care of the neonate in professional training, and neonatal indicators should be included in monitoring and evaluation procedures (ibid).

6.0 Conclusion

While DHS estimates of neonatal mortality are subject to a number of both sampling and non-sampling errors, they are, for many countries, the only viable source of direct estimation of NMR. There is little evidence that inaccuracies are widespread or severe enough to render the data of no value, though sampling and non-sampling errors suggest they are most appropriate for identifying general trends rather than detailed information on specific countries, or family-level analysis of determinants.

Progress in the reducing neonatal deaths is consistently poorer than in post-neonatal infancy or early childhood. Although rates of progress both between and within regions show considerable variation, there are few signs of widespread stagnation in NMR outside sub-Saharan Africa. However, estimates from Sub-Saharan Africa suggest a picture of stagnation, with reversal of earlier gains made. This is particularly concerning as the highest rates of NMR are found within this region.

Neonatal mortality is strongly correlated with GDP per capita income, but there are wide variations in NMR between countries with similar levels of resources. This offers interesting opportunity for further work to identify and describe best practice at the national level.

This study demonstrates that the elasticities for GDP per capita and NMR are lower than for PNMR or ECMR when both cross-sectional and trend data is examined. This suggests that gains in child health resulting from economic growth will be less marked in the neonatal period. It has often been suggested that relatively limited progress in reducing neonatal mortality is a result of existing child health services failing to meet the needs of this vulnerable group. However, poorer progress in the neonatal than in the post-neonatal periods could also result from achievements in child mortality reduction being partially driven by a number of broader socio-economic factors which appear to beneficially influence the neonate to a lesser degree than older age groups. Both of these potential explanations reflect a need for the development of widespread maternal and child health services providing cost-effective, proven interventions to reduce neonatal mortality. Further analysis would be useful to look at the probable broader factors fuelling progress in countries that have had success in reducing child mortality, and the degree to which this will differentially affect neonates and older age groups.

CHAPTER 3: THE DETERMINANTS OF NEONATAL MORTALITY IN BANGLADESH

1.0 Introduction

While there is a significant body of evidence regarding the determinants of neonatal mortality, a number of important gaps in research still exist. In particular, knowledge on the impact of health care variables is limited, particularly when care at delivery is considered. This is partly due to methodological difficulties. In countries such as Bangladesh, where skilled care at delivery is rare, those who receive it are much more likely to have experienced complications that will impact on the probability of neonatal survival. This will undermine any attempt to directly compare outcomes from women who used or did not use skilled care at delivery, and indeed, previous bivariate analysis has actually found higher neonatal mortality for women delivering in institutions (Govindasamy *et al* 1993).

It could be hypothesised that this apparent increase in mortality masks marked differences in outcomes. While women who use delivery care only in emergencies are likely to have poor outcomes, those who plan their care and are "lower" risk may have lower neonatal mortality than their counterparts who deliver at home without skilled attendance. This study develops a concept of "higher" and "lower" risk for women using in-patient delivery care based on existing literature, and examines how the outcomes for these different groups differ in the hope of being able to demonstrate that some groups of women do experience lower neonatal mortality when using delivery care. The study will use multivariate analysis using composite variables to examine how maternal health and utilisation of care, as well as socio-economic status are associated with different neonatal outcomes for women giving birth in institutions. This will also highlight potential socio-economic inequities in outcomes. While there is a well-developed literature on the level of overall socio-economic inequalities in maternal and child mortality and use of services (which is described fully in Chapter 4), no previous studies have examined how outcomes vary specifically for women who experience skilled or institutional care at delivery. As the development of skilled attendance is the cornerstone of all efforts to reduce neonatal and maternal mortality, an understanding of these inequities and the pathways through which they occur is vital. The study also examines the impact of antenatal care and tetanus toxoid immunisation.

Few studies using multivariate analysis have compared determinants of neonatal mortality with post-neonatal mortality. Based on what is known from existing literature (see Chapter 1), it could be hypothesised that neonatal mortality is more likely to be influenced by biodemographic and health care variables, whereas post-neonatal mortality will have a stronger association with socio-economic factors. A greater understanding of these differences could shed light on why progress in reducing neonatal mortality is lagging in most countries. This study systematically compares the results of bivariate and multivariate analysis for the determinants of neonatal and post-neonatal mortality.

This study bases the development of the multivariate regression model on the conceptual framework for analysing neonatal mortality developed in Chapter 1. It includes a broader range of determinants than is commonly used in such analysis in an attempt to reduce the impact of confounding on the key variables of interest. Factors included: are socio-economic, maternal health and nutrition, biodemographic, environmental, behavioural, health service usage and biological. It provides an opportunity to test the theoretical model using empirical data. If both model and data is comprehensive, the regression should find that the distal variables are no longer significant once the proximal variables are added. This obviously assumes the data is of high quality, and potential problems with this are discussed in the methodology section.

The objectives of the study are to:

- Analyse the determinants of neonatal mortality in Bangladesh using multivariate logistic regression, and identify the factors most strongly associated with increased neonatal survival;
- Specifically examine the association between maternal health service variables and neonatal mortality in Bangladesh, and how this varies between different groups of women who are more or less likely to plan an institutional delivery;

- Examine whether "distal" socio-economic determinants associated with neonatal survival remain significant even after adjusting for a range of "proximal" determinants; and
- Compare the determinants of neonatal mortality with post-neonatal mortality.

The paper starts by briefly outlining the Bangladesh context, and why this country was chosen for the study. Section three presents a review of the literature on the determinants of place of delivery. Section four outlines the methodology used, and the results of the analysis are presented in section five. Section six concludes with a discussion on the relevance and policy implications of these findings.

2.0 <u>The Bangladesh context</u>

2.1 Economic progress

Bangladesh has shown impressive progress in many areas of development since gaining independence in 1971. Economic performance has been relatively strong in the past decade, with annual growth of gross domestic product (GDP) averaging 5% (World Bank 2004). However, Bangladesh remains one of Asia's poorest countries with a GDP per capita of $400 per annum (2003 estimate, Atlas method, ibid.), and a position of 138 in the Human Development Index ranking (out of a total of 177 countries) (UNDP 2002). It has an extremely high proportion of its population living in poverty, with approximately 36% of people surviving on less than one dollar a day (ibid.).

2.2 Progress in reducing child mortality

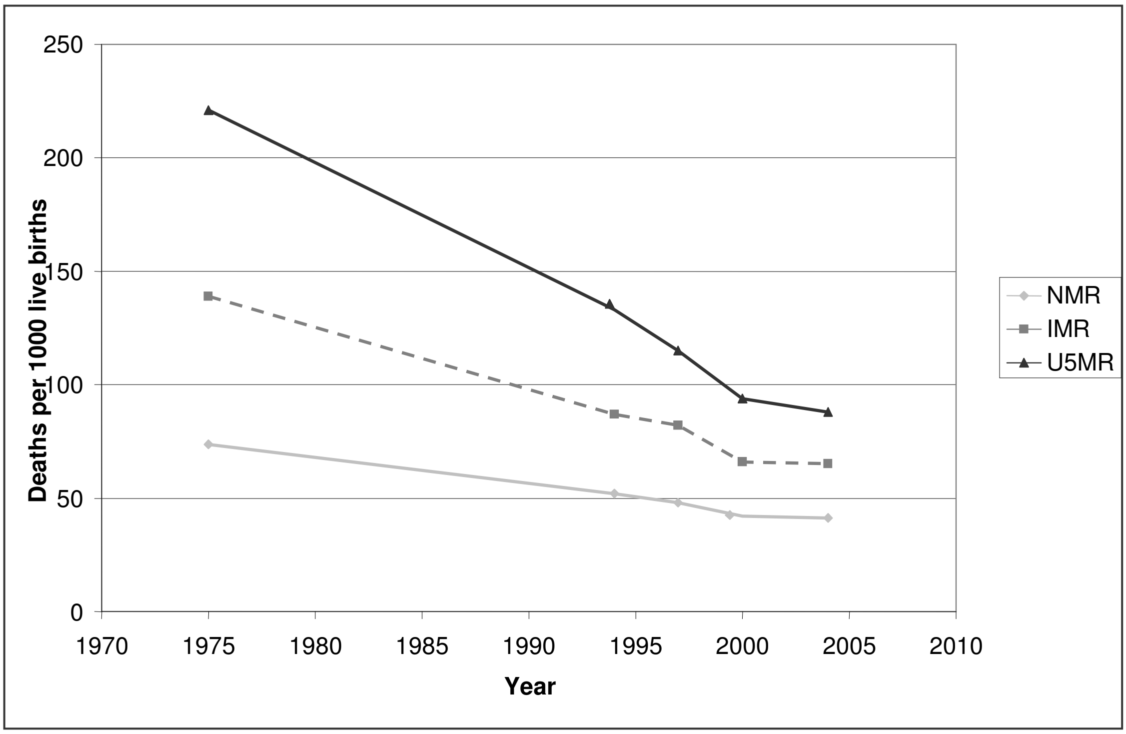
Mortality in children under five has declined over the last few decades from a rate of about 221 deaths per 1000 in 1975 to 88 per 1000 in 2004 (Rutstein 1983 and DHS estimates[27]). Neonatal mortality has also fallen sharply during the same period, from an estimated 74 to 41 per 1000 (ibid). Much of this decline is thought to be as a result of efforts to reduce neonatal

[27] http://www.measuredhs.com & www.statcompiler.com

tetanus through maternal immunisation (WHO 2001). While this is impressive, as in many countries neonatal mortality has tended to fall less sharply than deaths in older children, and recent years have seen comparatively limited progress (see Figure 17).

The current estimated rate of neonatal mortality is high when compared to countries with similar rates of GDP (see Chapter 2 of this thesis). It is the same or even greater than for many countries in Sub-Saharan Africa with much higher rates of overall child mortality: for example Tanzania and Cameroon both have child mortality rates of over 145 per 1000, but estimated NMRs of 40 and 37 per 1000, respectively. As a result, neonatal mortality now makes up nearly half of all deaths in Bangladesh in children under the age of five, and about two-thirds of infant deaths. Progress in neonatal deaths is now crucial if under-five mortality is to be further reduced and the Millennium Development Goals reached. This makes Bangladesh a particularly interesting focus for study, as it is hoped that by developing a clearer understanding of the determinants of newborn mortality it may be possible to shed light on the reasons for this relatively poor progress and recent stagnation. It may also be possible to draw more general conclusions about countries with similar profiles to Bangladesh: *i.e.* countries with high levels of poverty and high neonatal mortality where coverage of maternal health services is extremely low. The inclusion of analysis on the determinants of post-neonatal mortality, where progress has been greater, will also allow comparisons to be drawn, and may allow some tentative suggestions to be made on the factors underlying this differential progress.

Figure 17: Progress in reducing neonatal, infant and child mortality: Bangladesh 1974-2000



2.3 Reproductive and maternal health care

Over the last three decades Bangladesh has made considerable progress in some areas of reproductive health: for instance, nearly half of all couples are now using family planning methods, with a consequence that fertility has halved (NIPORT *et al* 2003). However, indicators of safe motherhood have not improved markedly: two thirds of pregnant women still do not receive any antenatal care, and 90% of women still deliver at home, almost all without skilled assistance (ibid). As maternal health services are the key channel of delivery for interventions to improve neonatal health, this is likely to have a profound effect on newborn mortality. Earlier attempts to improve mother and child health (MCH) generally focussed on community or intermediate level facilities. However, by the 1980s there was growing understanding of the need for access to facility-based emergency obstetric care if maternal (and early neonatal) mortality was to be reduced. Only limited progress has been made and during the 1990s there was little evidence of increased coverage and usage of services (ibid). If strong linkages are found between neonatal mortality and maternity service usage in this study, lack of progress in this area could partly explain the relatively limited reductions in newborn deaths. As well as the challenge of providing accessible quality services, there is also a recognised need to develop a greater understanding of, and response to, the cultural barriers that prevent women accessing the services they need.

2.4 Why base the study on Bangladesh data?

Bangladesh was an ideal study country for a number of methodological reasons. Firstly, three Demographic and Household Surveys (DHS) have been carried out in quick succession, and can be combined to provide a large sample size. These surveys included a number of key variables not always included in all surveys, including complications at time of delivery. Secondly, internal validity checks on the reporting of neonatal mortality (which are discussed later in the methodology section) suggest that the data on mortality is relatively reliable when compared to other countries. This is particularly important, as the analysis in Chapter 2 suggested that there is evidence of missing neonatal deaths in some countries. Finally there is a range of literature on health services in Bangladesh already in existence, which can be drawn on for interpretation of results and discussion.

3.0 Factors affecting the use of professional care at delivery

3.1 Socio-economic factors

There is a significant body of evidence (including a number of studies based in Bangladesh) examining how women choose their place of delivery or use of professional assistance in environments where home deliveries without skilled attendance are the norm. Studies across a number of countries have consistently shown that higher levels of education and greater assets increase the chances of women delivering in institutions with skilled care. One Bangladesh-based study using DHS data found that in rural areas women with 10 or more years of schooling were 29 times more likely to utilise a professional birth attendant than those with no education (Kabi 2007). Another study, which also used DHS data from Bangladesh, found that about 4% of women from the poorest quintile received professional care at delivery, compared to over 40% in the wealthiest quintile (Saha and Kabir 2006). An Indian-based study demonstrated that women with a high-school education were 15 times more likely to deliver with professional assistance than those with no education, and those classified as having a “low” standard of living were eight times less likely to have professional assistance as those with a “high” standard of living (Salama and Siddiqui 2006). Many studies also show marked differences between rural and urban dwellers, with urban dwellers having markedly higher use of professional delivery services (*e.g.* Saha and Kabir 2006). When all these factors are combined, massive differentials in service usage are demonstrated: a study in Bangladesh found that 86% of live births among the richest urban women with secondary or higher education were attended by a health professional, whereas only 2% of births were attended among the poorest rural women without formal education (Collin *et al* 2007).

3.2 Complications of pregnancy and childbirth

One of the most important factors in choice of place of delivery is the presence of complications. A number of studies using multivariate analysis have found the identification of complications either during pregnancy or actually at the time of labour (*e.g.* Paul and Rumsey 2002) as one of the main factors influencing birth in a modern facility with skilled care. A history of complications in previous pregnancies may also increase the likelihood of seeking skilled care at delivery for subsequent births (Majoko *et al* 2005). However, a recent study from Bangladesh highlights that there is still a strong economic gradient for seeking care even when complications are evident (Chowdhury *et al* 2007). It concludes that even when the need for skilled care is identified it is only the wealthier who can afford to seek appropriate care.

3.3 Use of antenatal services

Another key factor that is consistently shown by previous studies to improve the likelihood of women delivering in hospital / receiving professional delivery care is prior use of antenatal care (*e.g.* Mpembeni *et al* 2007, Mayhew *et al* 2008). Saha and Kabir (2006) found that woman who received at least one antenatal check-up were over three times more likely to receive professional care at delivery. However, some data exists that suggests that the outcomes from antenatal care are related to quality and quantity of antenatal visits received.

A Kenyan study (*e.g.* Magadi *et al* 2000) found that the average odds of home deliveries for pregnancies that received only one or two antenatal care visits were 4.5 times more than more than for pregnancies that had at least seven antenatal care visits. Some studies also suggest that other aspects of health care usage are determinants of professional care at delivery, *e.g.* use of family planning methods (ibid).

3.4 Other factors

Other studies have found a number of other factors influence use of professional attendance at birth or use of birthing facilities. Several studies have suggested that biodemographic factors may influence place of birth, but these are not necessarily consistent and may well be context-specific. For instance, Saha and Kabir's (2006) Bangladesh-based study found that first births were more likely to receive professional assistance than higher order births, whereas Magadi *et al* (2000) found the opposite. Age of mother is also found to be a determinant in some studies, although again this is not consistent. Saha and Kabir (2006) found that women over the age of 25 were significantly more likely to have a professional attendant, whereas other studies (*e.g.* Magadi *et al* 2000) found age was not significant in multivariate analysis. Several studies (*e.g.* ibid.) have also shown geographical access to be a key determinant of use of delivery services, but no Bangladesh-based studies have included this factor in the analysis (probably due to lack of data). Studies have also suggested that exposure to mass media increases the likelihood of women seeking skilled care at delivery (*e.g.* Saha and Kabir 2006).

4.0 <u>Methodology</u>

4.1 The data

The analysis is based on data collected from three DHS surveys in 1996/7, 1999/2000 and 2004. These are nationally representative household surveys providing a combined sample size of 29,036 households, with 19,929 children born to 14,689 mothers within the previous five years from the three surveys. Table 10 shows key characteristics from each survey. The data was collected in order to provide information on a wide range of monitoring and impact evaluation indicators in the areas of population, health and nutrition. In general the questions asked by the three surveys are identical and responses directly comparable. Full birth histories were collected from women aged between 15 and 49 years in sampled households, and data are comparable both over time and between countries. The datasets were supplied online from Macro International and analysis was carried out using STATA.

Table 10: Key characteristics of 1996/7 and 1999/00 Bangladesh DHS Surveys

Characteristic	1996/7	1999/00	2004
Number of households interviewed	8682	9854	10500
Number of women interviewed	9127	10544	11440
Number of children included (born in last 5 years before survey)	6189	6832	6908
Neonatal mortality rate* (SEs in brackets)	48.4 (2.9)	42.0 (2.8)	41.4 (2.9)
Post-neonatal mortality rate* (SEs in brackets)	33.8 (2.6)	24.3 (1.9)	23.8 (2.0)
Early Childhood mortality rate* (SEs in brackets)	36.5 (2.8)	29.7 (2.4)	23.9 (2.4)
Response rates (for women)	97.8	96.9	98.6

Source: Mitra *et al* 1997 and Mitra *et al*. 2000
* The mortality rates differ slightly from those in the cross tabulations carried out in this study as they are true probabilities calculated according to the life table approach. Those calculated for the cross tabulations are simple calculations of the number of deaths per 1000 within the sample.

4.2 Statistical methods

The data was initially examined using simple cross tabulations and chi-squared tests to establish bivariate relationships between individual variables and outcomes. These tables provide a useful picture of associations between specific variables and neonatal mortality. While this is valuable in identifying general patterns such as socio-economic inequalities *etc.*, interpretation is difficult as many of the factors affecting neonatal mortality are closely correlated. For instance, any apparent association between use of health services and rates of mortality could be a result of direct benefit from the care received, or could merely reflect the characteristics of the women who use them (wealthier, more educated *etc.*). Multivariate analysis offers the opportunity of examining the impact of specific variables while adjusting for the effect of other correlated factors. Multivariate logistic regression was therefore carried out in order to better establish the impact of specific factors while adjusting for others, using the standard logistic regression equation:

$$\prod = B_0+B_1X_{1+} B_2X_{2+...}B_pX_p$$

where

$\prod$ is the log odds or logit function;

B_0 is the constant;

B_1 - B_p are the variable coefficients and

X_1-X_P are the explanatory variables.

Binomial logistic regression was chosen as the outcome variables (died/survived) are dichotomous.

As there may be significant correlations for many unobservable characteristics between births to the same mother, complete independence of observations cannot be assumed. One way of addressing the problem is to only take one birth from each mother for the sample, but this has the obvious disadvantage of reducing the sample size. Instead, the data are clustered using the mother's identity number in order to adjust the standard errors (14,606 clusters). Clustering is also likely to occur at other levels (*e.g.* community), but as STATA cannot cluster by more than one variable this has not been addressed in the methodology. One way around this problem would be to use multilevel modelling, but as this study is not attempting to measure variations within or between clusters, this was deemed unnecessary. It was also considered that, particularly in the case of the neonate, clustering for communities would not be nearly as important as clustering related to the mother, so it is unlikely to make a major impact on standard errors. In order to acknowledge that standard errors may be slightly wider than calculated, little weight is given to results at 5% significance.

DHS produces sampling weights for each case in order to adjust for the differences in probability of selection between cases in a sample. It is not uncommon for samples to be selected to expand the number of cases in certain areas or subgroups where estimates are needed. This most commonly leads to an over representation of urban dwellers, which was the case in the Bangladesh surveys. Weights were applied to the bivariate analysis, but for the multivariate analysis weighting was not found to make any difference, probably because region and quintile by urban/rural are included among the variables.

One of the major problems with this data is that the children within the sample could have been born at any time within the five years prior to the survey, and the period that the child has been at risk will vary greatly. This means that those born within a month of the survey will not have been exposed to the full period of potential neonatal mortality, and those born within a year of the survey will not be exposed to the full post-neonatal period. This was addressed by removing those children who have not been fully exposed to the relevant period from the analysis for the bivariate analysis and logistic regression[28].

4.3 Outcome variables

Outcomes used are neonatal mortality and post-neonatal mortality. Data on these outcome variables was deruved from a series of questions asked to women about each birth they had experienced, including month and year of the infant's birth and, if no longer living, age at death (in days if under a month old, in months if over 1 month but less than two years old and in years if over two years old).

A number of potential difficulties exist with these data which have been discussed fully in Chapter 2. In particular, under-reporting on neonatal deaths can be an issue, particularly when the deaths occur in the first week of life. In the data used, the percentage of neonatal deaths occurring in the first six days is reasonably high for all three surveys compared to countries with similar NMR (62% in 1996/7, 70% in 1999/2000 and 73% in 2004) suggesting there is relatively little under-reporting of early neonatal deaths. The somewhat lower figures in the 1996/7 survey may well be due to marked heaping at seven days in that survey, or may be due to a higher overall neonatal mortality rate (as mortality rates decrease, the overall proportion of mortality in the first week increases).

[28] While DHS surveys should not include children born within a month of the interview, in a number of cases these children were found to have been included. Because of the problem of age heaping (described later) infants have been removed from the neonatal equation who were born one month or less before the survey (rather than only those less than 28 days). For the post-neonatal work infants who were born less than 13 months before the survey were removed for the same reason.

A further potential data quality issue is raised by the use of the mother as a primary sampling unit. If a mother has died, then the child will be automatically excluded from the sample, and this problem has also been extensively discussed in Chapter 2. However, even in Bangladesh where maternal mortality is high, the death of a mother is a relatively rare event compared with a neonatal death. Bangladesh has a maternal mortality ratio of 380 per 100,000 live births, (*i.e.* approximately one fifteenth of the NMR) (WHO 2005) so this is unlikely to have a major effect on the population as a whole. However, maternal deaths are likely to be concentrated within certain "high risk" subgroups, and could cause underestimation of neonatal mortality for some of the disaggregated analysis.

Another concern is that of sample size. While the standard errors for neonatal mortality for each survey are quite small (see Table 10) much of the analysis in this study involves examining rates between population subgroups, where confidence intervals will be relatively larger. While appending three consecutive datasets creates a fairly large sample size, this still means that many of the findings need to be interpreted with caution.

4.4 Explanatory variables

4.4.1 Socio-economic factors

A number of possible distal socio-economic variables are available from the DHS which are relevant for this study. Data are available on highest educational attainment of the mother, as well as whether the family live in an urban or rural environment. While DHS do not provide direct information on income or expenditure, they do collect information on a range of assets, dwelling characteristics and basic services (*e.g.* access to water and electricity) which have been used to develop a statistically weighted asset-based index. The method uses a principal component technique to determine weights (Filmer and Pritchett 2001). These data are provided by Macro International both as a continuous index and divided into asset quintiles. Studies have indicated a mixed picture in relation to whether such indices are effective measures of economic status, but the general findings appear to support their use as a valid measure for ranking the wealth of populations (Falkingham and Namazie 2002). However, Houweling *et al* (2003) found that the choice of assets (which varies between countries) greatly affected the wealth differentials for health outcomes. In particular, addition of amenities such as water source and electricity are controversial as they could be a reflection of public provision rather than household assets.

Further concerns have also been raised as to whether such indices are able to effectively capture the differing assets of urban and rural populations, or are able to recognise that the meaning of specific assets may differ between contexts. For instance, piped water may indicate improved wealth in a rural setting, but may reflect public provision for slum dwellings in urban areas. Recommendations have been made for greater efforts to more accurately quantify assets pertinent to rural communities, *e.g.* land ownership and livestock (ibid). In response to this issue, and to address unexpected results in the bivariate analysis that will be discussed later, asset scores and quintiles were recalculated separately for urban and rural populations. The same methodology and variables were used as in the original DHS: a principal component analysis (PCA) was run on the selected variables for urban and rural dwellers separately, and the individual score estimated for each case, which became the asset score. Quintiles were then calculated separately for urban and rural dwellers (see Appendix 7 for further details of methodology). The only difference from the original DHS technique was that missing data was substituted using the mode rather than the mean for the individual variable as this was thought more appropriate for binary variables.

There was some concern about including the water and sanitation variables in the PCA for the asset index, as they are included separately in the regression equation (see following section). It was decided to leave them in as it provided a more thorough basis for the asset index calculation, but when the quintiles were calculated with them omitted, it made no difference to the multivariate analysis.

One of the potential problems with socio-economic variables such as wealth indices and urban/rural residence is that they reflect the mother's status at the time of the survey, not when the child was born (which may have been up to five years previously). Many parts of Bangladesh experienced major economic transition and high levels of internal migration during the 1990s, which may mean that wealth as derived from the asset index or place of residence has changed during that time. While asset indices are probably more stable over time than estimates of income, changes between the time of birth and survey would lead to the underestimation of socio-economic effects within the model. As information is available on length of residence and previous place of residence it was possible to examine whether the association between mortality and urban/rural dwelling is affected when families who have moved relatively recently are excluded. In addition it was possible to examine whether the association between assets and mortality is greater in infants born nearer the survey date (with consequently less opportunity for assets to change) than those born at the beginning of the period (this information is included in Appendix 8).

Analysis contained in Appendix 8 (which will be discussed later in the results section of this chapter) shows that for neonatal mortality, there is very little variation in the asset index for urban and rural quintiles 1-4. Because of this, and also small sample sizes in some key categories (*e.g.* women in the poorest quintiles who have institutional deliveries), quintiles 1-4 are grouped together for the multiviariate analysis (and some of the bivariate analysis). This results in four asset quintile groups: rural quintiles 1-4, urban quintiles 1-4, rural quintile 5 and urban quintile 5.

4.4.2 Environmental variables

Variables for drinking water source and sanitation facilities were included as these are proximal variables for child survival. As mentioned earlier these are already included as part of a much wider range of factors in the asset index, but the decision was made to include them in their own right as they are such a key determinant of child health. Ideally the model would include some indication of distance from water supply, which would act as a proxy for water quantity (which is often thought to be a more important determinant than water quality); however, this information was not available. These variables may also have changed between the risk period and data collection as services become upgraded within communities or by individual households.

Unfortunately no question exists in the two earlier Bangladesh surveys for type of cooking facilities, so it is not possible to include a variable for increased indoor air pollution from the combustion of biomass fuel.

4.4.3 Biodemographic variables

Biodemographic variables used were birth order, preceding birth interval and mother's age at time of birth. The variables for birth order and preceding birth interval were combined for the multiple regression models in order to avoid the problem of multicolinearity (*i.e.* first birth order infants will all have missing data on preceding birth interval).

4.4.4 Maternal health and nutrition

The study includes data on maternal recall of complications in pregnancy, as these are an important cause of neonatal mortality. Data is available for all three surveys on four complications around the time of the birth: long labour (more than 12 hours); excessive bleeding that was so much that the mother feared it was life-threatening; a high fever with bad-smelling vaginal discharge; and convulsions. These four symptoms are designed to represent four of the major causes of maternal death: obstructed labour, postpartum haemorrhage, sepsis and eclampsia. However, the responses to these questions will again be strongly influenced by maternal perception rather than any objective measure. Studies indicate that while self reporting of symptoms may be useful in determining the gross burden of maternal morbidity, they are rarely able to diagnose conditions or provide accurate data on incidence (Fortney and Smith 1999). Ronsmans *et al* (1997) suggests that self reported morbidity tends to lead to overestimation, which seems to be the case with the Bangladesh DHS data: many of the levels of reported symptoms seem higher than would be expected from the population, though it is difficult to compare across studies because of differing definitions. While 13% of women reported excessive bleeding in the Bangladesh DHS data, a community study in rural India found an incidence of primary post-partum haemorrhage of only 3% (Bang *et al* 2004). Over 3% reported the symptoms of eclampsia, which is normally considered a rare disease. While no estimate could be found for direct comparison, the global estimate for pre-eclampsia (a much more common and less severe condition that usually precedes eclampsia) is only 3% (AbouZahr 2003).

It is worth noting that the DHS data does show a marked decrease in the percentage of complications reported between the 1996/7 survey and the 2004 survey, suggesting that data may be becoming more accurate. For example 31% of women reported prolonged labour in 1996/7 compared with 17% in 2004, and this pattern is repeated for all four complications. In addition, some expected patterns can also be demonstrated: for example it would be predicted that a greater number of primigravidae[29] would experience prolonged labour, and this is the case: the complication was reported for 30% of first births as opposed to about 20% of second and third order births, and this difference is significant at the 1% level. Risk of eclampsia is also associated with increased maternal age, and this again can be demonstrated in the data (although the difference is not statistically significant at the 5% level): 4.7% of women over 40 reported the symptoms of eclampsia, compared to 3.2% in the 21-30 age group. This may suggest that while the data is undoubtedly flawed to some degree, the complications reported do at least have some association with their medically determined occurrence.

A further limitation of the DHS data is that it only provides information of four possible complications, whereas there are a number of others which can severely affect the survival chances of the infant (*e.g.* premature labour, breech or other malpresentation of the foetus, antepartum haemorrhage). The 2004 DHS includes information on foot or hand presentation (two particularly serious albeit rare malpresentations), but while this has been included in the bivariate analysis it has been excluded in the composite "complication" variable used in the multivariate analysis in the interests of consistency (only a very small number of women reported it). Some consideration was given as to whether to include all or only some of these complications, as while some (*e.g.* convulsions and prolonged labour) have a direct causal effect on neonatal mortality the other two have a less direct link. However, they are likely to be influenced by underlying causes which impact on both maternal and neonatal health: sepsis is more likely if the mother experienced a reproductive tract infection in pregnancy or has an unclean delivery, and postpartum bleeding is often associated with a long or difficult labour. In addition, severe maternal morbidity is likely to significantly affect the mother's ability to care for her newborn in the first weeks of life. The decision to include all four was confirmed by bivariate analysis which found a significant association between all four complications and increased neonatal mortality.

While the DHS data provide information on maternal body mass index, this was thought not to be a good variable to use as an indicator of maternal nutrition as it reflects nutritional status

[29] A woman experiencing her first pregnancy.

at the time of the survey rather than when the child was in-utero. Instead maternal height is used as an indication of stunting, as this is only likely to change in very young women who have increased in stature since their infant was born. Stunting tends to reflect severe malnutrition in childhood, and is linked to poor pregnancy outcomes as a result of increased incidence of obstructed labour and low birth weight (although little evidence exists on direct impact on increased neonatal mortality). While the definition of stunting varies, a criteria of less than 145cm is frequently used (Mitra *et al* 2001), and has been adopted for this study. However, it must be recognised that this indicator does not encompass the whole range of possible maternal nutritional factors that affect neonatal health outcomes.

4.4.5 Family care practices and child nutrition

One of the major data limitations of DHS data is lack of information on family care factors relevant to neonatal health. Breastfeeding is almost universal in the first month of life so is not an appropriate variable. Infants not breastfed are likely to be those who are either ill or premature at birth, and the small sample that was not breastfed had an extremely high rate of mortality. The only other data collected of use is that of timing of initiation of breastfeeding. However, this is likely to be prone to recall errors from the mother as it is unrealistic to expect accurate estimates. Ideally it would have been preferable to include whether or not the mother gave her infant colostrum, as this may be less prone to error, but unfortunately data on this was only collected for two of the three surveys included (and again, those babies who did not receive it were likely to be those who were weak or unwell at birth). As the only possible variable, time of initiation of breastfeeding was included in the bivariate but was removed from the multivariate analysis because of its endogeneity.

4.4.6 Health care utilisation variables

Relevant health service variables included were antenatal care (ANC) and two or more doses of tetanus toxoid (TT) immunisation received by the mother during pregnancy, which should provide adequate protection to her and the baby. The antenatal variable collects data from all providers, be they trained professionals, semi-skilled or traditional birth attendant/other. While there is some agreement that providers of antenatal care do not need to fulfil the criteria of skilled attendants (*e.g.* WHO 2003), they do require a set of skills which may not be held by all category of providers in the survey. For this reason, the data have been recoded for this study to include only those who received antenatal care from a doctor or nurse/midwife, or semi-skilled cadre employed within the government health system such as family welfare visitors[30]. There is also an important limitation with the information on tetanus toxoid, as it only records doses received during a specific pregnancy. It is possible that multiparous women may not have received TT because they have already received a total of four doses during previous pregnancies, which will confer lifetime immunity.

Unfortunately, information on TT immunisation and antenatal care was only collected for the last birth in the 1999/2000 survey, so a relatively large proportion of this data is missing. A dummy variable was created for the multivariate analysis for missing data. As a result, the two variables were combined to avoid colinearity during the multivariate analysis to create five categories: ANC with two or more TT, ANC with less than two TT, no ANC but two or more TT, no ANC and less than two TT; and data on ANC and TT missing. Simplified categories for antenatal care are therefore used (*i.e.* one or more visits, or no visits) which means that factors such as number of visits cannot be examined in more detail in the multivariate analysis.

Ideally one of the most interesting variables to look at would be whether or not the birth is attended by a skilled attendant – one of the most important goals for improving both maternal and neonatal survival (WHO 2004a). However, it is not possible to ascertain from DHS data whether the birth attendant meets the agreed definition of a skilled attendant: *i.e.*

> "*.. an accredited health professional – such as a midwife, doctor or nurse – who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth and the immediate postnatal period and in the identification, management and referral of complications in women and newborns*" (WHO 2004a).

It is possible to ascertain whether the mother reports that a birth was attended by a doctor or nurse/midwife. However, there can be no certainty that these personnel fit the definition of a skilled birth attendant or, as the classification is made on the somewhat subjective judgement

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[30] Only a very small percentage of cases (2.8% of all women reporting they had received ANC) reported receiving ANC from another provider (TBA or other unspecified). Women who received antenatal care from these unskilled providers were recoded as having had no ANC.

of the mother, whether they are in fact professionally qualified. Bangladesh has developed several cadres of what can best be described as "semi-skilled" attendants, such as family welfare visitors (FWVs). Both these cadres have some training in providing ante-natal care and normal delivery but are not skilled in obstetric first aid so do not fulfil the international criteria for a skilled attendant (WHO SEA Office 2005). There is likely to be considerable confusion among women about the qualifications and roles of these different cadres, which makes analysis problematic. It was decided that these semi-skilled cadres would be treated separately in the bivariate analysis. Because of classification difficulties the term "professional" rather than "skilled" attendant will be used in recognition that not all personnel included in this category will fulfil WHO criteria for a skilled attendant.

The types of country-specific attendant recorded over the three surveys are not completely consistent, and in some cases numbers are extremely small. For these reasons the attendants were categorised into five groups:

- Professional (doctor, nurse, midwife)
- Semi-skilled (*e.g.* family welfare visitor (FWV), Medical assistant)
- Informal (*e.g.* traditional birth attendant, trained traditional birth attendant[31])
- Family/friend
- No-one

Place of delivery is a somewhat more objective measure, and is therefore the variable used to define type of delivery in the multivariate analysis. However, institutional delivery cannot be assumed to be synonymous with professional attendance. There is a very strong correlation between institutional delivery and attendance by professional personnel, but a small number of women who delivered at home (4.2%) reported having received a professional attendant. In addition about 3% of women who delivered in government institutions and less than 1% who delivered in private/NGO institutions believed they were cared for by someone other than a professional attendant. While projects within Bangladesh do exist which provide

[31] There was some uncertainty as to whether the category of "trained traditional birth attendant" should be included in semi-skilled or informal as it is unclear to what kind of worker it refers. Training of TBAs played a role in the Bangladesh safe motherhood strategy until 1998, when it was abandoned because it had not significantly affected the maternal mortality rate. As the concept of a "trained TBA" cannot be clearly defined, it was decided to put them it in the "informal" section. About 5% of women were delivered by this group.

midwives for home deliveries (*e.g.* at Matlab) most strategies at the community level rely on semi-skilled cadres, which may suggest that some of these women have misreported their type of attendant. Because of the small percentage of women delivering in institutions, data was recoded to include only two categories: government institutions and private/NGO institutions. NGO institutions were placed with private on the basis that in general they charge a fee, whereas government institutions should at least in principal be free (although it is recognised that this distinction is not accurate in practice).

Caesarean section is an important indicator of access to emergency obstetric care. Unfortunately data on this is only available for the latter two surveys, so while it is included as a variable in the bivariate analysis, it in not included in the multivariate analysis.

4.4.7 Biological variables

Variables for sex and multiple births are both included. Birthweight was not included as maternal estimates of size based on five categories were available for only one survey. In addition there are suggestions that maternal estimates may not be reliable (Channon 2004) and, as discussed earlier, birth weight is itself an outcome and may be part of the causal mechanism by which distal and proximal variables affect mortality.

4.5 The development of composite variables

Unfortunately it is not possible to clearly identify those who planned their institutional delivery from the survey data, but as outlined earlier in this chapter there are is a body of literature (both from studies in Bangladesh and other countries) that enable us to identify characteristics of women who would be more or less likely to do so. These include whether or not a woman reports complications, use of antenatal care and socio-economic status. Composite variables have been developed which identify subgroups based on these factors and place of delivery[32].

[32] An alternative approach to the development of composite variables would have been to fit interactions in the models between the various care and complication variables. However, composite variables are explicit expressions of interactions and easier to interpret.

4.5.1 Reporting of complications/place of delivery

In developing countries women might only attend hospital for delivery once complications have become evident. Obviously these women are more likely to experience poor outcomes, particularly if there has been delay in seeking care. In order to identify this group of women and to examine how reported complications affect outcomes, a composite variable was developed which grouped women into six categories based on their place of delivery coupled with whether or not they reported a complication (*e.g.* home with complication; home with no complication; government institution with complication; government institution without complication; private/NGO institution with complication; and private/NGO without complication).

4.5.2 Antenatal care/place of delivery

A variable with six categories was constructed based on whether a woman had received any ANC, and where she had delivered (*i.e.* no ANC and home; no ANC and government institution; no ANC and NGO/private institution; some ANC and home; some ANC and government institution; and some ANC and NGO/private institution). However, as discussed earlier in the chapter, some data exists that suggests that the outcomes from antenatal care are related to quantity of antenatal visits received (Magadi *et al* 2000). WHO (2003) recommends that women should have four or more visits commencing not later than the end of the 4th month of pregnancy. This recommendation was incorporated into a further set of composite "recommended care" variables so women were grouped by whether they had received the suggested level of antenatal care and where they had given birth (*i.e.* recommended ANC and home; recommended ANC and government institution; recommended ANC and NGO/private institution; not recommended ANC and home; not recommended ANC and government institution; and not recommended ANC and NGO/private institution) [33].

[33] Before this variable was developed it was considered whether antenatal care may be endogenous: *i.e.* women who experienced complications in pregnancy were more likely to have a greater number of antenatal visits. However, there is no correlation between reported complications and number of antenatal visits, and bivariate analysis showed an inverse relationship between neonatal mortality and number of antenatal visits, which seems to suggest this is not a major issue.

4.5.3 Socio-economic factors/place of delivery

Other factors that influence whether a woman has a planned delivery are maternal education and wealth (Chowdhury *et al* 2007, Magadi *et al* 2000, Salama and Siddiqui 2006). As well as an indicator of service use pattern, the analysis of institutional outcomes disaggregated by level of maternal education and asset quintile is important as an indicator of equity: it is well known that poor women experience worse neonatal outcomes generally, but it could be hypothesised that this difference is even greater when only institutional delivery is examined, as they are less likely to plan their deliveries and may wait longer before seeking care. A composite variable has been developed for the multivariate analysis to define subgroups of women based on educational level/place of delivery and asset quintile/place of delivery. The fact that asset quintiles are disaggregated by place of residence means that the urban/rural factor, which is also an important determinant of place of delivery, is also included. A composite variable with 12 categories is developed for asset quintile and place of delivery (as previously outlined quintiles 1-4 for both urban and rural are grouped together), and a further one with nine categories for maternal education and place of delivery.

5.0 <u>Results</u>

In total, 19,929 births occurred within five years prior to the survey dates. Those children not exposed to the full period of risk were removed for both bivariate and multivariate analysis. Because of problems with heaping, infants born less than one month (as opposed to 28 days) before the survey were removed for the analysis of neonatal mortality, and less than 13 months for the analysis of post-neonatal mortality. 19,321 had been exposed to the full neonatal period and 14,514 to the full post-neonatal period. Of these, 829 (4.3%) died in the neonatal period, and 435 (2.9%) died in the post-neonatal period.

5.1 Descriptive statistics and bivariate analysis

I have developed a comprehensive analysis of the association between the proximal, distal and health care variables included in this study and neonatal/post-neonatal mortality based on cross tabulations with chi-squared tests. However, in the interests of brevity, the full results for socio-economic, environmental and biological factors are reported in Appendix 8, with just a brief synopsis of findings presented in this section. The main focus of this section is on the health care variables. There is particular emphasis on place of delivery, and a number of subgroups are identified to see how associations between neonatal mortality institutional deliveries differs between groups that are perceived as "higher" and "lower" risk. This provides the basis for the development of composite variables in the multivariate analysis.

5.1.1 Brief outline of socio-cross tabulations between socio-economic variables and neonatal/post-neonatal mortality

Initial analysis did not find the expected monotonic relationship between neonatal mortality and wealth quintile (although the poorest quintile had higher mortality than the wealthiest quintile). It was thought this may be because the methodology used by Macro International creates disparities in the way that wealth is captured for urban and rural dwellers, and therefore asset quintiles were developed separately for the two groups (see Appendix 8 for full details). This resulted in some improvement in the pattern between wealth and neonatal mortality, but it was still not monotonic, probably due to lack of variance in asset scores for most of the population (especially in rural areas). For post-neonatal mortality there was a marked gradient in mortality for rich and poor when the original Macro-calculated quintiles were examined, and also when quintiles were recalculated for urban/rural dwellers, but again the relationship was not monotonic.

Clear gradients were found when the relationship between maternal education and neonatal/post-neonatal mortality were examined. Women who had received no education experienced over twice the rates of mortality as women who had received secondary/further education for both age groups.

There was no marked difference in the rate of neonatal or post-neonatal deaths between urban and rural dwellers. This is somewhat surprising, as child mortality is normally higher in rural areas, and further analysis to examine this can be found in Appendix 8.

5.1.2 Environmental variables

Environmental variables showed expected patterns for both neonatal and post-neonatal mortality. Mortality for children of families with no sanitation facilities was higher than for those who had access to a latrine, and mortality was even lower for families with flush toilets. Families with access to piped water had lower mortality than those using water from a well, who in turn had lower mortality than those using open water sources.

5.1.3 Biodemographic variables

Biodemographic variables showed expected patterns. Birth order demonstrated a "U" shaped relationship for neonatal mortality, with high rates of mortality for first births. Mortality began to increase again for births of order five and above. Post-neonatal mortality also showed an increase for birth orders five and above, but not for first births. Short preceding birth intervals (less than 24 months) are associated with greater mortality in both neonatal and post-neonatal age-groups. Neonatal mortality is greater in mothers under 20 years of age, and both neonatal and post-neonatal mortality increases markedly in mothers over the age of 40.

5.1.4 Biological factors

Cross tabulation for biological factors also showed expected patterns with extremely high neonatal and post-neonatal mortality for twins. Males had significantly higher mortality than females when neonatal mortality was examined, but not for post-neonatal mortality.

5.2 Maternal health and health care variables

5.2.1 Maternal health and nutrition

A total of 32% of women reported that they had experienced one of the four recorded complications during pregnancy, delivery or in the immediate post-partum period (prolonged labour, convulsions, excessive bleeding or fever and discharge). Those who reported one or more of these complications were significantly more likely to experience a neonatal death; newborns of mothers reporting complications experienced an NMR of 57 per 1000, as opposed to 37 per 1000 in newborns of mothers who did not report complications. Table 11 shows a breakdown of neonatal mortality by individual complication, and as can be seen all complications are associated with significantly increased NMR, but not PNMR. Data on whether the infant was a hand or foot presentation were only collected for the 2004 survey, but shows extremely high NMR.

Maternal height of less than 145cm (which is an indication of stunting, Table 12) was also associated with significantly increased mortality for NMR and PNMR, but if the missing data category is removed it is no longer significant for PNMR.

Table 11: Bivariate analysis of mortality by reported maternal complications

Complication	% of total sample†	NMR	PNMR
High fever/discharge	11.7	64.0**	41.5
Convulsions	3.6	84.1**	39.7
Prolonged labour	27.2	56.6**	29.3
Excessive bleeding	14.3	66.6**	32.3
No complication	68.2	36.0	30.7
Foot or hand presentation (data from 2004 only)	0.48	204.3**	0.0

** denotes chi-squared significant at the 1% level for NMR between women experiencing the complication and women who did not.
† Sample does not add up to 100% as some women reported more than one complication

Table 12: Bivariate analysis of mortality by maternal height

	% of total sample	NMR	PNMR
Maternal height		**	**
Less than 145cm	16.6	55.6	35.7
More than 145cm	81.8	39.0	27.1
Data missing	1.6	105.0	65.6
Total	100	42.9	29.1

** denotes chi-squared significant at the 1% level (however not for PNMR when missing data category removed)

5.2.2 Tetanus toxoid and antenatal care

A total of 53% of women reported receiving two or more doses of tetanus toxoid before or during pregnancy, which would have afforded adequate protection to both herself and the baby. A cross tabulation of tetanus toxoid immunisation and neonatal mortality (see Table 13) showed women who had received two or more doses had significantly lower neonatal mortality, and this was also the case for PNMR.

Table 13: Bivariate analysis of mortality by antenatal care and tetanus toxoid (TT) immunisation

	% of total sample	NMR	PNMR
Tetanus toxoid (TT) immunisation		**	**
0 or one TT	31.4	43.7	35.2
2 or more TT	52.6	26.0	18.3
Data missing/not known	16.1	95.5	50.5
Number of antenatal visits		**	**
0	51.5	38.1	30.7
1	8.8	27.3	19.1
2	13.8	25.4	15.3
3	6.2	18.4	4.5
4 or more	3.7	17.1	5.7
Data missing	16.1	95.2	50.4
Timing of first antenatal visit by trimester		**	
First trimester	38.4†	15.9	10.4
Second trimester	41.0†	26.1	16.0
Third trimester	20.6†	33.2	12.5

** Denotes chi-squared tests were significant at the 1% (including when missing data category excluded)
† Percentages are of all those women receiving antenatal care, not sample as a whole

Only about 32% of the women received some antenatal care. The NMR and PNMR were inversely proportional to the number of antenatal visits a woman received. In addition, earlier initiation of antenatal care was association with decreased NMR: those who attended their first antenatal appointment in the first trimester were nearly half as likely to experience a neonatal death as those who attended their first appointment in the third trimester. No pattern was ascertained for PNMR and timing of first antenatal visit.

Mortality was very high in the groups where data on antenatal care and TT were missing which suggests that women in this group possess characteristics that differ from the wider sample.

5.2.3 Attendance at delivery

Table 14 shows the attendants women reported at delivery. For the purposes of this table types of attendants have been recoded from the original DHS categories into:

- Professional (doctor, nurse, midwife)
- Semi-skilled (Family Welfare Visitor, medical assistant)
- Informal (Traditional/trained traditional birth attendant)
- Family/Friend and
- No-one.

Many respondents listed more than one attendant, but only the highest qualified attendant has been included (*i.e.* if a woman reported she was attended by a semi-skilled worker and a traditional birth attendant, only the semi-skilled worker was included in the analysis). As can be seen, the majority of women were cared for during labour by informal attendants (68%), with the next largest group attended by a friend or relative (17%). Only about 13% were delivered by a professional attendant. The group who received a semi-skilled attendant was extremely small (0.4%) despite being a key component of the Bangladesh Safe Motherhood Strategy. However, it is possible that some trained attendants may have been misclassified by respondents, and were, in fact from the semi-skilled cadres. The lowest levels of mortality were associated with semi-skilled attendants for both NMR and PNMR (though as previously mentioned sample size is extremely small for this group), and mortality rates were very high among women who were attended by no-one. There is little difference in NMR rates for babies delivered by professional attendants, informal attendants or family, but there appears to be lower mortality for PNMR among those who received professional or semi-skilled attendance. While the chi-squared statistic is significant at the 1% level for both NMR and PNMR, this is driven by the group attended by no-one, and the other/missing category, where mortality is extremely high (although numbers are very small) and the difference is not significant if this group is removed.

Table 14: Bivariate analysis of mortality by birth attendant

Type of attendant	%	NMR	PNMR
		**	**
Professional (doctor or nurse)	12.8	46.6	19.0
Semi-skilled	0.4	24.1	0.0
Informal (traditional birth attendant/untrained doctor)	67.7	40.0	28.2
Friend/relative	17.4	47.4	36.0
No-one	1.2	73.0	53.5
Other/missing	0.4	116.7	101.1
Total	100	42.9	29.6

** Chi-squared tests were significant at the 1% level for association between birth attendant and NMR/PNMR (however difference not significant if missing data category removed)

5.2.4 Place of delivery

Table 15 shows a breakdown of neonatal mortality by place of delivery. As can be seen, the vast majority of women (91%) gave birth at home. There appears to be a higher rate of mortality in neonates born in a government institution (57.2 per 1000 compared with 41.3 per 1000 for those born at home), and this difference is significant at the 5% but not the 1% level. Mortality for PNMR is particularly low among women who gave birth in private and NGO institutions, and multivariate analysis will determine if this reflects the fact that this group are likely to be socio-economically advantaged.

Table 15: Bivariate analysis of mortality by place of delivery[34]

Place of delivery	**% total sample**	**NMR** *	**PNMR** **
Home, own or other	91.1	41.3	29.6
Government institutions	5.5	57.2	24.0
Private/NGO institutions	3.4	43.6	8.6
Total	**100**	**42.9**	**28.6**

[34] Standard errors are presented rather than chi-squared for some of the subgroups in this table as this allows comparison between as well as within groups, and makes interpretation easier. PNMR is not calculated for the subgroups because of the very small number of deaths.

5.3 Bivariate analysis of "high" and "low" risk factors to be used as composite variables

As previously explained, this study aims to identify women who would be expected to have "high" and "low" risk factors for delivery in institutions based on socio-economic status, maternal health and health care utilisation variables. Table 16 shows neonatal mortality by place of delivery disaggregated by residence and socio-economic status. When the sample is disaggregated by place of residence, there is little difference in mortality by place of delivery for those in urban areas. However, a very mixed picture is demonstrated for rural areas, where NMR for home deliveries is 38 per 1000 compared with 86 per 1000 for births in government hospitals. There is little difference between the two groups for home births, but those in rural areas have much greater NMR for government deliveries than those in urban areas (86 compared with 36 deaths per 1000), and this is significant at the 1% level. There is no significant difference in mortality for private/NGO births compared with home births for either rural or urban dwellers.

While the sample sizes are very small, this disparity appears to be very much dependent on economic status (Table 16): for women in rural wealth quintile 1 (*i.e.* the poorest), the NMR for women delivered in a government institution was extremely high (190 per 1000). It was low for urban quintile 1, but the sample size was very small. Because of the very small number of women in quintile 1 delivering in hospital, the cross tabulations were recalculated with quintiles 1-4 grouped together (although still separated by urban/rural). When mortality for women in quintiles 1-4 is examined, it would still appear that the increase in mortality between those delivering at home and in an institution is much greater in rural than urban areas: women in rural quintiles 1-4 who deliver in government institutions have an NMR of 130 deaths per 1000 compared to and NMR of 50 for women in the same quintile from urban areas (delivery at home produced fairly similar levels of NMR for these women). There was no significant increase in mortality between home and government hospital deliveries for urban quintiles 1-4. This would suggest that place of residence is an important mitigating factor in determining the influence of socio-economic status on women's outcomes from institutional deliveries.

When difference in outcomes between women from quintiles 1-4 and 5 for different places of delivery is examined, the difference in NMR is only significant for rural women when home births are considered. When births in government institutions are considered the same pattern is seen: while there is a marked difference in NMR for urban women in quintiles 1-4 and 5, it is not significant. However, there is a vast difference for women living in rural areas: women in quintiles 1-4 have an NMR of 130 compared to only 22 in quintile 5, and this is significant at the 1% level. Differences between mortality for the two quintile groups are marked when private/NGO institutions are considered, but not statistically significant because of large standard errors.

Figure 18 shows NMR by educational level among those who delivered at a government institution and those who delivered at home, and again a similar pattern can be seen, with much greater differences between educational levels for those who delivered in an institution than those who delivered at home.

Table 16: Bivariate analysis of mortality by place of delivery and socio-economic grouping

Place of delivery disaggregated by subgroup	Sample size (actual numbers)	NMR
Home birth, urban only	3401	38.2 (SE 3.2)
Government institution, urban only	614	35.8 (SE 7.5)
Private/NGO birth, urban only	442	45.2 (SE 9.9)
Home birth, rural only	14109	42.1 (SE 1.7)
Government institution, rural only	452	86.3 (SE 13.2)
Private/NGO birth, rural only	200	40.0 (SE 13.8)
Home birth, wealth quintile 1 only (urban/rural)	880/3010	44.6/47.9 (SE 7.0/4.0)
Government institution, wealth quintile 1 only (urban/rural)	38/42	27.0/190.5 (SE 27.0/61.3)
Private/NGO institution, wealth quintile 1 only (urban/rural)	3/6	NA/333.3 (SE NA/211)
Home birth, wealth quintile 5 only (urban/rural)	365/2677	27.9/33.6 (SE 8.6/3.5)
Government institution, wealth quintile 5 only (urban/rural)	245/229	12.5/50.7 (SE 7.2/13.3)
Private/NGO institution, wealth quintile 5 only (urban/rural)	295/138	35.3/22.3 (SE 11.0/12.8)
Home birth, wealth quintiles 1-4 (urban/rural)	3042/11522	39.4/44.0 (SE 3.5/1.9)
Government institution, wealth quintiles 1-4 (urban/rural)	394/231	50.5/129.9 (SE 11.3/8.6)
Private/NGO institution, wealth quintiles 1-4 (urban/rural)	158/66	63.2/75.8 (SE 19.4/32.8)
Home birth, no maternal education	8888	46.0 (SE 3.3)
Government institution, no maternal education	199	92.8 (SE 20.9)
Private/NGO institution, no maternal education	33	133.3 (SE 63.1)
Home birth, secondary or further education	338	33.8 (SE 3.0)
Government institution, secondary or further education	231	39.7 (SE 7.8)
Private/NGO institution, secondary or further education	247	34.6 (SE 8.0)

Figure 18: Neonatal mortality by mother's education and place of delivery

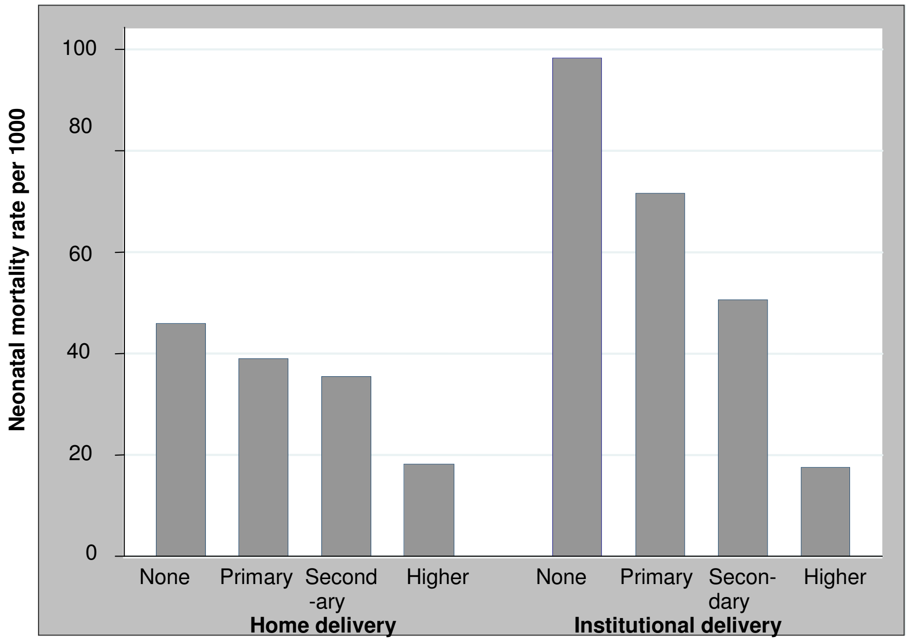


Table 16 shows the neonatal mortality outcomes differentiated by those who either received or did not receive "recommended antenatal care" (*i.e.* four or more visits commencing before the 5th month) by place of birth. While numbers are very small, mortality rates are very low for women who received the recommended level of antenatal care for both institutional and home deliveries. Again the difference in mortality is vast between those who received and did not receive recommended antenatal care and gave birth in an institution: of women who gave birth in a government institution, the neonatal mortality rate was 12 per 1000 among women who received recommended levels of care, and 87 per 1000 among those who did not. The difference is slightly less for deliveries in private/NGO institutions, and considerably less for those who gave birth at home. While confidence intervals are large, the differences between those who have and have not received recommended antenatal care are significant at the 1% level for government institution and home births and at the 5% level for private/NGO births.

Table 17: Bivariate analysis of neonatal mortality by place of delivery and maternal health care and reported complications

Place of delivery disaggregated by subgroup	Sample size (actual numbers)	NMR
Government institution, received "recommended antenatal care"	356	12.4 (SE 5.9)
Government institution, did not receive "recommended antenatal care"	742	86.7 (SE 10.5)
Private/NGO institution, received "recommended antenatal care"	358	18.3 (SE 7.2)
Private/NGO institution, did not receive "recommended antenatal care"	310	71.9 (SE 15.0)
Home delivery, received "recommended antenatal care"	783	12.8 (SE 4.1)
Home delivery, did not receive "recommended antenatal care"	17275	41.6 (SE 1.5)
Government institution, reported complication	491	99.1 (SE 13.7)
Government institution, no reported complication	607	35.3 (SE 7.6)
Private/NGO institution, reported complication	248	58.1 (SE 15.2)
Private/NGO institution, no reported complication	420	35.9 (SE 9.2)
Home delivery, reported complication	5734	53.1 (SE 3.0)
Home delivery no reported complication	12324	34.7 (SE 1.6)
	% total sample	
Birth by Caesarean section (data for 1999/00 and 2004 only)	3.6	40.2 (SE 9.0)
Birth not by Caesarean Section (data for 1999/00 and 2004 only)	96.3	40.3 (SE 1.7)

Table 17 also shows neonatal mortality by place of delivery differentiated by whether a woman reports a complication or not. Again, the differences in neonatal mortality between those who did and did not report complications are extremely high for those who gave birth in government institutions, and despite large standard errors the difference is significant at the 1% level. Differences are also significant for those who gave birth at home, but while still marked, differences are for births in private/NGO facilities and are not significant.

Only 3.5% of births were by Caesarean section. There was no difference in neonatal mortality between those who did or did not delivery by Caesarean section.

Bivariate analysis also shows a strong correlation between reported complications, ANC and maternal education for women who delivered in institutions. Among those who gave birth in institutions, more educated women were less likely to report complications and more likely to have received either any or recommended levels of ANC (Table 18). The converse was true for women with no education: well over half reported complications, and nearly a third had received no antenatal care. This is important when considering the composite variables based on these subgroups to be used in the multivariate regression, as they will be correlated.

Table 18: Bivariate analysis showing correlation between maternal education and reported complications/antenatal care for women giving birth in institutions only (both government and private/NGO institutions)

	% reporting complications	**% no antenatal care**	**% "recommended" AN care**	**Neonatal mortality rate**
Level of education	**	**	**	**
No education	58.1	31.9	11.2	98
Primary education	56.8	18.7	18.1	71
Primary education	39.6	5.6	43.5	51
Further education	17.2	2.1	66.7	18

** Chi-squared shows differences significant at 1% level

5.4 Summary of key results for bivariate analysis

- Maternal complications are associated with a significant increase in neonatal but not post-neonatal mortality. Maternal height below 145cm (*i.e.* stunting) is associated with increased mortality for both age groups.

- Two or more TT immunisations and antenatal care are associated with reduced mortality for both neonatal and post-neonatal mortality. There is a negative monotonic relationship between the number of antenatal visits attended and mortality in both age groups. Time of commencement of antenatal care only appears to be associated with neonatal mortality, with early commencement associated with the lowest levels of mortality.

- There is no significant difference for either neonatal or post-neonatal mortality based on type of birth attendant. Women who delivered in government institutions had significantly higher neonatal mortality than those who delivered at home or in private/NGO institutions. Women who delivered in private/NGO institutions had lower post-neonatal mortality than those who delivered at home or in a government institution.

- Differentials for mortality by socio-economic group (*e.g.* asset quintile and maternal education), are much greater for women who deliver in institutions than for those who give birth at home. Differentials between women who do or do not receive antenatal care and those who do or do not report complications are also greater for institutional than home deliveries.

5.5 Results of logistic regression for neonatal mortality

5.5.1 The development of the basic model

The strategy for progressive inclusion was based on the conceptual framework developed and described in Chapter 1. The distal determinants - socio-political and socio-economic variables - were added first. The proximal variables were added based on the groupings defined in the empirical model. Health service variables were added towards the end, in order to see whether these mitigated the impact from either proximal or distal determinants.

- Model (1) contains year of survey and socio-economic variables only
- Model (2) adds in environmental variables

- Model (3) adds in biodemographic variables and maternal health and nutrition variables
- Model (4) adds in variables for maternal health care
- Model (5) adds in biological variables.

Biological variables were added last. Results are reports as odds ratios (ORs), and as the data is clustered around the mother's ID, robust standard errors are produced and reported.

All five models can be seen in Appendix 9, with significant variables summarised in Table 19. In model 1 (*i.e.* year of survey and socio-economic variables) only Sylhet district, rural asset quintile 5 and further education are significant. The variable for Sylhet remains significant for all models, as did the one for further education. When environmental variables (model 2) were added the variable for rural asset quintile 5 was no longer significant, but possession of a flush toilet was significantly associated with improved odds ratio for survival.

When variables for biodemographic determinants are added (model 3), first birth order and short birth interval (less than 18 months) are associated with increased mortality, with large coefficients. These remain highly significant in the final model (odds ratios of 1.8 and 1.5, respectively). Maternal age is not significant in any of the models despite showing a clear pattern in the bivariate analysis. Self reported maternal complications were significant when added, with a marked increase in odds ratio for mortality. Stature of less that 145cm was also significantly associated with increased neonatal mortality and remains so in the final model, which highlights the importance of a life cycle approach in reducing neonatal mortality. Stunting is usually the result of nutritional deficiency in young children, and therefore improving the health and nutrition of females at all stages of their growth and development will impact in the long term on birth outcomes.

The addition of variables for health service use (model 4) resulted in a marked increase in pseudo r-squared. The mother having received two or more doses of TT either with or without receiving ANC was found to be a significant association with improved survival: the decrease in odds ratio for those who had receive both was particularly large (odds ratio 0.43).

Receiving ANC without TT did not appear to have a significant association, but there was a large increase in the odds ratio of mortality for the group where the data on AN care and TT were missing. Delivery in a government or private/NGO institution were both significantly associated with increased odds ratios for mortality.

Table 19: Multivariate analysis for neonatal mortality (only variables that are significant in model 5 are included: see Appendix 9 for full model)

Variables	(1) *Socio-political /socio-economic*	(2) *Environment-al added*	(3) *Bio-demographic/ maternal health added*	(4) *Maternal health care added*	(5) *Biological added*
Year of survey					
1996 (ref)	1.0	1.0	1.0	1.0	1.0
2004	0.85	0.83	0.99	0.62	0.64
	(0.08)	(0.08)	(0.10)	(0.07)**	(0.07)**
2000	0.884	0.890	0.970	0.569	0.598
	(0.082)	(0.083)	(0.093)	(0.063)**	(0.066)**
State					
Barisal (ref)	1.0	1.0	1.0	1.0	1.0
Sylhet	1.78	1.80	1.69	1.47	1.45
	(0.28)**	(0.28)**	(0.27)**	(0.24)*	(0.24)*
Maternal education					
No education (ref)	1.0	1.0	1.0	1.0	1.0
Further education	0.54	0.58	0.44	0.44	0.45
	(0.17)*	(0.18)	(0.14)*	(0.16)*	(0.16)*
Birth order					
Second or subsequent			1.0	1.0	1.0
First birth			1.74	1.64	1.84
			(0.22)**	(0.22)**	(0.25)**
Preceding birth interval					
24-35 months (ref)			1.0	1.0	1.0
Less than 24 months			1.51	1.47	1.49
			(0.20)**	(0.20)**	(0.21)**
Maternal height					
Over 145cm (ref)			1.0	1.0	1.0
Less than 145cm			1.31	1.30	1.29
			(0.12)**	(0.12)**	(0.13)**
Maternal complication					
No complication (ref)			1.0	1.0	1.0
Reported complication			1.56	1.67	1.60
			(0.12)**	(0.14)**	(0.13)**
Tetanus toxoid /ANC					
No ANC/TT (ref)				1.0	1.0
TT only				0.61	0.61
				(0.07)**	(0.07)**
TT and ANC				0.43	0.45
				(0.06)**	(0.06)**
Data missing				2.65	2.33
				(0.30)**	(0.27)**
Place of delivery					
Home (ref)				1.0	1.0
Government facility				1.96	1.70
				(0.33)**	(0.30)**
Private/NGO facility				2.09	1.77
				(0.48)**	(0.46)*
Child is a twin					7.08
					(1.39)**

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

When the biological variables are added in model 5, the increased OR for twins is particularly large. The variable for the infant being male narrowly misses having a significant negative impact on survival.

The following variables are significant in model 5 (the full model).

- Year of survey: decreased odds ratio for survey years 2004 and 2000
- District: increased odds ratio for Sylhet
- Education: decreased odds ratio for further education
- Birth order: increased odds ratio for first birth order
- Birth interval: increased mortality for birth interval less than 24 months
- Height below 145 cm: increased odds ratio
- Reported complication: increased odds ratio
- AN Care/Tetanus Toxoid: decreased odds ratio for mothers who had received two or more TT immunisations or TT and ANC. Increased odds ratios when data is missing
- Place of delivery: increased OR for mothers delivering in government or private/NGO institutions
- Biological: greatly increased OR for twins.

This presents a picture of neonatal mortality being strongly influenced by a wide range of variables: biodemographic, maternal health, health care and biological. In addition several "distal" variables (year of survey, education and district) remain significant, suggesting that the model does not effectively capture all proximal variables.

5.5.2 The addition of composite variables

Models 6-10 (Appendix 10) add a number of composite variables to model 5. When the composite variables were added in, their component variables were removed (unlike when interactions are used, in which case component variables are included). The composite variables were constructed by creating every possible combination of the two component variables as previously described in the methodology section. One of these categories is then used as a reference category. As previously discussed the quintiles were divided into four groups only: urban and rural quintiles 1-4 and urban and rural quintiles 5. This resulted in the creation of 12 composite variables for quintile/place of delivery. Composite variables were also created for place of delivery/any ANC and place of delivery/"recommended" ANC, which was as previously outlined based on the WHO definition of recommended ANC: four or more visits commencing before the fifth month of pregnancy. A composite variable was also developed for reported maternal complication/place of delivery.

- Model (6) adds in composite variables for place of delivery/maternal education
- Model (7) adds in composite variables for place of delivery/wealth quintile
- Model (8) adds composite variables for place of delivery/ANC
- Model (9) adds composite variables for place of delivery/recommended level of ANC
- Model (10) adds composite variables for place of delivery/complication

A summary of the results for the composite variables is found in Table 20.

When a composite variable for education/place of delivery was added, no education and delivery in a government facility showed a very marked increase in OR (1.9) which was significant at the 5% level (when no education/home delivery was the reference variable). Increase in OR are also found for the composite variables for both urban and rural quintiles 1-4 (*i.e.* the poorer four quartiles) giving birth in government or private/NGO institutions, but are only statistically significant for rural quintile 1-4, government delivery, and urban quintile 1-4, private/NGO delivery (when reference category is rural quintile 1-4, home delivery).

Table 20: Multivariate analysis for neonatal mortality (composite variables only: see Appendix 10 for full model)

COMPOSITE VARIABLES	Maternal education/ place of delivery	Quintiles/ place of delivery	ANC /place of delivery	Recommended level of ANC/place of delivery	Complications/place of delivery
Maternal education/place of delivery					
Ref: No education, home delivery					
No education, government facility	1.92 (0.58)*				
No education, private/NGO facility	4.20 (3.21)				
Primary education, home delivery	0.90 (0.09)				
Primary education, government facility	1.51 (0.46)				
primary education, NGO/private facility	1.61 (0.78)				
Secondary or further education, home delivery	0.93 (0.13)				
Secondary or further education, government facility	1.27 (0.35)				
Secondary or further education, private/NGO facility	1.23 (0.40)				
Quintiles/place of delivery					
Ref: rural 1-4, home					
Urban 1-4, home		1.00 (0.12)			
Urban 1-4, government		1.54 (0.42)			
Urban 1-4, NGO/private		2.24 (0.92)*			
Rural 1-4, government		2.83 (0.67)**			
Rural 1-4, NGO/private		1.53 (1.00)			
Rural 5, home		0.62 (0.26)			
Rural 5, government		0.35 (0.26)			
Rural 5, NGO/private		0.85 (0.39)			
Urban 5, home delivery		0.83 (0.12)			
Urban 5, government		0.49 (0.24)			
Urban 5, NGO/private		0.52 0.39)			

COMPOSITE VARIABLES	Maternal education/ place of delivery	Quintiles/ place of delivery	ANC /place of delivery	Recommended level of ANC/place of delivery	Complicat-ions/place of delivery
Recommended level of ANC, place of delivery					
Ref: Not recommended ANC, home delivery					
Not recommended ANC, delivery in government institution				1.67 (0.30)**	
Not recommended ANC, delivery in private/NGO institution				1.77 (0.52)*	
Recommended ANC, home delivery				0.62 (0.20)	
Recommended ANC, delivery in government institution				0.60 (0.32)	
Recommended ANC, delivery in private/NGO institution				0.99 (0.45)	
ANC, Place of delivery					
Ref: Home delivery, no ANC					
Delivery in Government institution, no ANC			3.00 (0.81)**		
Delivery in private/ NGO institution, no ANC			1.51 (1.20)		
Home delivery, some ANC			0.63 (0.08)**		
Delivery in government institution, some ANC			0.80 (0.23)		
Delivery in a private/NGO institution, some ANC			1.01 (0.37)		
Complications/place of delivery					
Ref: no complication, home delivery					
No complication, government institution					1.03 (0.32)
No complication, delivery in private/NGO institution					1.89 (0.63)
Complication, home delivery					1.44 (0.15)**
Complication, government institution					3.04 (0.61)**
Complication, private/NGO institution					2.61 (0.91)**

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

A very marked increase in OR (3.0) was found for women delivering in government institutions with no prior ANC, but there was no significant increase for delivery in a private/NGO institution. Marked increases in OR for mortality were also found for women giving birth in either government or private/NGO institutions who hadn't received recommended ANC (*i.e.* at least four visits commencing before the fifth month of pregnancy).

When a composite variable for complication/place of delivery is added, there is a marked increase for women reporting complications for all places of delivery (reference category is home delivery with no complication). However the increase in OR is much greater for women who give birth in government or private/NGO institutions (3.0 and 2.6 respectively) than for those at home (1.4).

This analysis clearly shows that socio-economic, health care and maternal health factors influence how outcomes differ by place of delivery. In particular, lack of antenatal care and reported maternal complications are associated with very marked rises in OR for women giving birth in institutions. It is, however, interesting to note that while these regressions are able to identify groups of women who experience increased neonatal mortality, it is not possible to identify any group that experiences reduced mortality from institutional delivery. A number of groups of women who have delivered in institutions including urban and rural women in quintile 5 and women who have received recommended ANC demonstrate a marked but insignificant decrease. Larger sample sizes could mean that these differences reach significance. However, it must be viewed in the context of the reference variable *i.e.* women giving birth in institutions in quintile 5 are being compared to home birth in quintiles 1-4. In practice changing the reference category makes little difference for the composite variable asset quintile/place of delivery. If the reference category for the regression is changed to women giving birth at home/rural wealth quintile 5, women from rural quintile 5 who give birth in government institutions still have a marked but not significant reduction in OR of 0.32 for birth in a government institution and 0.82 for a private/NGO institution. If urban quintile 5/home birth is used as the reference category women from urban quintile 5 also have a marked but non-significant decrease in OR of 0.48 for government institution deliveries and 0.50 for private/NGO institutional deliveries. A similar situation is found if the reference variable is changed for recommended ANC/place of delivery. If the reference variable is changed to received recommended ANC/home delivery, women who received recommended ANC and delivered in government institutions still had a non-significant reduction in OR of 0.56. This may indeed suggest that some groups of women do experience benefit from institutional delivery, but samples are too small to be able to prove this.

The changes in OR for all composite variables are demonstrated visually in Figures 19-23. However, they must be interpreted with caution as it must be remembered that many of the ORs are not significantly different from the reference category. It is quite striking that increases in OR for mothers giving birth in institutions are very much focussed in the "higher risk" groups (*e.g.* lower socio-economic groups, no ANC and reported complications). It is also noticeable that while there is normally a disparity between ORs for "higher" and "lower" risk groups for home delivery, this is normally much smaller than for births at government and private/NGO facilities. It is also worth noting that there is no discernible pattern for differences between government and private/NGO facilities: for some groups of women the odds ratio of mortality for giving birth in government facilities is highest, whereas for other groups of women the converse is true.

Figure 19: Graph showing odds ratios for neonatal mortality for composite variable education/place of delivery

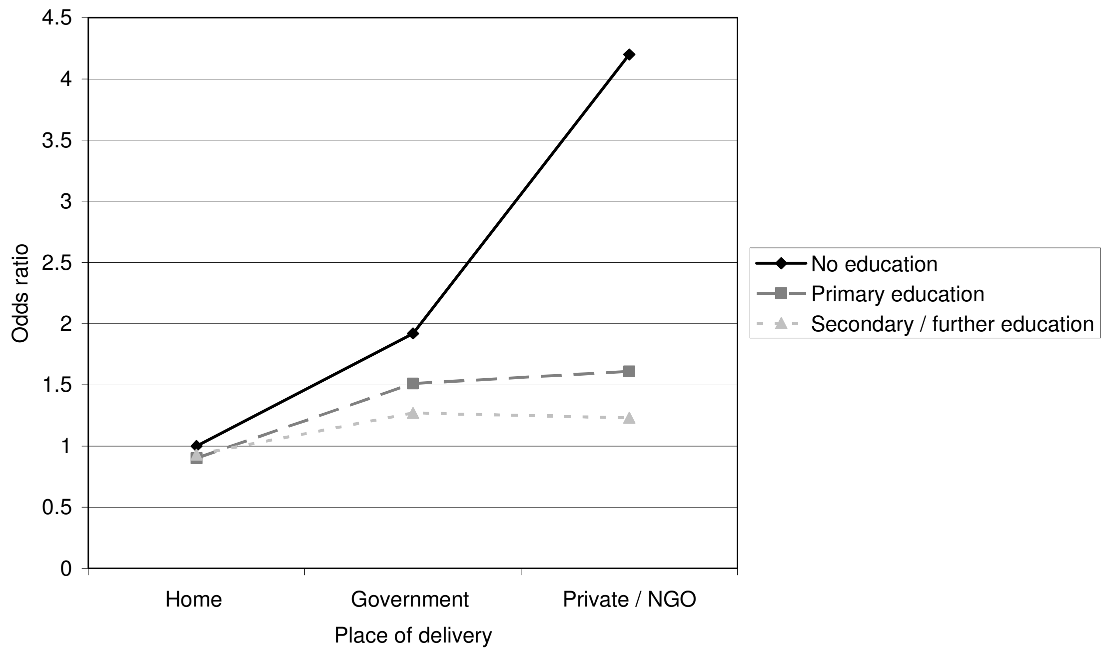


Figure 20: Graph showing odds ratios for neonatal mortality for composite variable wealth quintile/place of delivery

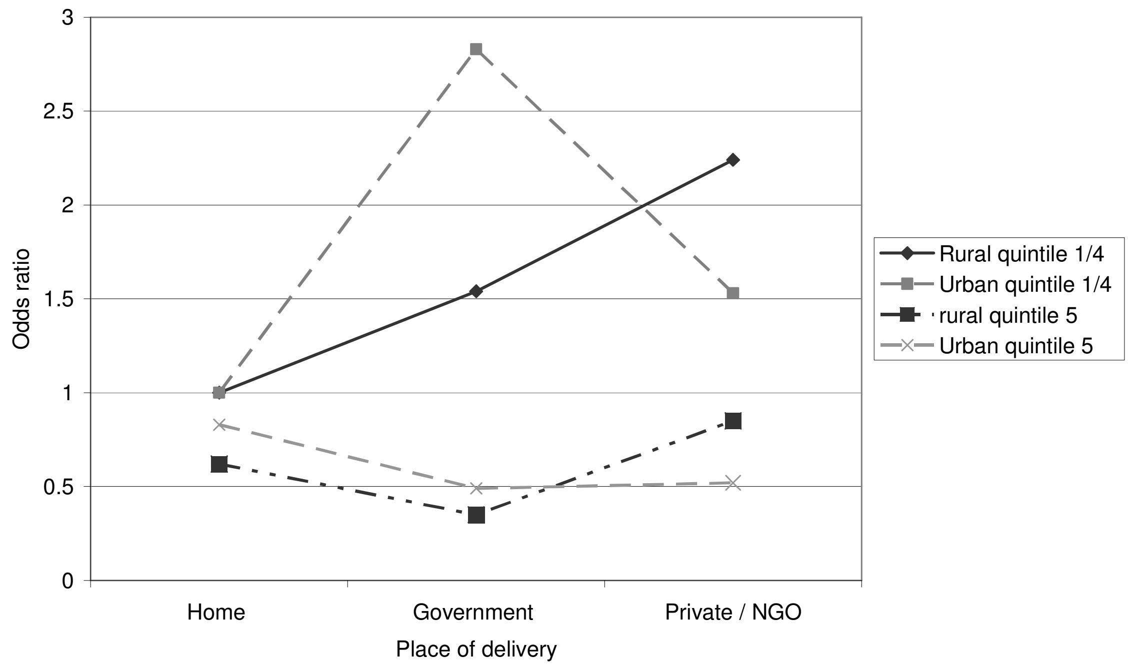


Figure 21: Graph showing odds ratios for neonatal mortality for composite ANC /place of delivery

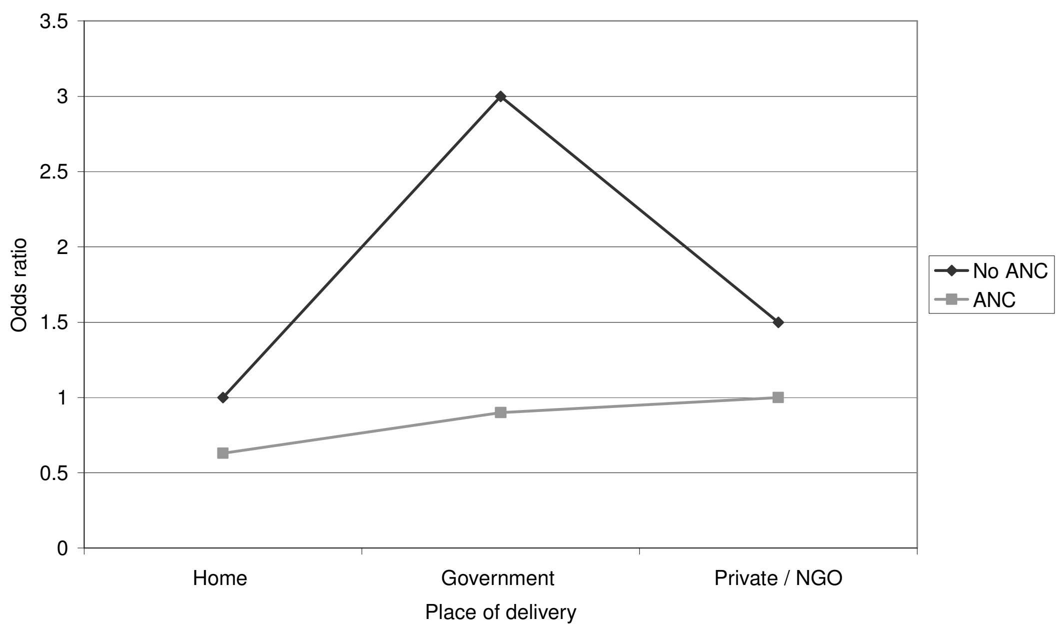


Figure 22: Graph showing odds ratios for neonatal mortality for composite variable recommended ANC/place of delivery

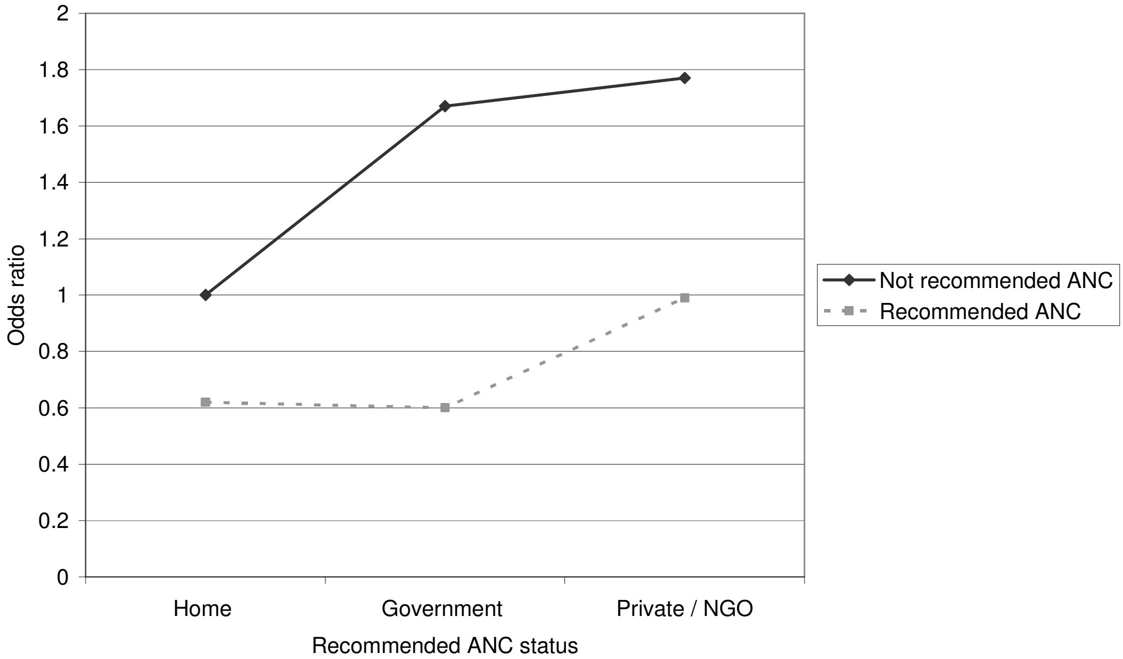
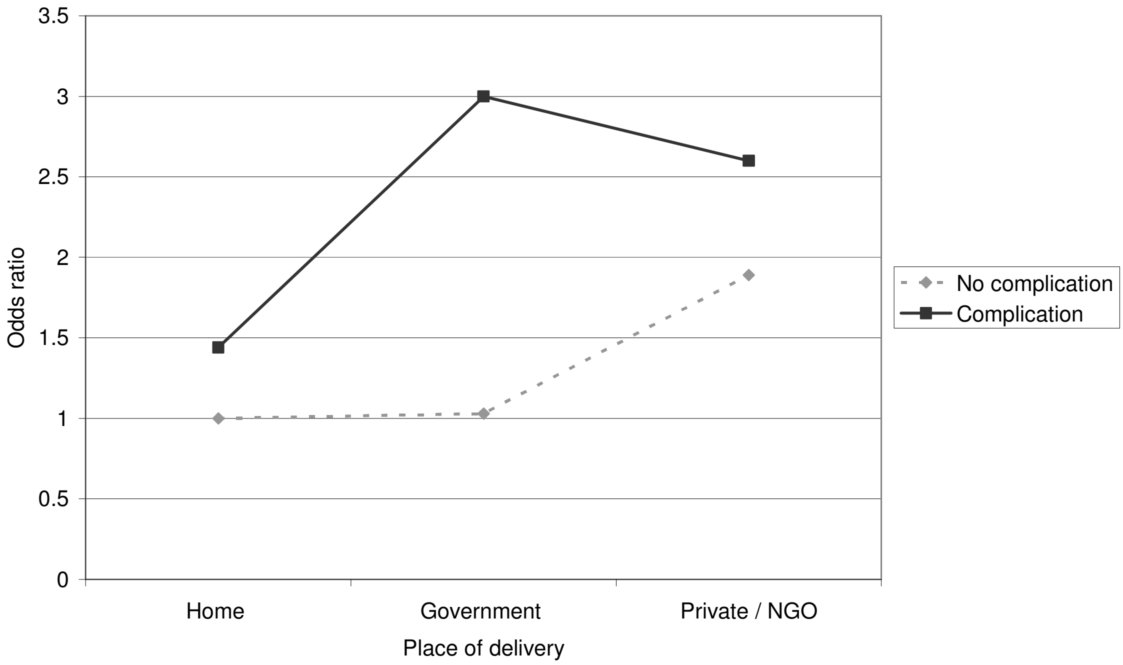


Figure 23: Graph showing odds ratios for neonatal mortality for composite variable complications/place of delivery



5.6 *Logistic regression for post-neonatal mortality*

For post-neonatal mortality, variables were added in the same order as for the earlier neonatal model. Significant variables are displayed in Table 21, and the full regression can be found in Appendix 11. In all models for post-neonatal mortality year of survey is significant at the 1% level from model 1 onwards with children included in the 1999/2000 and 2004 surveys showing significantly lower odds ratios for mortality than those in the 1996/7 survey. This pattern differs from that for neonatal mortality, where year of survey only becomes significant once health care variables are added. For the regions, Khulna is associated with significantly lower odds ratios for mortality, and again this is significant in all models. Quintiles show a mixed picture: when quintiles 1-4 (rural) are the reference category, only rural quintile 5 has a significant OR. When environmental variables are added rural quintile 5 is no longer significant but urban quintile 5 is (although still only at the 5% level) suggesting a possible interaction. The picture changes again when health care variables are added (model 4): neither urban nor rural quintiles 5 are significant, but urban quintile 1-4 shows a marked increase in OR significant at the 1% level. It remains significant at the 5% level in the final model.[35] Both secondary and further education are associated with reduced odds for mortality (reference category: no education) until model 4 (although in the case of further education only at the 5% level), when health service variables are added. In models 4 and 5 only secondary education remains significant, and only at the 5% level. Secondary education was not significant in any of the neonatal mortality models.

[35] When all quintiles were included individually with quintile 1 (rural) as the reference category, urban quintile 5 is significantly associated with reduced odds of mortality for all models, but in most cases only at the 5% level. Quintile 2 (rural) is also associated with a fall in mortality at the 5% level in the final model, and quintile 2 (urban) is associated with a rise in mortality (also at the 5% level).

Table 21: Multivariate regression for post-neonatal mortality (variables remaining significant in model 5 only)

	(1) *Socio-political /socio-economic*	(2) *Environmental added*	(3) *Bio-demographic/ maternal health added*	(4) *Maternal health care added*	(5) *Biological added*
Year of survey					
1996 (ref)					
2004	0.69	0.69	0.74	0.51	0.52
	(0.08)**	(0.09)**	(0.09)*	(0.07)**	(0.08)**
2000	0.697	0.699	0.716	0.464	0.482
	(0.084)**	(0.085)**	(0.089)**	(0.066)**	(0.069)**
State					
Barisal (ref)					
Khulna	0.47	0.47	0.47	0.48	0.46
	(0.12)**	(0.12)**	(0.12)**	(0.12)**	(0.12)**
Wealth quintile					
Quintile 1-4/rural (ref)					
Quintile 1-4/urban	1.00	1.30	1.32	1.45	1.43
	(0.10)	(0.17)	(0.18)	(0.20)**	(0.21)*
Maternal education					
No education					
Secondary education	0.54	0.55	0.53	0.67	0.66
	(0.10)**	(0.10)**	(0.10)**	(0.13)*	(0.13)*
Preceding birth interval					
Less than 24 months			1.50	1.49	1.48
			(0.24)*	(0.24)*	(0.24)*
36-47 months			0.65	0.67	0.69
			(0.12)*	(0.12)*	(0.12)*
Mother's age					
Under 16 (ref)			1.0	1.0	1.0
41 and over			2.82	3.38	3.29
			(1.07)**	(1.32)**	(1.29)**
Antenatal care /TT					
No ANC/TT (ref)				1.0	1.0
TT only				0.62	0.62
				(0.09)**	(0.09)**
TT and ANC				0.38	0.39
				(0.08)**	(0.08)**
Data missing				1.98	1.80
				(0.31)**	(0.28)**
Child is a twin					7.18
					(1.76)**

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

No environmental variables are significant, which is somewhat surprising. For the biodemographic variables, first birth is not significant for post-neonatal mortality, (unlike for the neonatal models where it is associated with a marked and significant increase in mortality). Birth interval of less than 24 months is associated with increased odds for mortality, but only at the 5% level, and birth interval of 36-47 months is significantly associated with reduced mortality, but only at the 5% level for the final 2 models. This differs from neonatal mortality, where birth intervals of less than 24 months are associated with increased mortality at the 1% level, but longer birth intervals are not significant. For post-neonatal mortality mother's age over 40 is significant (with a very large OR, although numbers in the sample are very small). Maternal height and reported complications are not significant. While place of delivery is not significant antenatal care and TT are: the final model shows a similar pattern to the neonatal regression. Two or more TT immunisations and TT plus antenatal care both significant, with markedly reduced odds of mortality. Again, there were increased odds of mortality in the group where data on antenatal care and TT was missing. However, unlike the neonatal models, place of delivery is not significant. When the biological variables are added, sex is not significant, but twins associated with a very large increase in odds of mortality.

A comparison between model 5 for neonatal and post-neonatal mortality (*i.e.* which includes all basic variables but does not include interactions) can be seen in Table 22. To summarise, wealth quintiles appear to have a somewhat stronger association with post-neonatal than neonatal mortality as would have been expected, but the picture is rather mixed and unclear. Biodemographic variables have strong associations for both neonatal and post-neonatal mortality, but, with the exception of birth intervals shorter than 24 months, different factors appear to have importance for the two age groups: for neonatal mortality first birth order is very important, whereas for post-neonatal maternal age of 40 and over is associated with greatly increased mortality. Somewhat surprisingly, tetanus toxoid and antenatal care are associated with very similar decreases in mortality for both neonatal and post-neonatal mortality. Maternal health and nutrition variables and place of delivery are only significant for neonatal mortality. When biological variables are considered, being born a twin is associated with a similarly large increase in mortality for both age groups.

Table 22: Comparison of significant variables for neonatal and post-neonatal mortality

Variables	**Neonatal mortality**	**Post-neonatal mortality**
Year of survey		
2000	- **	-**
2004	- **	-**
State		
Sylet	+ *	
Khulna		-**
Asset quintile		
Quintile 1-4 (urban)		+*
Mother's education		
Secondary		-*
Further	- *	
Biodemographic		
First birth	+ **	
Birth interval < 24 months	+**	+ *
Birth interval 36-47 months		- *
Maternal age over 40		+ **
Maternal health and nutrition		
Height < 145cm	+ **	
Reported complications	+ **	
Health care		
TT	- **	- **
TT/ANC	- **	- **
Delivery in government institution	+ **	
Delivery in private/NGO institution	+ **	
Biological		
Twin	+ **	+**

+ denotes increase in odds ratio for mortality - denotes decrease in odds ratio for mortality

* denotes finding significant at 5% level ** denotes finding significant at 1% level

6.0 <u>Discussion</u>

6.1 The link between maternal and neonatal health and health care

6.1.1 Inequalities in outcomes from institutional deliveries

This study clearly demonstrates that different groups of women experience different outcomes from institutional deliveries. No previous multivariate analysis in developing countries have ever explored this, with most focussing solely on overall socio-economic inequalities, or inequalities in access to care. The study shows that women from low socio-economic backgrounds who delivered in institutions had generally poorer outcomes than their counterparts who delivered at home, and also poorer outcomes than mothers from more wealthy or educated backgrounds who delivered in hospital. For instance, a woman with no education who delivers at home will have a probability of neonatal death of 0.07. If she gives birth in a government institution this nearly doubles to 0.12[36]. Women from higher socio-economic groups did not have significantly different odds of neonatal mortality than the reference group (*i.e.* women from the lowest socio-economic grouping who gave birth at home).

As previously discussed, poorer women are less likely to have planned their delivery care, and are more likely to have attended hospital only in the event of complication. This is likely to be partly responsible for their poorer outcomes. However, it must also be recognised that poor socio-economic status will influence outcomes through pathways other than this. For example, the Bangladesh Maternal Health Services and Mortality study (NIPORT *et al* 2003) found that women in the poorest centile were least likely to recognise serious complications and seek appropriate care, and when care is sought, they are likely to wait longer, possibly resulting in poorer outcomes. Previous studies have also shown that cost is a major prohibiting factor for the use of maternal health services (Afsana and Rashid 2001), meaning poorer people are even less likely to seek institutional delivery in the absence of

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[36] Probabilities were calculated using the equation:

$$\text{Probability of mortality} = \frac{e\ (b_0+b_1X_1+b_2X_2....)}{1+e\ (b_0+b_1X_1+b_2X_2....)}$$

With all other variables based on the reference groups complications, or may wait longer before seeking care when problems arise. Government services are ostensibly free, but studies have identified significant out-of-pocket expenses (*e.g.* medication, staff fees) for those who use them, which often add up to much more than the fees charged by some NGO facilities (ibid). The costs and practicalities of transportation to hospital presents another barrier to poor women and it is possible that cultural barriers and knowledge of available resources may differ between different socio-economic groups, further adding to differential usage (Anwar *et al* 2004).

Women who have not received antenatal care appear also to have less positive outcomes from hospital deliveries, probably as these are less likely to plan care and more likely to only deliver in an institution once a problem arises. They may also have been less exposed to information about danger signs, meaning their response is slower when complications occur. A woman with no ANC giving birth at home had a probability of 0.06 of suffering a neonatal death: this rises to 0.15 if she gives birth in a government institution. The multivariate regression found no difference in neonatal mortality between women who received ANC and gave birth at in a hospital and those with no ANC who gave birth at home (*i.e.* the reference group). Somewhat unsurprisingly, women with complications also experience higher odds of neonatal mortality. If a woman with no ANC also reports complications, she will experience an odds for neonatal mortality of 0.21 if she gives birth in a government institution: *i.e.* a more than one in five chance of a newborn death.

6.1.2 The impact of institutional deliveries on neonatal mortality

While both the bivariate and multivariate analysis in this study were able to identify groups of women who experienced particularly poor outcomes, the multivariate analysis was unable to demonstrate that any group has significantly reduced mortality as a result of utilising institutional care at delivery when compared with women who have home deliveries with similar characteristics (*e.g.* reported complications, level of antenatal care). This may be partly a reflection of sample size: as discussed in the results section, a number of groups show a marked reduction in OR for institutional delivery, but the variables do not reach significance.

It must also be remembered that in an environment such as Bangladesh where very few women give birth in an institution, it is reasonable to assume that relatively few women with completely uncomplicated pregnancies will utilise services. Many mothers in the higher socio-economic "low risk" groups may still have utilised hospital care at delivery in response to complications, as even wealthier/more educated women still do this. While their outcomes may be better because of faster recognition of and response to complications than their poorer counterparts, their underlying condition will still affect the neonatal outcome. This problem is compounded by flaws in the quality of the data that make it impossible to differentiate with any certainty between those who did or did not suffer complications.

Efforts to improve timely uptake of services for all women (not just those with complications) will require a number of both demand- and supply-side interventions to improve quality of services and also increase understanding of the need for skilled attendance for all deliveries. In addition, services must be accessible to all sectors of the community, which will require innovative and far-reaching solutions to solve the problems of both formal and informal health care costs.

6.1.3 Issues of health care quality

While much of the difficulty in showing a reduction in mortality for neonatal mortality may be related to methodological issues, it is also possible that if quality of care is poor, the potential benefits from institutional delivery may be reduced or in some cases even negated. Data is very limited, but there is some evidence that poor quality of care is an issue in some hospitals in Bangladesh. An assessment of the Bangladesh Maternal Mortality programme in 1997 found patients' wellbeing placed at risk by a lack of drugs and sterilised equipment and poor hygiene practices (Huque *et al* 1999). Dysfunctional staff configurations, inadequately skilled staff and poor infrastructure were also identified as barriers to quality care. One reviewer commented that delivery in an institution differed little from delivery by an untrained traditional birth attendant (ibid). A further study (Policy Project 2002) detected improvements in quality of care between 1997 and 2002 in some areas, but implementation of antenatal and delivery care was still inadequate. Bangladesh scored particularly poorly on access to emergency obstetric care and breastfeeding advice when compared with the other 54 developing countries included in the study.

While data is again limited, there is growing evidence that the potential for improved outcomes from increased institutional delivery in developing countries may be reduced by the high incidence of hospital-acquired (nosocomial) infections in newborns. The incidence of these is difficult to measure: most available studies have focussed on low birth weight or sick infants in neonatal care facilities, who are at much increased risk of acquiring such infections. A meta-analysis (Zaidi *et al* 2005) found a range of bloodstream infections in hospital-born newborns ranging from 1.7 – 33 per 1000 live births. However, many of these studies may be underestimations as healthy neonates are usually discharged within a few days of birth before they become symptomatic. The authors suggest that the true sepsis rate in hospital-born babies in south Asia could be similar to rates of sepsis found in very low income communities where nearly all deliveries are carried out by unskilled attendants (unpublished data, Pakistan, cited in Zaidi *et al* 2005). A longitudinal study of data in Malaysia (Boo and Chor 1994) showed clear increases in neonatal sepsis during periods when cleanliness of equipment was compromised and water supply unreliable, both of which are factors that have been raised in studies of services in Bangladesh.

Data from DHS also suggests that in some cases women and their babies may be subjected to unnecessary and potentially harmful interventions. While the overall rate of Caesarean section is very low (3.6%), the socio-economic gradient is high: women who have receive no education have a Caesarean section rate of 0.7%, whereas those who have received higher education have a rate of 27%. While the optimum rate of Caesarean section is a subject of controversy, a WHO consensus statement states that there is no evidence of further health benefit from a Caesarean section rate above 10-15%. This suggests that while many poor women who need the intervention are failing to receive it, those from higher socio-economic groups are having Caesarean deliveries for reasons other than medical necessity. While Caesarean sections are a vital component of emergency obstetric care, their unnecessary use carries increased risk for the neonate, including respiratory distress and iatrogenic prematurity. The increased use of Caesarean sections for non-medical reasons is now seen in many parts of the developing world among the more economically advantaged and, as well as carrying increased morbidity and mortality for both mother and baby, the phenomenon diverts scarce resources and attention from those who really require intervention.

A recent study in Bangladesh also demonstrated that differential quality of care may well contribute to socio-economic inequalities in outcome. Poor women who are unable to pay for care are likely to experience delays and poor quality care once they arrive at an institution, which seriously threaten the wellbeing of themselves and their infant. Pitchforth *et al* (2006) showed that both official and unofficial finance systems designed to assist those who cannot afford the cost of drugs and other out-of pocket expenses are under-resourced and inadequate in emergency situations. This led to significant delays in patients receiving life-saving interventions.

6.1.4 Further research on the association between neonatal mortality and professional delivery

Further research examining outcomes from institutional deliveries would be useful, but methodological problems are considerable. The only certain way of ascertaining the association between neonatal mortality would be a randomised controlled trial, but this would be neither ethical nor practical. Since this study commenced, data have been released from the 2001 DHS Special survey in Bangladesh, which includes a very large sample size of women, and further information on maternal and child health care. Further analysis of this dataset may provide more insights into this issue. Ideally, however, further studies would be able to clearly differentiate between women with uncomplicated pregnancies who planned institutional deliveries, and those who attended only when complications became evident. While this dataset does provide some information on motivation underlying place of delivery, it does not ask this question. Another possible approach to overcoming the problem of the endogeneity of the institutional health care variable would be to develop a model which uses instrumental variables within the regression. The success of this approach would rely on the identification of an instrumental variable that is correlated with the use of health facilities, but not with mortality. A possible candidate would be distance from a health facility, and this is explored in the next chapter.

6.1.5 The role of antenatal care

This study raises questions about the role and importance of antenatal care. While antenatal care alone does not appear to be associated with significantly reduced mortality, the models shows a significantly reduced odds ratio for neonatal mortality for women who have received two or more TT, and an even greater reduction for those who have antenatal care in addition to TT. The fact that women who had ANC had better institutional outcomes than women who didn't suggests ANC may have an important role in promoting planned institutional deliveries, or giving women the information they need to identify complications and respond appropriately.

Some of the reduction in mortality associated with TT vaccination may be as a direct impact from protection against this disease, which is estimated to be a cause of 15% of neonatal deaths in Bangladesh (Chowdhury *et al* 2005). However, it remains a significant variable in the logistic equation for the post-neonatal period, when tetanus is almost never a cause of death. It may be that maternal immunisation is a measure of a mother's access to, and use of, effective health care services. Despite major efforts within Bangladesh to eradicate this disease the Bangladesh Service Provision Assessment Survey 1999-2000 found that while 88% of health facilities provide antenatal care, only 58% were able to provide tetanus toxoid immunisation (Saha 2002). A further consideration is that the TT/antenatal care variable may actually be acting as a proxy for a socio-economic or personal characteristic not included in the model. While education and wealth are included within the model, any measure of female autonomy is missing. Numerous studies have shown an association between aspects of female autonomy and use of maternal health services, in particular antenatal care (*e.g.* Matthews *et al* 2003, Bloom *et al* 2001).

The model probably oversimplifies the situation for antenatal care. Bivariate analysis suggests impact is likely to depend on the number of visits and the timing of first visit, as well as the quality and content of the service, and the model does not allow for these differences. Furthermore, detailed analyses would be required to ascertain what impact these factors may have on outcomes.

6.2 Neonatal and post-neonatal mortality: similarities and differences

The study highlights both the similarities and differences that exist between the determinants of neonatal and post-neonatal mortality. Both outcomes are heavily influenced by biodemographic factors and access to antenatal care, as well as twin births. However, the study strongly highlights the importance of maternal health and events around the time of delivery for newborns, which is not mirrored in the post-neonatal period. The relatively poor progress made by Bangladesh in improving access to delivery services may be one of the reasons for the relative stagnation of neonatal mortality in relation to the older age-groups.

Based on existing literature, it might have been expected that socio-economic variables would play a greater role in the regression model for post-neonatal than neonatal mortality. Indeed when the models containing only socio-economic variables are compared, the pseudo r-squared for post-neonatal mortality is considerably greater. However, the relationship between asset quintiles and neonatal mortality is unclear, and the variables for education have fairly similar associations with neonatal and post-neonatal mortality. It might have been hypothesised that environmental variables would be more significant in post-neonatal than neonatal mortality but this is not the case: no environmental variables are significant in any of the models for post-neonatal mortality. This may reflect shortcomings in the way the environmental variables are categorised, and small sample sizes for some variables may also be an issue.

6.3 The importance of biodemographic variables

In addition to maternal health and nutrition, the study highlights the importance of the mother's reproductive career in determining neonatal and post-neonatal outcomes. In particular, it highlights the role of optimal birth spacing as both a key reproductive health and child health intervention. Bangladesh has generally made good progress in reducing the number of women giving birth within 24 months of a previous delivery (which is associated with the greatest negative effect). The percentage of children with a previous birth interval less than 2 years was 17% in the 2004 DHS – lower than other countries in the region such as India and Nepal (source: www.statcompiler.com). The median birth interval has increased from 35 months in 1993/4 to 39 months in 2004 – changes which could conceivably have contributed to falling NMR and PNMR. However, as fertility has decreased the proportion of first births has increased from 26% in 1993/4 to 30% in 2004. In the absence of improved maternal health care to deal with the complications of pregnancy and labour that are more common in primagravidae, this change could actually hold back progress in reducing neonatal mortality to some extent. This could also have contributed to differential progress between neonatal and post-neonatal mortality: the increased risk to first births is only evident in the neonatal period. While family planning programmes have a role to play in contributing to reduced child mortality rates, neonatal mortality will not fall unless there are concurrent improvements in health services.

6.4 Issues of data collection and quality

6.4.1 The need for disaggregated data

A strong theme of this study is the differential outcomes that are achieved from institutional deliveries for women of different socio-economic groups, which are at least partly due to different patterns of usage. It highlights the need for disaggregated data when evaluating services. Declines in institutional mortality rates could be caused by an increased number of more wealthy women planning facility-based deliveries for uncomplicated pregnancies, which could mask the fact that poor women are still accessing services too infrequently and too late, with resultant poor outcomes.

6.4.2 Management of missing data

The study also highlights the importance of appropriate management of missing data, which may not be homogenous. In the Bangladesh DHS it appears that mortality is very high among children for whom data is missing, even when the percentage of missing data is small. This is a phenomenon that has been identified elsewhere. It has been suggested that it is because of a natural reticence on the part of interviewers to ask detailed questions about care factors related to a child who has died as it may be distressing for the mother (Arnold and Blanc 1990).

6.4.3 The potential for underestimating deaths

Despite evidence of a very high degree of excess mortality for institutional deliveries for some groups of women, it is highly possible that this study still underestimates the true situation. One possible reason for underestimation of mortality in high risk groups could be that maternal mortality is concentrated in these groups. As discussed earlier, if a mother dies the child will be excluded from DHS surveys because the mother is the primary sampling unit. Neonatal and maternal deaths are closely correlated, which probably isn't a major problem in the whole population as maternal deaths are rare. However, if they mostly occur in the same groups of women where neonatal deaths are highest, this could have an important impact on the findings. More detailed research into the impact of maternal mortality on potential data quality would be useful.

Another important point to consider is that this study does not include stillbirths. DHS usually do not have data on stillbirths, and for the surveys where it is collected there are usually major concerns about quality (Mahy 2003). Stillbirths have many of the same causes as neonatal deaths, and the very high level of neonatal deaths found in hospitals may also indicate an equal (or even greater) rise in stillbirth rates for women using facilities. The babies of many women attending hospital late with complications such as obstructed labour or pre-eclampsia may already have died in utero, meaning that they are not included in the survey data. While the very high rates of neonatal mortality found among "high risk" subgroups of women using facilities for delivery are quite disturbing, it is probable that this study greatly underestimated the degree to which infants of these women suffer excess mortality.

6.4.4 The asset index as a measure of wealth

It is very difficult to judge the degree to which the asset index and asset quintiles are an accurate or appropriate indicator of economic status. The lack of a clear, monotonic relationship between either of the DHS defined wealth quintiles and the quintiles derived from separate rural and urban asset analysis and mortality in all age groups may suggest an inherent limitation in this method of ascertaining wealth. This can also sometimes be noted in studies of infant and child mortality in other countries, including those that use alternative data sources (*e.g.* Wagstaff 2001). One reason why there is no clear pattern in the multivariate analysis could be the strong correlation with education: indeed if education is removed a much clearer pattern is seen. However, this does not explain the lack of clear pattern in the bivariate analysis. The fact that index scores for the sample are so tightly clustered around the median suggests that there is insufficient difference between the economic status of families within consecutive quintiles for a clear pattern of mortality to be ascertained: a problem that would be exacerbated by relatively large confidence intervals. In such cases it may be more useful to devise a method that identifies the most wealthy/poorest using country-specific criteria (although there is always likely to be a subjective element to this), rather than splitting the population into equal groups. In the absence of measures such as these, education may be a more appropriate variable for measuring socio-economic status.

6.5 The continued significance of the distal variables in the final model

The final model includes several distal variables. For example, the decreased odds ratio for the higher education variable remained consistent through the models for neonatal mortality, as do changes in the odds ratio for region. If the assumption of the empirical model is to be accepted, and distal determinants only act through proximal, the continued significance of distal variables in the final models suggests that important variables have been omitted, and/or some of the existing variables do not accurately capture the phenomena they are meant to measure. This is also supported by the relatively low pseudo r-squared found in all the models, and the continued significance of the survey date as a variable. There are a number of variables included in the original conceptual model which cannot be included because DHS do not provide adequate information (particularly household behaviours and aspects of the mother's health and nutrition). There is, unfortunately, little that can be done to rectify these omissions. Another factor which is currently included in neither the conceptual model nor the logistic regression is some measure of the mother's empowerment and autonomy, and this may offer interesting opportunities for further work. Possible limitations in the degree to which some variables accurately measure the phenomena have already been discussed in relation to maternal self-reported complications and qualifications of health care staff, as well as the asset index itself. In addition the variables for ANC/TT are very much simplified, and this may again limit the opportunity for it to accurately capture one of the pathways through which distal determinants influence outcomes.

Even when adjustment is made for all other variables, neonates born in Sylhet experience a greater risk of mortality. This finding is by no means unique: despite not being considered one of the poorest regions, Sylhet lags behind in a number of indicators, including contraceptive acceptance and nutritional status (*e.g.* Mitra 2001). While no studies have been carried out to explain this phenomenon, explanatory factors put forward include ecology (the region is prone to flooding), poor ratios of health staff to population, “conservatism” resulting in women having low levels of autonomy and resistance to new ideas and few NGO programmes (Chowdhury *et al* 2002). In the post-neonatal regression, Khulna had a significantly reduced odds ratio. This again is supported by other studies: Khulna has been cited as having generally good health care indicators, including high rates of immunisation. The 1999/2000 service provision assessment showed that Khulna provided amongst the highest rates of access to child and maternal health facilities and family planning services (Saha 2002), which may go some way to explain this advantage. The reason why the results differ between neonatal and post-neonatal mortality, however, remains unexplained.

7.0 **Conclusion**

This study used both bivariate techniques and logistic regression to develop an understanding of the relationship between a wide range of variables and neonatal mortality. In particular, it finds that specific groups of women (those from lower economic groups and who do not use antenatal services) have particularly poor outcomes from institutional deliveries. This is probably at least partly because these women are more likely to seek professional assistance only after complications in pregnancy or labour have occurred. The study was unable to identify any subgroup of women who experienced significantly lower neonatal mortality by giving birth in institutions rather than at home.

The study also systematically reviews the differences and similarities between the determinants of neonatal and post-neonatal mortality. It finds that biological, biodemographic and antenatal care services are all important determinants of both neonatal and post-neonatal mortality. However, maternal health variables and care around the time of delivery were strongly associated with outcomes for neonates only. There was limited and slightly ambiguous evidence from the multivariate analysis that socio-economic factors were more strongly associated with post-neonatal mortality as may be expected from existing literature. The study also stresses the important role of birth spacing and family planning services in reducing both neonatal and post-neonatal mortality in collaboration with health services.

CHAPTER 4: THE IMPACT OF ANTENATAL INTERVENTIONS AND CARE AT DELIVERY IN REDUCING NEONATAL MORTALITY IN INDIA

1.0 Introduction

It is widely acknowledged that the development of health care interventions spanning the pre-conceptual, antenatal, intrapartum and postpartum periods are vital in reducing newborn deaths. However, while there is broad consensus on the content of services to promote maternal and child health, the actual impact of some of these packages of care is difficult to measure. In particular, while a skilled attendant at delivery is generally accepted as a major pre-requisite in reducing both maternal and neonatal mortality, there is little real evidence of impact in practical scenarios. This is because in countries where skilled attendance is not universal, women are more likely to seek professional care only when they experience complications, thus making poor outcomes more likely. It is therefore difficult to carry out a study that effectively compares outcomes from those who use skilled attendance with those who do not while controlling for confounding factors. Evidence of impact would be invaluable for focussing attention and resources on developing appropriate services providing skilled care at delivery.

Even when the effect of services on neonatal mortality can be measured, it may have differing impacts on different groups of women based on their socio-economic status or access to services. While there is a very large body of work documenting inequalities in health care and mortality, little research has been carried out on how different subgroups of the population may experience different levels of benefit from services, or indeed if the provision of services can reduce inequalities in health.

This chapter has two distinct strands. The first strand investigates how the impact of health care variables differs based on individual socio-economic status and access to health care services at the population level. The second uses the Instrumental Variable (IV) technique to try to determine the effect of professional attendance on neonatal mortality. This technique tries to overcome the problem of endogeneity by only measuring the exogenous component of the relationship between professional attendance and mortality.

The objectives of the study are:

- To investigate how heath care determinants of neonatal mortality (antenatal care, tetanus toxoid immunisation and professional attendant at birth) differ between socio-economic groups in India;
- To investigate how the impact of these determinants varies between populations with differing access to services; and
- To investigate the use of instrumental variable methodology to measure the impact of professional attendant at birth on neonatal mortality.

This study uses data from the second Indian National Family Health Survey (NFHS 2), which was carried out in 1998/9 by the International Institute for Population Sciences and Macro International as part of the ongoing Demographic and Household Surveys (DHS) series. The first two objectives present a fresh perspective on the analysis of the determinants of neonatal mortality by disaggregating findings by different population subgroups. The study, which uses both bivariate analysis and multivariate regression, builds on the findings from Chapter 3 by disaggregating by individual level characteristics (asset tertile/level of maternal education). This not only offers a fresh perspective from another country to add to the previous findings from Bangladesh, but also the desegregation of data prior to regression has methodological advantages over the use of composite variables as used in Chapter 3. When composite variables are used combining socio-economic group and aspects of service use, coefficients will be compared against a reference category that is from one socio-economic group only. This means that it would be necessary to run the regression many different times in order to compare outcomes from service users from the same socio-economic groups.

This study also examines differences at the population level based on aggregate access to services. There are very marked differences in access to health services between Indian states, and this can be demonstrated in use of a skilled attendant at delivery. In this study, states are divided into three groups based on the percentage of women who receive professional care at delivery, and the health care usage variables are calculated separately for these groups. Determinants are also identified separately for rural and urban dwellers, as within the Indian context there is strong evidence that health care in rural areas is relatively underdeveloped and under-funded.

In order to achieve the third objective, a series of two-stage least squares regressions are developed using distance from health facility as an instrumental variable in an attempt to expose the impact of institutional delivery by qualified personnel while essentially adjusting for the different characteristics and risk factors of those who seek and do not seek skilled care at delivery. This is the first time this technique has been used to ascertain the impact of maternal health care on neonatal outcomes, although it has been used in a number of other health studies where similar issues of endogeneity are a problem. The sample will be divided by socio-economic grouping and level of state attendance and delivery. As the data required for this method is only available for rural dwellers it is not possible to include urban residents.

Section two covers the Indian context in which this study is carried out, and will highlight why this country was chosen for the analysis. Section three contains a literature review on inequalities in maternal and neonatal mortality and health care usage. It will also discuss the limited evidence on how health care service factors influence inequalities in maternal and child mortality, before outlining the methodologies used to measure the impact of maternal health services. The fourth section is an outline of the methodology used in this study, followed by a presentation of the results in section five. Section six will be a discussion of the findings, followed by a conclusion in section seven.

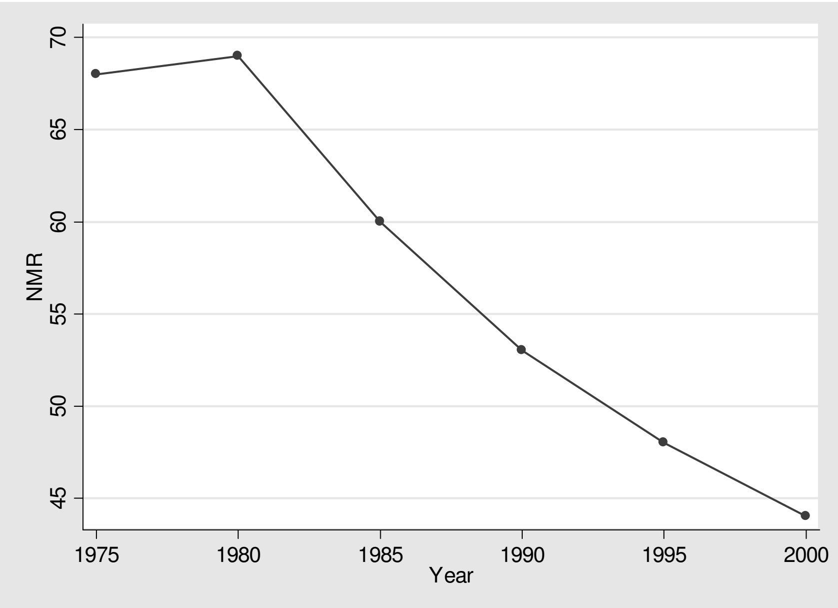
2.0 <u>The Indian context</u>

2.1 The burden of neonatal mortality in India

India suffers the highest number of neonatal deaths of any country in the world. Each year an estimated 1.2 million infants die during the first month of life, which equates to nearly a third of the global burden of neonatal mortality. Over the last few decades India has made major gains in reducing its neonatal mortality (see Figure 24), and estimates from the Sample

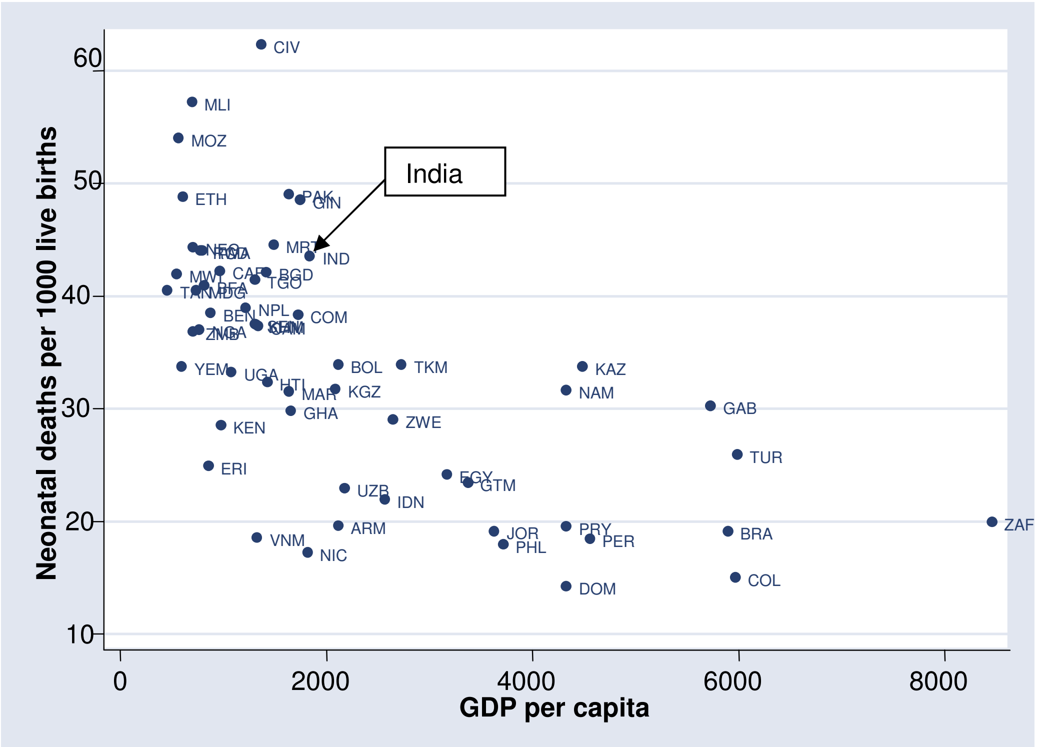
Registration Survey (SRS)[37] suggest a fall from about 68 per 1000 in 1975 to 44 per 1000 in 2000. Despite this impressive progress, India still has a relatively high level of NMR when compared to countries with similar GDP. As can be seen from the scattergram in figure 25, a number of countries with similar or lower levels of GDP (*e.g.* Kenya and Ghana) have markedly lower levels of NMR. The reason behind this is likely to be at least partly due to the very high rate of low birth weight babies within India, which is estimated at about 40% of all births (Dadhich and Paul 2004).

Figure 24: Time trends for neonatal mortality in India (1975-2000) based on Sample Registration Survey (SRS) data



[37] The Sample Registration System (SRS) is a large scale demographic survey conducted in India to provide annual estimates of birth rate, death rate and other fertility and mortality indicators at the national and sub-national levels. It has provided limited data since 1964, but became fully operational in 1970. It serves as the main source of fertility and mortality indicators both at State and national levels and covers a population of about 6.7 million in 1.3 million households. Data is collected on an ongoing basis using a resident enumerator (usually a teacher) and verified at 6 monthly intervals by an official survey.

Figure 25: Scattergram showing association between neonatal mortality rates and annual PPP per capita GDP



Data sources: NMR estimates are from DHS collected between 1990 and 2002. Estimates for GDP per capita are taken from the World Bank Development Indicators CD Rom (using purchasing power parity) for the mid year of the 5 year period covered in the DHS survey; see Chapter 2 for more details.

Table 23: NMR for Indian states based on NFHS 2 1998/9

State	% of total sample (children born within 5 years of survey date)	NMR estimate Based on NFHS 1998/9
Madhya Pradesh	8.7	51.3
Meghalaya	0.3	46.9
Rajasthan	6.5	46.8
Uttar Pradesh	20.5	45.1
Bihar	11.5	42.8
Assam	2.2	42.2
Orissa	3.4	40.9
Andhra Pradesh	6.9	40.6
Gujarat	4.6	36.9
Jammu and Kashmir	0.9	35.5
Haryana	1.9	34.7
Karnataka	4.4	32.8
Goa	0.1	32.4
Arunachal Pradesh	0.1	29.7
Maharashtra	8.9	29.3
Tamil Nadu	5.4	29.1
Punjab	1.9	27.8
West Bengal	7.1	26.6
New Delhi	1.2	25.9
Sikkim	0.1	21.8
Manipur	0.1	21.7
Mizoram	0.1	21.3
Himachal Pradesh	0.5	18.4
Kerala	2.3	12.3
Nagaland	0.2	17.7
All India	100	38.6

Source: NFHS 2

However, these figures mask very marked differences between Indian states. Table 23 shows estimates from the NFHS 2 for major states. Kerala has low neonatal mortality (around 12 per 1000) which is similar to a number of transitional economies in Central and Eastern Europe such as Poland, Romania and Bulgaria (WHO 2005). At the other end of the scale, Madhya Pradesh is estimated by the SRS to have an NMR of 51 per 1000, which is amongst the highest levels in the world and is more akin to the rates found in the poorest countries of Sub-Saharan Africa. These interstate differences are also reflected in other indicators such as maternal and infant/child mortality.

2.2 Economic inequality and neonatal mortality in India

Some of the wide interstate variation in mortality in India is due to marked differences in economic development. Economic growth in India since independence has been extremely unequal, and there is evidence that the disparities between growth in rich and poor states is widening. In recent years the more highly industrialised states such as Maharashtra and Gujarat have experienced particularly high rates of growth in State Domestic Product (SDP, approximately 7% and 8% per annum, respectively, between 1990 and 2000), whereas others such as Orissa and Bihar have only achieved SDP growth of about 3.6% and 3.5%, respectively (Bhattacharya and Sakthivel 2004). In general the fastest growing states have also been most successful in reducing overall levels of poverty (Purfield 2006). The least progress is generally found in the "BIMARUO" states. Originally the term "BIMARU" (which has somewhat pejorative undertones) was coined to describe the Hindi-speaking states of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh that share a number of cultural factors, but also have consistently made less economic and social progress than other Indian states. Characteristics include lower than average rates of economic growth, high levels of illiteracy, relatively high fertility levels and poor performance in health indicators including child mortality. Orissa is commonly now added to this group (although it is not a Hindi-speaking state) as it shares many of these characteristics, hence the variation "BIMARUO".

There are also marked socio-economic differences at the individual household as well as the state level in neonatal and child survival. A cross-sectional analysis of DHS data from 22 countries found that India had a ratio for poorest quintile to least poor quintile for under five mortality of 3.1 (based on 1998/9 DHS data, Moser *et al* 2004). This difference was markedly higher than a number of countries with similar under five mortality rates to those found in India (*e.g.* Bangladesh and Nepal had a ratio of 1.9), and the ratio had actually increased slightly since 1992/3 when it was 2.8.

Furthermore marked differences are found in mortality rates between those living in rural and urban areas. Neonatal mortality is 47% higher in rural areas than urban, and the excess is 73% for post-neonatal mortality (NFHS 2). A further dimension of inequality that is specific to the Indian context is that of caste. Neonatal mortality in "scheduled" castes/tribes is estimated at 51 per 1000, compared to 38 per 1000 in "forward" castes (Dommaraju *et al* 2007, based on NFHS 2 data 1998/9). While much of the literature assumes that the health disadvantages faced by those within the low castes or tribal groups are rooted in socio-economic differences, studies on racial inequities suggest that these groups may suffer specific barriers to health care, including low coverage of facilities in areas with high concentrations of low caste members, and discrimination by health care staff (*e.g.* Burgard 2002, cited in Dommaraju *et al* 2007). Recent government initiatives are believed to have made great strides in reducing caste-related disadvantage, but recent studies still detect health inequities. Dommaraju *et al* (2007) found an increased odds ratio for child mortality of 1.14 (which was significant at the 5% level) even after adjusting for a number of socio-economic and health care access.

2.3 The Indian health care system

Within India, responsibility for the provision of public health care is at state level, with the central government's remit limited to policy guidelines, technical assistance, supplementation of resources and the implementation of several national programmes in high priority areas. Only about 21% of total national expenditure on healthcare is provided by central or state level government (Ministry of Health and Family Welfare 2001-2), with most of the remainder being borne by the individuals seeking treatment as "out-of-pocket" expenses. As a result of government underspending the infrastructure for health is often ineffective. Marked differences in annual expenditure are seen at state level: 2001-2 figures of per capita public expenditure at state level vary from 84 rupees (Uttar Pradesh) to 1,360 rupees (Lakshwadeep: a Union territory not included in the NFHS 2 dataset). The proportion of public health expenditure as a proportion of total expenditure on health (*e.g.* out-of-pocket expenses) also varies greatly, from around 90% (*e.g.* Mizoram, Meghalaya and Sikkim) to just 7.5% (Uttar Pradesh). In general, high income states also have greater per capita government expenditure on health, greater numbers of facilities and improved staffing levels (Purohit 2004). People in poorer states experience greater supply- and demand-side barriers to care, leading to low levels of utilisation (ibid). In addition to being influenced by overall state GDP, per capita public health spending is often particularly high in some of the smaller, tribal states or union territories. However, there is some uncertainty as to whether state levels of health expenditure have a direct impact on child health: a recent study by Bhalotra (2007) found that variations in state health expenditure were associated with differences in infant mortality in rural areas, but not urban. Effectiveness of health expenditure varies significantly across states, and is likely to be at least partly linked to the quality and functionality of the infrastructure, as well as differences in the policy environment and overall strategies developed (ibid.).

At an individual level, high out-of-pocket costs of health care result in much lower utilisation rates among the poorest: despite greater exposure to disease, a person from the poorest asset quintile is six times less likely to access hospitalisation than someone in the richest quintile (Deogaonkar 2004). People from scheduled or tribal castes are also further disadvantaged: a tribal mother is more than 12 times less likely to be delivered by a professional attendant (*e.g.* doctor or nurse) (ibid). In addition to the state inequalities already discussed, there is also a massive urban / rural divide in health care: per capita spending on public health is seven times lower in rural areas than urban (ibid).

2.4 Maternal and newborn health care

It is currently estimated that only about 40% of Indian births are assisted by skilled birth attendants[38], with about a third occurring in health facilities. However, this figure masks great variations between states: In Kerala about 95% of women receive a skilled attendant, whereas in Bihar, this figure is only 20% (based on India NFHS data 1998/9). Over a third of all

[38] This figure includes Auxiliary Nurse Midwives (ANMs). However, it is debatable whether these would actually fulfil the WHO criteria for a skilled attendant. In particular, the WHO definition states that the skilled attendant should have the skills need to manage complications in women and newborns (WHO 2004), which does not seem to be included in the ANM remit as outlined in Dadhich and Paul (2004). Further clarity is needed.

births in India are still carried out by traditional birth attendants (TBAs)[39]. At the community level, the key cadre for maternal and newborn care is the Auxiliary Nurse Midwife (ANM), who receives an 18 month training including the skills to perform normal deliveries and identify and refer complications. As their name would suggest, their role was originally developed to focus on maternal health care including attendance at birth, but has more recently become extended to include a number of other health-related procedures (*e.g.* family planning). The proportion of births they attend is only about 10%. This low proportion is probably caused by a number of factors. Firstly, a large number of posts remain unfilled, and secondly while they are supposed to live in their catchments, many commute to rural areas from local towns because of practical or security reasons, meaning they are often not available to provide cover 24 hours a day (Dadhich and Paul 2004).

Utilisation of antenatal care is higher than for skilled attendants, with about two thirds of women receiving some degree of antenatal care at some point in their pregnancy. However, this figure again masks strong interstate differences: in some states such as Goa, Kerala and Tamil Nadu nearly all women receive some antenatal care, whereas in others over 60% receive no care (*e.g.* Bihar, Uttar Pradesh, based on India NFHS data 1998/9). Only about a third of women nationwide receive the four or more antenatal visits recommended by WHO, and the same percentage commence their antenatal care in the first trimester (Dadhich and Paul 2004). Much emphasis has been placed on tetanus toxoid (TT) immunisation within Indian health programmes, and an estimated 70% of women receive two vaccinations during pregnancy, which is enough to confer immunity to them and the baby (ibid).[40]

Specific programmes of postnatal care for neonates have been developed, but tend to be localised and often small scale. Availability of neonatal intensive care is restricted to a relatively small number of tertiary care hospitals (Dadhich and Paul 2004).

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[39] A traditional birth attendant can be defined as "*A community-based provider of care during pregnancy and childbirth. TBAs are not trained to proficiency in the skills necessary to manage or refer obstetric complications. TBAs are not usually salaried, accredited members of the health system."(*UNFPA.) http://www.unfpa.org/mothers/terms.htm

[40] This figure does not include women who may have received a total of four immunisations either pre-conceptually or during previous pregnancies, which would be enough to confer lifetime immunity. It therefore probably underestimates the proportion of women whose babies are protected.

2.5 National policy for maternal and neonatal mortality

The development of a national policy for maternal and neonatal health comes under the Reproductive and Child Health Programme phase 2 (RCH II, 2005-10). Key strategies for further service development include the promotion of institutional deliveries and strengthening of emergency obstetric care. A key aspect of this is the upgrade of 50% of all Primary Health Centres (PHCs) and all Community Health Centres (CHCs)[41] to enable the provision of basic emergency obstetric and neonatal care[42]. First Referral Units (FRUs) will be upgraded to provide comprehensive emergency obstetric care (all services included in basic emergency obstetric care plus Caesarean section and blood transfusion).

One of the more innovative developments currently being rolled out nationally to promote institutional deliveries is the "Janani Suraksha Yohana", whereby families living below the poverty line will receive financial incentives for delivering at government institutions, and traditional birth attendants (TBAs) will receive financial compensation for facilitating this. Another strand of the strategy is the development of home-based neonatal care by a semi-skilled cadre known as the Anganwadi worker (AWW), who receives basic training in aspects of child health and is paid a monthly honorarium by the Government. Somewhat controversially, TBA training and support is continuing in areas where facility-based delivery are considered unfeasible in the short term.

2.6 Choice of India as study country

As India bears such a high proportion of the global burden of neonatal mortality, a greater understanding of the factors behind these deaths is of clear policy relevance. It is also interesting that in some ways India is a particularly pertinent site for determining the potential

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[41] A PHC caters for a population of about 30,000 and has about 4-6 beds. It should be staffed by one or two general physicians as well as auxiliary nurse midwives. Currently some, but not all provide delivery care. There is one Community Health Centre for every 4-5 PHCs usually with about 30 beds. An FRU services a population of about 500,000, and about half have an obstetrician on the staff. Most have operating facilities, but few currently have linkages with blood banks (Dadhich and Paul 2004).

[42] Basic emergency obstetric care includes provision of intravenous antibiotics, oxytocics and anticonvulsants as well as manual removal of placenta and assisted vaginal delivery.

benefits of skilled attendance: while on one hand it is actively promoting births within institutions, it is, on the other, continuing to support TBA training (*i.e.* unskilled attendants) in some regions. While this study cannot hope to answer all the questions that still exist around the potential benefits of different levels of attendant, clearer evidence of the impact of skilled attendance would, if found, be useful for informing and supporting the policy process.

Data from the Indian DHS was chosen for this study as it is an extremely large dataset and appears to provide reasonably good quality data on neonatal mortality (see section four for further information on how this is ascertained). It also provides data on a good range of relevant indicators. However, another important benefit is that the data provides great diversity: India has marked polarisation between rich and poor which facilitates the analysis on how determinants of mortality vary between socio-economic groups. In addition, the difference in utilisation of care between different states also offers important opportunities for comparison. In particular, the vast range in the percentage of women receiving professional attendance offers excellent opportunities to compare how determinants vary within contexts where access to delivery care is either relatively good or extremely poor.

3.0 Literature review

3.1 Inequalities in maternal and neonatal mortality

The last few years have seen a very thorough documentation of inequalities in health and survival in developing countries, and maternal and neonatal mortality have been no exception. A study by Graham *et al* (2001) based on DHS data from 11 countries showed striking inequities in maternal mortality: for instance in Indonesia about a third of all maternal deaths occurred in women from the poorest asset quintile, whereas only 9% occurred in the richest asset quintile. A marked socio-economic gradient for mortality has also been documented for newborns (Lawn *et al* 2005), although the differential does not seem to be as great as for deaths in older children (ibid).

3.1.1 Inequalities and access to health care

Most studies examining the role of health care in health inequities focus on inequalities in health care usage. There is a wealth of evidence that poorer people have less access to, and make less use of, health services. One particularly striking study (Houweling *et al* 2007) examines the rich-poor differentials in the utilisation of maternal health services. While rates of professional care at delivery in most countries are over 80% for women in the wealthiest asset quintile, they are often less than 30% for the poorest quintile. These differentials between rich and poor within countries are generally far greater than those between countries: *i.e.* rich women in countries with low national rates of attendance are more likely to receive skilled care than poor women in countries with relatively high levels of attendance study (Kunst and Houweling 2001). Only a very small amount of the rich-poor differential can be explained by confounding or modifying factors such as urban/rural dwelling, ethnic background or geographical factors (ibid). Economic constraints are a key factor in explaining these inequities, be it due to overt or "hidden" costs of accessing care (*e.g.* Nahar and Costello 1998, Afsana and Rashid 2001).

Large differentials have also been widely reported in other aspects of maternal and health care. Gwatkin *et al* (2000) found marked differences between rich and poor in use of antenatal care in a study of 45 countries. This study also found marked socio-economic differences in uptake of immunisation and treatment of childhood illness (*e.g.* respiratory tract infections and diarrhoea).

Even when the poor do access care, their patterns of use may differ from their more wealthy counterparts in a manner which make outcomes less favourable. For example, poorer women who access skilled care at birth may only do so once complications are evident, and may wait longer before getting assistance. The Bangladesh Maternal Health Services and Mortality study (NIPORT *et* al 2001) found that women in the poorest asset quintile were less likely to recognise serious complications and seek appropriate care, and when care is sought, they are likely to wait longer. Studies in both developing and developed countries have also found that financial barriers prevent early uptake of antenatal services, and may limit the number of visits made.

There is a more limited body of evidence suggesting that the quality of care that poor women receive may be worse than for more wealthy women, which is a further factor that could adversely affect outcomes. Probably one of the most striking studies to examine this is Pitchforth *et al*'s (2006) qualitative study of emergency obstetric care in Bangladesh. This clearly illustrates how women's ability to pay affected the quality and timeliness of the care they received in a government hospital. Other studies have also found differences in quality of care received between the rich and poor, whether measured by the number of antenatal procedures received (*e.g.* Pallikadavath *et al* 2007) or levels of provider knowledge and competence (*e.g.* Das and Hammer 2007). While some of these differences may relate to the ability of the more wealthy to access private practitioners, this is certainly not the only issue. A Turkish study (Cicekliogl u *et al* 2005) found that a number of factors including level of education and wealth affected the number of antenatal procedures women receive in public facilities**.** A further study examining more general health care in India found that there were lower levels of competence in both private and public sectors in geographical areas where clients were poorer (Das and Hammer 2007). Further evidence also suggests that efforts to improve quality of care are often not initially targeted at the most disadvantaged regions: for example Victora *et al* (2000) found that selection of sites for the early development of Integrated Management of Childhood Illness in Brazil, Peru and Tanzania did not generally reflect the areas with highest need[43].

Even if women receive the same quality and amount of care, it is likely the rich women may still experience differential outcomes from poor women as a result of some interventions. However, very little evidence exists on this subject. In particular, many preventive interventions are aimed at reducing diseases of poverty, and therefore it could be assumed that their impact will be disproportionately beneficial amongst the poorest (assuming this group has effective access). An example of such an intervention is tetanus toxoid immunisation. Several studies have found low socio-economic status to be a major risk factor (*e.g.* Chai *et al* 2004), and cases to be concentrated within economically disadvantaged communities where hygiene is poor and births occur at home without skilled attendance. While no studies have

[43] The Integrated Management of Childhood Illness (IMCI) is a systematic approach to providing effective health care to children under five years through three main areas of focus: improving health worker skills, improving health systems and improving family and community practices. The strategy is being rolled out in most developing countries, supported by UNICEF and WHO.

examined tetanus immunisation specifically, a study looking more broadly at childhood immunisation found that impact on mortality was greater for the poorest compared with the wealthier (Bawah *et al* 2006). It is also possible that antenatal care may have a greater effect on women from poorer socio-economic groups. While some components (*e.g.* detection of pre-eclampsia and other potential complications) are unlikely to favour the poor as there is no socioeconomic difference in incidence, others such as provision of iron or folic acid may have a greater impact on the poorest as they may be more prone to nutritional deficiency. Advice on newborn care, complications of pregnancy and delivery may also be more beneficial for those who are poorer as they may have less access to such information from other sources.

3.1.2 Provision of health care as a means of improving equity

Provision of health care is often promoted not just as a channel for reducing mortality and morbidity, but as a means of reducing health inequities. However, while a number of studies have examined how different methods of service delivery have affected differentials in use between rich and poor, few studies have established whether the provision of interventions and services really impacts on inequities in mortality or morbidity. One of the few studies to examine this (Bawah *et al.* 2006) found that immunisation services in Ghana actually negate the socio-economic differentials in child survival between rich and poor. Bhuiya *et al* (2001) in Bangladesh recorded a greater decrease in socio-economic disparities in child survival where children were exposed to the MCH-FP programme developed by ICDDR(B)[44], and found greater absolute and relative reductions in mortality among the poorest. As in the Ghanaian study, improvements among the poorest in the group exposed to this programme were enough to negate any socio-economic gradient.

At a cross-national level Houweling *et al* (2005) carried out analysis of 43 countries using wealth groups to establish the relative effects of a number of variables on child mortality. Increased public spending on health was more strongly correlated with decreases in mortality among the poor than the wealthy, as was the correlation between health spending and use of services (tetanus toxoid immunisation and skilled attendance).

[44] International Centre for Diarrhoeal Disease Research, Bangladesh

3.1.3 Gaps in knowledge and relevance to policy

In recent years much has been documented about the levels of inequality in mortality between socio-economic groups, and how different patterns of health service usage contribute to these. However, there is much less data available on the impacts of specific health interventions on different groups, and in particular how this varies between communities with different levels of access to health services has not been explored. This is an important omission for policy makers: in particular there has been ongoing debate on the degree to which a number of preventive services should be universal or targeted to specific groups. If it can be demonstrated that specific interventions produce particularly positive outcomes within particular groups, this could support the argument for greater targeting of services, particularly in situations where attempts at universal coverage appear ineffective, or fail to reach the most vulnerable groups. This chapter provides a first step in exploring some of these issues of differential outcomes.

3.2 Measuring the impact of maternal and neonatal health services

While at the individual level much is known on which specific interventions will save the lives of mother and their babies, knowledge of how maternal health care services reduce mortality at the community level is much sparser. This paucity of clear evidence has contributed to a lack of policy direction, with time and resources being wasted on developments such as the training of TBAs, which has later been found to have little impact. More recently, opinion has coalesced around the importance of skilled attendance in reducing maternal and neonatal mortality, but difficulties in ascertaining the impact of skilled attendance has led to a relative lack of debate on the quality of evidence (Graham 2002).

3.2.1 Randomised controlled trials

The “gold standard” for evidence is a randomised controlled trial (RCT), as these can address the difficulty of different groups of patients having different and often unmeasurable characteristics that affect the outcome under investigation. However, they often raise ethical, financial and practical considerations. Carrying out high quality studies in developing countries is often particularly fraught with difficulty, as funding is particularly difficult to secure, follow-up in situations where vital registration is unknown is problematic and ethical considerations are often complex (Duley *et al* 2006). There have been examples of successful RCTs carried out in developing countries in the area of maternal and neonatal health, but most focussed on specific maternal health interventions, such as optimal treatment of eclampsia (*e.g.* Eclampsia Trial Collaborative Group 1995) or management of postpartum haemorrhage (*e.g.* Gulmezoglu *et al* 2001). None has looked at the impact of maternal delivery services or skilled attendants at birth more generally, but a number have attempted to examine the impact of packages of antenatal care. WHO carried out a meta-analysis of available randomised controlled trials before developing a model of care with reduced numbers of visits (Carolli *et al* 2001). Bang *et al* (1999) also carried out a community randomised trial in India looking at a package of postnatal interventions for reducing neonatal mortality, but again this did not address issues of delivery care *per se*.

3.2.2 Quasi-experimental designs

A very small number of quasi-experimental studies have been carried out looking at the impact of improved maternal health services. Probably the most comprehensive data of this type come from Matlab in Bangladesh, where mortality records have been kept since the 1960s. Initial analysis of a community based maternal health programme which included skilled attendants at delivery suggested it had resulted in a marked drop in maternal mortality when compared with the control area (Fauveau *et al* 1991). This change was originally believed to be attributable to improved services. However, later analysis carried out over a longer period found that mortality also fell in parts of the comparison area which, despite not having access to the main programme interventions still had access to essential obstetric services (Ronsmans 1997a). The ongoing debate on the reasons behind mortality decline in Matlab highlights some of the difficulties of quasi-experimental designs in measuring the impact on maternal health services, particularly over relatively short periods of time, as the overall success of such programmes rely on the effective functioning of the whole health system rather than specific components.

3.2.3 Observational studies

As data from experimental studies are limited, a number of studies have used techniques such as regression analysis on retrospective cross-sectional data in attempts to establish associations between health care variables and outcomes. In particular, evidence for the impact of skilled attendants at the international level has been drawn from the correlation with maternal or neonatal mortality. A number of studies have shown a negative relationship between NMR/MMR and the national level of skilled attendants: countries with a high proportion of skilled attendants tend to have relatively low NMR and MMR (*e.g.* Lawn *et al* 2005, Graham *et al* 2001). This correlation has been extremely influential in promoting the policy of skilled attendance, but the approach is actually flawed. Firstly, most (though not all) of these studies do not adjust for other factors such as national levels of GDP, education and fertility, all of which are also likely to be correlated with maternal and neonatal mortality. Secondly, studies of maternal mortality often use country estimates derived by modelling methods based on the proportion of skilled attendance, which will obviously strengthen the correlation (Graham *et al* 2001). Thirdly, the strength of the correlation is considerably weaker if developed countries with very high levels of skilled attendance are not included (ibid). One study that did adjust for socio-economic and fertility variables found that a correlation with MMR existed when skilled attendance was carried out by doctors, but this was much less obvious when midwives were examined (ibid.). The authors concluded that this was due to the range of skills and abilities covered by this professional label.

Several studies have examined the impact of antenatal care (ANC) at the individual level using regression techniques, which adjust for socio-economic characteristics (*e.g.* Hong and Ruiz-Beltran 2006), and such techniques were used in Chapter 3 of this thesis and will be used again in this chapter. While there is some variation, some studies have found that use of antenatal care is associated with improved perinatal or child health outcomes (*e.g.* Hong and Ruiz-Beltran, 2006, Kavoo-Linge 1992). This methodology makes the assumption that women use ANC as a routine preventive health intervention, rather than only when a complication arises. It is possible that regression findings may somewhat underestimate the benefit, as a higher proportion of women using ANC may have experienced complications. This issue will be discussed in more detail later in the chapter.

The endogenous nature of skilled attendants at delivery means that the impact of this cannot be effectively measured through standard regression techniques because those who make use of delivery services are more likely to suffer complications, and therefore be at greater risk of adverse outcomes. In the absence of information on the mother’s condition during pregnancy and delivery (which is rarely available in datasets) standard regression techniques cannot adjust for these factors but, as will be discussed later in section 3.3, regression using instrumental variables may offer a possible solution to this problem.

Several studies have attempted to model the potential global impact on MMR or NMR of scaling up aspects of maternal health services such as skilled attendance or emergency obstetric care. (*e.g.* Graham *et al* 2001, Darmstadt *et al* 2005). These studies are usually based on estimations of the burden of disease that are amenable to specific interventions. The limitations of such studies for what are quite complex packages of interventions are that they are unable to factor in aspects of service quality: they tend to assume a “best case scenario” with full staffing ratios, adequately qualified personnel and functioning infrastructures, transport and referral facilities. It is therefore not really possible to relate these artificially derived figures to developing country scenarios where quality of care is almost always less than optimal and may vary dramatically both between countries and individual institutions.

3.2.4 Retrospective case studies

Most evidence of impact from maternal health services is based on country case studies and retrospective analysis of data, and focuses on maternal rather than neonatal mortality. A number of historical case studies have been carried out in developed countries. In Sweden it has been argued that early professionalisation and widespread use of midwifery services, along with appropriate use of technologies resulted in the country achieving the lowest MMR in Europe by the beginning of the 20^{th} century (Van Lerburghe and De Brouwere 2001) . In contrast, rejection of midwifery and failure to provide access to quality institutional care by obstetricians resulted in little progress in the US until the 2^{nd} World War (Scmidt and Valadian 1969, cited in Van Lerburghe and De Brouwere 2001). Several of these studies suggest that professional midwifery made a marked difference to mortality even in the absence of hospital technology, and midwifery-led services were safer than those provided by doctors: for example a Frontier Nursing Service in the USA achieved a maternal mortality ratio of 66 per 100,000 in the 1930s, whereas hospital physicians in Lexington, Kentucky were still facing mortality of 800-900 per 100,000 (Van Lerburghe and De Brouwere 2001). Fewer studies have examined neonatal mortality. However, there is some evidence to suggest that, while late neonatal mortality declined before the advent of comprehensive maternal health care services, decline in early neonatal mortality did not accelerate until access to skilled attendance and emergency obstetric care became widespread (*e.g.* Loudon 1992).

These historical case studies leave many questions unanswered: why for example, did the UK and USA have such widely differing levels of maternal mortality in the 19^{th} century (around 400 per 100,000 in the UK compared to around 700 per 100,000 in the USA) in the absence of any coherent maternity policy or services? There are also issues about whether such studies can be generalised for modern developing countries, which may face very specific and complex problems such as cultural factors, widespread and extreme poverty and HIV.

A number of case studies which draw on time series data have also been carried out in developing countries. A study examining maternal mortality in Malaysia and Sri Lanka highlights the link between the development of maternal health services, and in particular the professionalisation of midwifery, and falling death rates (Pathmanathan *et al* 2003). Case studies in a number of countries where significant gains have been made in reducing maternal mortality (Bolivia, China, Egypt, Honduras, Indonesia, Jamaica and Zimbabwe) also highlight the importance of the development of skilled attendants and/or effective linkage with emergency care facilities (Koblinsky 2003). These studies have not focussed on neonatal mortality (although it can be noted that a number of these countries have also achieved low NMRs).

While the overall weight of evidence provided by these retrospective studies offers a convincing body of knowledge related to the components of effective maternal health services, studies have serious methodological limitations. The linkages between service development and outcome can only be viewed as ecological, and causation cannot be proved. In particular they may not take into account other economic and social changes taking place during this time. Also, the case studies may not be representative of countries as a whole, and the experiences may not be generalisable in an international context. Such case studies also produce anomalies which are hard to explain as they rarely provide detailed comparative information on service strategy and content: for instance Mexico developed a comprehensive system of hospital based delivery care, but retained an MMR of over 100 (Bobadilla *et al* 1996).

3.3 The potential use of regression using instrumental variables in estimating treatment effects

There is increasing interest in the use of non-experimental studies using regression methodology as a tool for estimating treatment effects in health care where randomisation is either unethical or impractical. As previously mentioned, such techniques have already been used to analyse the potential impact of some maternal health care interventions such as antenatal care. However their use is limited when considering delivery care because of the endogenous nature of the variables. Maternal health care is by no means unique in that measuring outcomes is confounded by selection bias among those who seek or receive treatment. One potential approach is to gather extensive clinical data at the individual level which can be used within the analysis but this is complex and time consuming, and such information is not available in existing datasets. The use of instrumental variables (IVs) offers an alternative solution as it overcomes the problem of non-randomisation by estimating the exogenous component of the treatment variation. Including appropriate IVs within the regression that are correlated with the exogenous variable (*i.e.* in this case delivery with a professional attendant) but independent of the outcome enables analysis of the relationship of the endogenous variable to the outcome. IV techniques were originally developed and mostly utilised within the discipline of economics, but an increasing number of studies have applied this method within the health care context. These studies appear to have been limited to developed countries (and in particular the US), and have proved successful in a range of other situations where endogeneity is an issue. One example is a US study examining whether early discharge of neonates from hospital was associated with a higher rate of readmission (Malkin *et al* 2000). Obviously the length of original stay after birth may well be influenced by factors that will affect the rate of readmission (*i.e.* the infant may have been unwell at, or shortly after birth), so direct comparison of readmission rates for those experiencing early or late post-partum discharge would be affected by bias. In order to overcome this, two IVs were identified: time of birth and method of delivery. Their choice was based on the assumption that they were highly correlated with length of stay, but not with the final outcome (*i.e.* readmission)[45]. A probit model using these IVs found that a 12 hour increase in

[45] The time of day affects the length of stay as few women are discharged at night. Therefore those who give birth late in the day will usually stay at least one night. Type of delivery (*e.g.* Caesarean) will affect the time the mother will need to spend in the hospital. The authors do point out that these IVs are not perfect, and in fact

length of stay resulted in a decrease in the readmission rate of 0.6 percentage points: regression without instruments only found a decrease in readmission rate of 0.3 percentage points.

Another area where IV variable methodology has been used is in estimating the quality of care in hospitals. Quality of care is frequently measured by mortality rates for particular diseases, but allocation to a particular hospital may be affected by unmeasured factors that impact on this outcome *i.e.* patients with more severe illness may be admitted to a hospital where quality of care is higher. This may bias comparisons of quality of care between hospitals, resulting in institutions where quality is high comparing unfavourably with other institutions where care may poorer, but patients have higher levels of survival because on average their condition is less serious. Another US study (Gowrisankaran and Town 1999) found that very different results were obtained when comparing risk of mortality from pneumonia between hospitals when IV variables were used (distance from the hospital, which is correlated to choice of hospital, but not severity of illness) rather than other regression techniques.

Two other North American studies apply the instrumental variable technique to ascertain the impact of an aggressive approach to the management of acute myocardial infarction (AMI) in elderly patients. Both of these studies used distance from a hospital that was able to provide specific interventions (*e.g.* cardiac catheterisation) as the IV in order to overcome the problem of unobserved heterogeneity between those who received such treatments and those who did not. The first study, which was carried out in the US (McClellan *et al* 1994), found only a very small advantage to aggressive treatment, which was thought to be commensurate with the results of randomised controlled trials looking at similar questions. A second comparable study, based in Canada (Beck *et al* 2003), was expected to show a greater improvement in outcomes because of differences in treatment protocols between the two countries, but actually found no statistically significant difference in outcomes between patients treated aggressively or more conservatively. The study concluded that the non-significant benefit

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there is some likelihood that these criteria are not fully met. In particular, in some cases method of delivery may have some bearing on readmission.

may be clinically, if not statistically significant, and further research should be carried out, including larger scale international studies using IV methodology.

There are obviously important parallels between these papers and the methodological problems in ascertaining the impact of professional care at delivery: *i.e.* unobserved heterogeneity between groups that do or do not receive a particular treatment or service will introduce bias into the results. The key factor in the success of this technique is the availability of appropriate IVs, the criteria for which are discussed more fully in the methodology section of this chapter.

4.0 Methodology

This section will discuss the methodologies used in this study. It will start by outlining the study approach and the characteristics of the data used, and will then discuss the three statistical methods used: cross tabulations and chi-squared test for bivariate descriptive analysis, logistic regression for the work comparing determinants of neonatal mortality by various subgroupings of the population and two-stage least squares regression with IV variables.

The section will then outline the variables used in both types of regression, before outlining how the comparison groupings have been developed for comparing the determinants by socio-economic group, state coverage of professional attendant at birth and urban/rural.

4.1 Approach to the study

The study will initially use bivariate analysis to examine how neonatal outcomes vary by health service variables (TT immunisations, ANC and place of delivery) when the sample is disaggregated by socio-economic groups, urban/rural residence and state percentage of professional attendants. This provides a general and simplified picture of how these factors affect the determinants of neonatal mortality. However, as health service usage variables are heavily affected by a number of confounding factors, the next step is to carry out multivariate analysis which adjusts for these.

Table 24: Summary of research objective and research methods to be used

Objective	Methods used	Data used
1. To investigate how heath care determinants of neonatal mortality (antenatal care, tetanus toxoid immunisation and delivery at an institution) differ between socio-economic groups in India.	Bivariate analysis (cross tabulations with chi-squared) and multivariate multiple regression disaggregated by wealth tertiles and mother's education.	Indian NFHS 2 (1998/9) All children born within 5 years of survey date.
2. To investigate how these determinants differ between populations with differing access to services.	Bivariate analysis (cross tabulations with chi-squared) and multivariate multiple regression disaggregated by state levels of professional attendance and rural/urban residence.	Indian NFHS 2 (1998/9) All children born within 5 years of survey date.
3. To investigate the use of instrumental variable methodology to measure the impact of institutional delivery on neonatal mortality in India.	Multivariate 2-stage least squares regression using instrumental variables (distance from health facility) disaggregated by wealth tertiles, mother's education and state levels of professional attendants.	Indian NFHS 2 (1998/9) Children born within 5 years of survey date in rural areas only.

The study draws on the model developed in Chapter 1 to identify a range of control variables that can be grouped within the following headings: broad socio-political; socio-economic; environmental; maternal health and nutrition; and biological. Initially logistic regression will be used, and once again separate regressions will be run with the data disaggregated by socio-economic groups, urban/rural residence and state level of professional attendance. The disadvantage of this method is that, as discussed, it is not able to give an accurate estimation of the association between place of delivery/professional attendance and neonatal mortality, as it does not adjust for the endogenous nature of the professional attendance/institutional delivery variables. However, it is still possible to make some sort of meaningful comparison across groups: *i.e.* it might be expected that poorer women or rural residents experience a greater risk of neonatal mortality associated with institutional/professional attendants because they are less likely to plan the use of these services in advance, and more likely to use them in an emergency where outcomes are likely to be less favourable. The final element of the study involves the use of two-stage least squares regression using IV variables in an attempt to adjust for the unobserved heterogeneity between women who do and do not seek professional care during labour. The data will be disaggregated by socio-economic groups, and state level of professional attendance, but is only available for rural residents, so urban dwellers will be excluded from the analysis.

4.2 The data

The data is drawn from the Second Indian National Family and Household Survey (NFHS 2), which was carried out in 1998/9. It covers all 26 states (although not union territories) and has an overall target sample size of approximately 90,000 ever-married women aged between 15 and 49. As with all Demographic and Household Surveys (DHS), the NFHS 2 provides nationally-representative data on a number of indicators in population, health and nutrition which are comparable across time and countries. Data is collected on all children born up to five years prior to the study.

Table 25 shows the sample sizes used in this study. Any child not exposed to the full neonatal period was removed (children born less than a month before the survey should automatically be excluded, but in practice this was not always the case).

Table 25: Sample sizes from Indian NFHS 2 used in this study

	Number
Households	91,196
Ever-married women 15-49	89,199
Women who gave birth to a live child in 5 years prior to survey	28,061
Total number of children born in 5 years before survey exposed to neonatal period	31,539
Total number of neonatal deaths	1,155
Number of early neonatal deaths	863
Number of late neonatal deaths	292

4.3 Statistical methods

4.3.1 Cross tabulation

The data was initially examined using cross tabulations and chi-squared tests to establish bivariate relationships between individual variables and outcomes. As bivariate associations for a range of variables had been explored fully for Bangladesh in Chapter 3, not all variables will be examined. The paper will focus on those health service variables of particular pertinence to the research questions, and will differentiate by wealth tertile, maternal level of education, state percentage of professional attendance and urban/rural residence. DHS sample weights[46] were used for both cross tabulations and regressions to address any issues of over-representation from particular groups within the sample. As discussed more fully in Chapter 3, the nature of DHS surveys means that data is clustered rather than truly random, but unfortunately STATA does not enable adjustment for clustering when calculating chi-squared results. It is therefore probable that the standard errors are actually somewhat larger than those on which the analysis is based. Therefore differences in mortality rate that are only significant at the 5% are with caution, as these differences may well no longer be significant if the data is adjusted for clustering.

4.32 Binomial multivariate logistic regression

As many of the input variables are likely to be closely correlated, binomial multivariate logistic regression was then carried out in order to better establish the impact of specific factors while adjusting for others, giving the equation:

$$\prod = B_0 + B_1 X_1 + B_2 X_{2+ \ldots\ldots} B_p X_p$$

where:

$\prod$ is the log odds of neonatal mortality or logit function; B_0 is the constant;

B_1 to Bp are the variable coefficients and X_1 to X_P are the explanatory variables.

DHS sample weights were once again used. As there are likely be significant correlations for many variables between births to the same mother, the data was clustered using the mother's identity number in order to adjust the standard errors. Clustering is also likely to

[46] Chi-squared tests were carried out on unweighted samples as STATA does not allow them to be carried out on weighted data. In reality the weighting made very little difference to the results.

occur at other levels (*e.g.* community), but STATA cannot cluster by more than one variable. An alternative approach would be to use multilevel modelling, but as this study does not attempt to measure variations within or between clusters, this was deemed unnecessary. In order to acknowledge that standard errors may be slightly wider than calculated, little weight is given to results at that are only just significant at the 5% level. The results are reported as odds ratios (ORs).

4.3.3 Regression using two-stage least squares regression instrumental variables

For the regression using IVs, the model is estimated as a linear probability model using two-stage least squares (2SLS) regression. This is the most commonly used model of regression using IV, even when (as in this case) the outcome variable is binary, and allows both multiple instruments and multiple treatments. It has been successfully used in a number of previous health-related studies with dichotomous outcomes (*e.g.* McClellan *et al* 1994). As its name would imply, 2SLS is estimated in two steps, each involving an ordinary least squares (OLS) regression. In the first stage, the endogenous treatment variable or variables (in this case delivery attendance) is regressed on the exogenous covariates and the instruments. In the second stage, fitted values from the first stage regression are included within the regression in place of the endogenous regressor. The 2SLS was calculated using a STATA package, as performing the two stages separately can produce problems with the standard errors. A Hausman test was used to compare the efficiency of a basic OLS regression model (without instrumental variables) with the IV 2SLS model. This test is based on the principal that coefficients from OLS and 2SLS should be consistent if the variables are exogenous.

4.3.4 Choice of instrumental variable

There are four conditions to ensuring the validity of instrumental variables (Harris and Remler 1998). Firstly, the IV must affect the probability of receiving treatment: *i.e.* receiving professional attendance or delivering in an institution. Secondly, the IV must have no independent effect on outcomes, and is not a proxy for any variables that cannot be included within the equation. Unlike the first criteria, this cannot readily be objectively tested. Thirdly, the IV must be exogenous *i.e.* it should not be related to health status, and fourthly the relationship between the IV and the probability of receiving treatment should be monotonic.

The IVs chosen for this study are distance from government hospital, distance from private hospital and distance from an all-weather road. The India NFHS 2 provides information on distance to a number of health facilities (for rural areas only), including primary health care centres, but hospitals were chosen as many lower level facilities do not have delivery facilities. Figures 26-28 show the relationship between these variables and professional attendance/delivery in an institution, which suggests that the IV meets the first and fourth criteria for an effective IV in being directly and monotonically-associated with the likelihood of receiving treatment. However, establishing whether the IVs meet the other criteria is more problematic. It is impossible to demonstrate that the IVs have no other pathway of influence on the outcomes: indeed it is possible that they could. The distance from hospital is also likely to be correlated with the distance a family would have to travel to obtain care for a sick newborn, which could somewhat complicate the relationship. However, as newborn care may be available at primary health care facilities, which are more numerous and therefore more closely located to communities, this relationship is likely to be weaker than that for institutional delivery. There is no reason to believe that the distance from institution or an all-weather road would themselves be related to health status, so the third criterion is met.

Figure 26: Bar graph showing relationship between delivery in government institutions/and distance from government facilities (rural dwellers only)

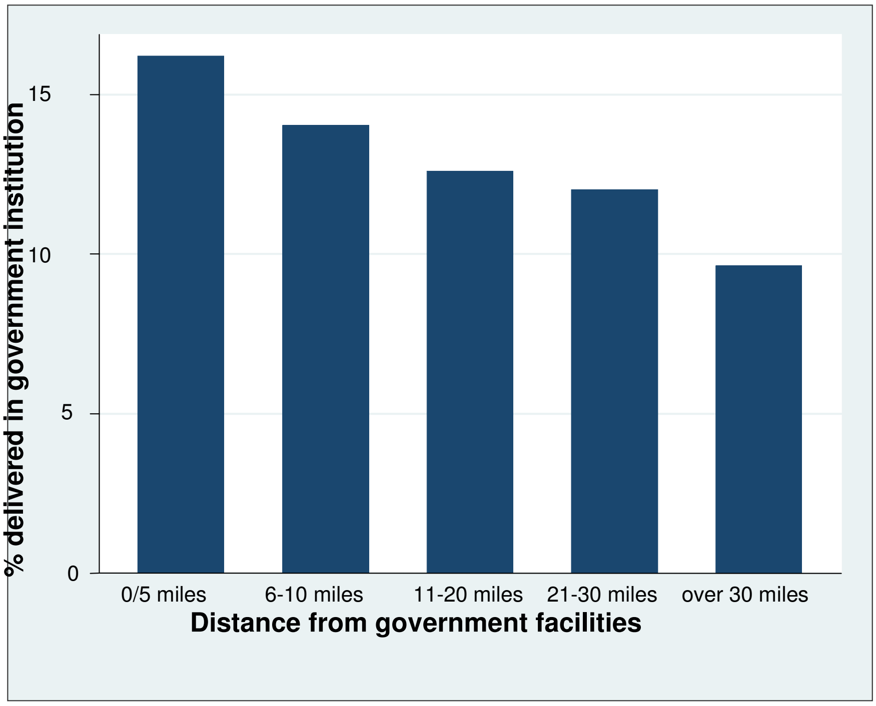


Figure 27: Bar graph showing relationship between delivery in private/NGO institutions and distance from private/NGO facilities (rural dwellers only)

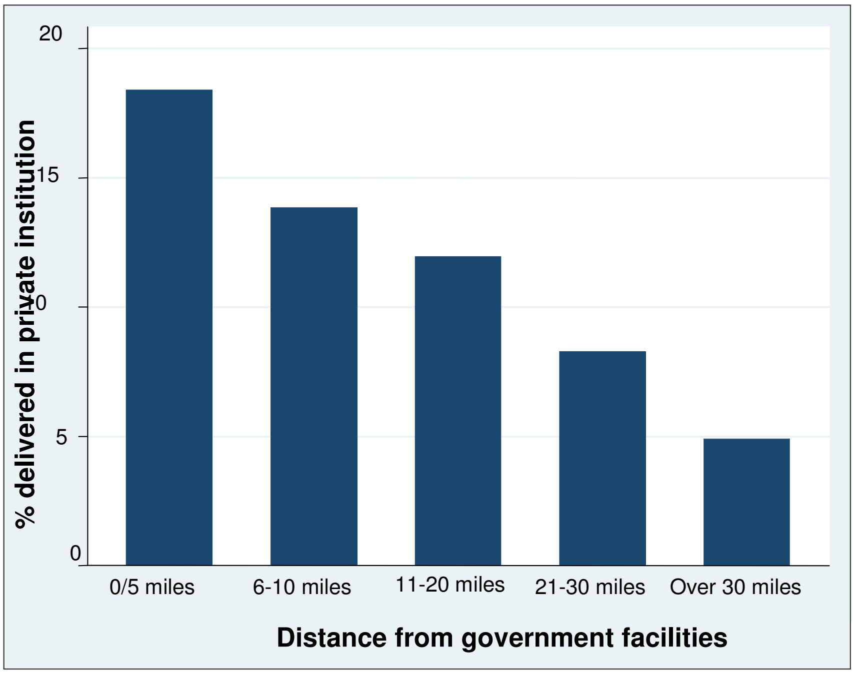
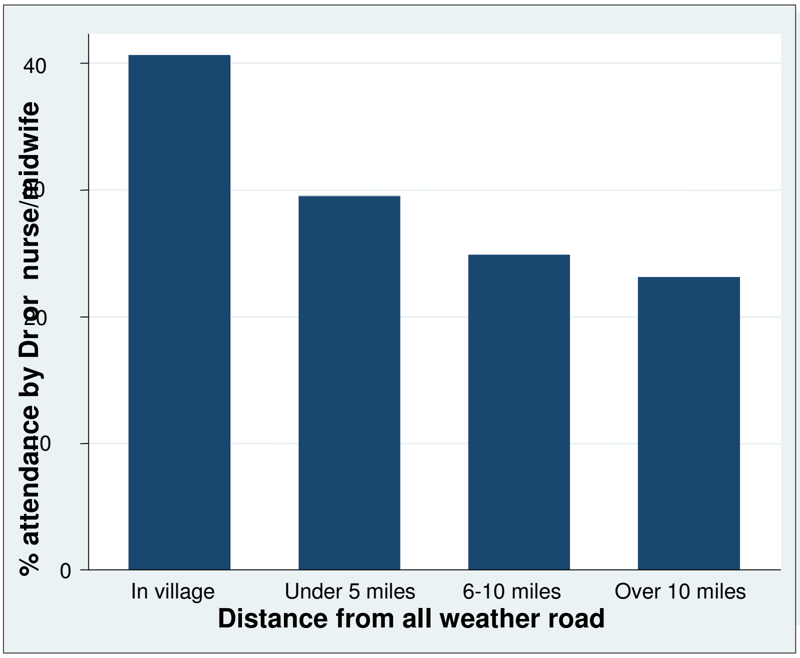


Figure 28: Bar graph showing relationship between delivery by professional attendant institutions and distance from all weather road (rural dwellers only)



A further potential limitation in using distance is that in India some women (particularly those expecting their first baby) return to the parental home to await the birth. This may somewhat weaken the relationship between treatment and IV. In fact, it is possible a similar issue is also a consideration for Beck *et al* (2003) and McClellan *et al* (1994). Both these studies use distance from home to the hospital as the IV, but in fact it is likely than many of the sample did not suffer their myocardial infarction while at home, and therefore were not transported to hospital from there. This potential problem does not seem to be addressed in these studies.

4.3.5 Limitations of IV methodology

There are a number of limitations to the instrumental variable methodology. Firstly estimates are less precise than those from other methods, and confidence intervals are often wide (Zohoori and Savitz 1997, cited in Beck *et al* 2003). Another is that while the validity of the instrumental variable is paramount to the success of the analysis, this validity cannot be proven: it is possible that the subjects within the instrumental variable groups differ in terms of some unobserved characteristics that may affect the outcome. When using IV methodology, it is also important to recognise that generalisability of findings are limited to a subgroup of marginal subjects whose access to treatment is restricted by the IV, not all subjects who do not receive the treatment. This is of particular importance when examining professional attendance at delivery, as failure to use the services may be because of a number of reasons other than distance *e.g.* financial or cultural constraints.

Another problem with the methodology used is that when used with binary outcomes, OLS regression can produce predicted probabilities outside the range 0-1. It can therefore be difficult to interpret results. In this case it would still be able to test the hypothesis that delivery in an institution or with a professional attendant is associated with reduced odds of neonatal mortality, but it would be difficult to ascertain with any certainty the extent of the reduction.

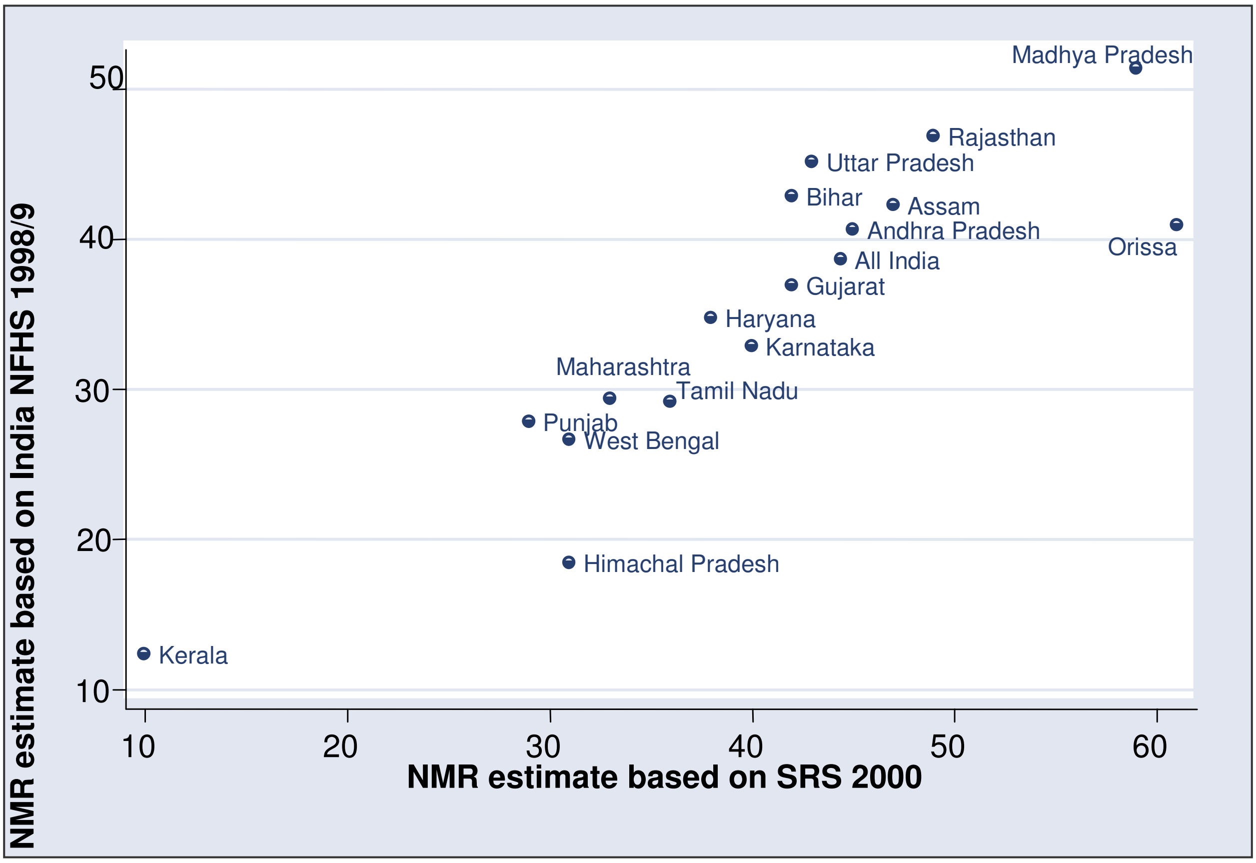
4.4 Variables included in the bivariate and multivariate analysis

The following section describes how the outcome and some of the key independent variables were chosen, and the limitations that may undermine their efficacy. Many of the variables are the same as those used in the Bangladesh study in Chapter 3, and have been discussed extensively. Therefore this section will only discuss those which differ from those used in the Bangladesh study, and the specific health care variables which are of particular interest to this study.

4.4.1 The outcome variable

Neonatal mortality is the outcome variable of interest. As previously discussed in Chapter 3, the recording of neonatal mortality can be prone to a number of errors. One way of establishing data quality is to examine the proportion of early to late neonatal deaths: a relatively low proportion of early neonatal deaths may indicate under-reporting as deaths are most frequently omitted in this group. The proportion of early neonatal deaths in the Indian DHS data was about 75% which, when compared to other countries with similar NMR, is about what would be expected (see Chapter 2 for further details). Unusually, there is also an opportunity for external validation as information is available from the Indian Sample Registration System (SRS). Figure 29 shows a scattergram comparing NMR estimates for NFHS 2 and SRS for 2000. The data, both at national and state level is fairly similar (with a few exceptions such as Orissa, Himachal Pradesh and Tamil Nadu), with an overall correlation coefficient of 0.89. The SRS state-level estimates of mortality tend to be generally slightly higher than the NFHS 2 estimates. This may suggest that there is actually some degree of underreporting in the NFHS 2, particularly as a previous study does suggests that the SRS system can lead to the under-enumeration of deaths, although it does not specify within which age group (Bhatt 2002).

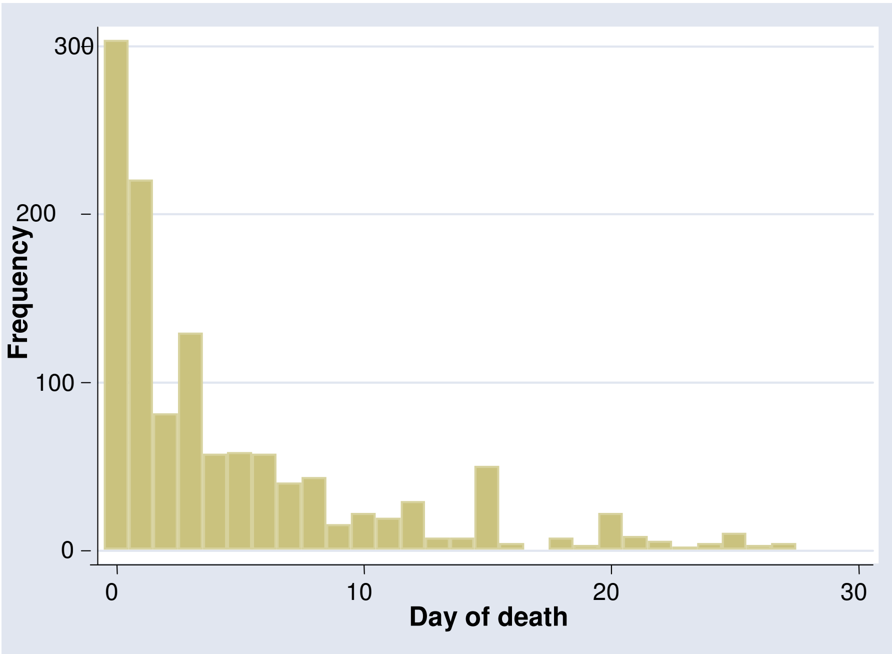
Figure 29: Scattergram of NMR estimates for SRS 2000 and NFHS 2 1998/9



Source of SRS data: SRS statistical Report 2000 (2004), cited in Dadhich J. and Paul V. (eds) (2004). *The State of India's Newborns*, National Neonatal Forum and Save the Children US, New Delhi/Washington DC.

Because factors around the time of birth (*e.g.* delivery care and maternal health) may have greater effects on early than late neonatal mortality, I originally considered examining early neonatal mortality separately. This is not always easy, as there are often inaccuracies in reporting of age of death, and in particular some datasets demonstrate marked heaping at seven days. Figure 30 shows the data on neonatal mortality by day of death, and in this case no particularly anomalies can be detected. It can therefore be assumed that early and late neonatal deaths can be disaggregated with relative accuracy, and regressions were originally run separately for early neonatal mortality. However, when the analysis was carried out, differentiation of early neonatal mortality actually added little to the findings. In general the results were the same for early neonatal mortality as for total neonatal deaths, although confidence intervals were relatively larger because of smaller numbers of deaths. In the interests of clarity and brevity, it was decided not to report the results for early neonatal deaths.

Figure 30: Distribution of day of death for neonatal mortality



4.4.2 Explanatory variables

The choice of variables is based on the model developed in Chapter 1 for the Bangladesh study (Figure 4). This model is based on the seminal framework developed by Mosley and Chen (1984), but adapted to acknowledge and highlight the specific determinants of particular importance to neonatal survival. A full list of the variables included can be seen in Appendix 12.

4.4.3 The wider socio-political environment: state groupings

It was decided to use groupings rather than individual states as dummy variables for location within the regression. Probably the most common method for grouping Indian states is based on geographical, ethno-linguistic and cultural factors, and creates six groupings: North, Central, East, North East, West and South. However, a more recent variation on this approach is to use the category of BIMARUO states, which include Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh and Orissa. The inclusion of this category is useful as it is a relatively coherent group of states that perform poorly across a number of social and economic criteria, and it has been used in a number of studies examining disparities within India (*e.g.* Basu *et al* 2007). However, the other geographical groupings are very heterogeneous: their inclusion in regression models can be justified as a measure of cultural factors, but the states within groups differ greatly in terms of health care and other health and social indicators. Table 26 shows the mean NMR for state groupings, as well as the range between states within each group. As can be seen, with the exception of the BIMARUO states (which all have high NMRs) the ranges are often vast: for instance in the Southern states NMR ranges from 12.3 (Kerala) to 40.6 (Andhra Pradesh)[47]. There are also wide differences between states within grouping for percentage mothers who received professional attendance, recommended antenatal care and no schooling (with the exception of the BIMARUO states) suggesting there is little correlation between state groupings and health or social indicators. This implies that while they may have some value as an indicator of cultural or geographic difference, they cannot be seen as a proxy for access to, or quality of, care. They are therefore included in the regression, but not used as a comparison grouping for access to health care.

[47] The "Other Eastern States" Group only has one state in it, so obviously shows no variation.

Table 26: Mean (unweighted) NMR, % professional attendance, % mothers with no antenatal care and % mothers with no education (with interstate range in brackets) for Indian state groupings

	% of total children in sample	NMR (Range for states within group in brackets)	% professional attendance (Range for states within group in brackets)	% some ANC (Range for states within group in brackets)	% mothers with no education (Range for states within group in brackets)
BIMARUO	50.6	45.6 (40.9 -51.3)	25.5 (20.3-35.7)	54.7 (79.2-35.6)	69.2 (55.4-76.1)
Other Northern States	6.4	29.9 (18.4 –35.5)	51.9 (40.5-66.0)	77.7 (65.5-85.6)	42.3 (23.4-59.5)
West Bengal	7.1	26.6	44.1	90.5	44.8
Northeast	3.2	38.3 (17.7 – 42.2)	36.1 (20.3-66.2)	62.2 (52.8 - 86.4)	44.9 (8.4-50.4)
West	13.6	31.9 (29.3 – 36.9)	67.6 (53.5-90.8)	89.0 (86.3-97.9)	37.6 (15.0-45.9)
South	19.2	32.1 (12.3 – 40.6)	71.8 (59.0-94.0)	93.8 (86.2-99.7)	35.7 (2.1-48.7)

Group 1: BIMARUO: Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh, Orissa
Group 2: West: Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, New Delhi
Group 3: Other Eastern States: West Bengal
Group 4: North East: Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura
Group 5: West: Goa, Gujarat, Maharashtra
Group 6: South: Andhra Pradesh, Karnataka, Kerala, Tamil Nadu

4.44 Socio-economic variables

Most of the socio-economic variables reflect those used in Chapter 3. No direct measure of wealth or income is available for DHS surveys, so a proxy of asset quintiles is used (which have been established using the same technique by Macro as for the Bangladesh DHS in Chapter 3). This method has a number of important limitations, and the problems have been extensively discussed in the previous chapter. Some of the most pertinent concerns include that the measurement of assets is made at the time of the survey, not at the time of the child's birth. It is quite possible that the family's economic position may have changed markedly in what could be up to five intervening years. There are also concerns that the use of assets may not adequately capture the differences between rural and urban wealth: *i.e.* the possession of livestock may be a key measure of rural wealth, but is not appropriate in the urban context (Houweling *et al* 2003). Asset indices are also unable to consider the quality of the asset: in some cases a large proportion of the population may possess an asset, but more wealthy families would possess one that is more costly and of greater quality.

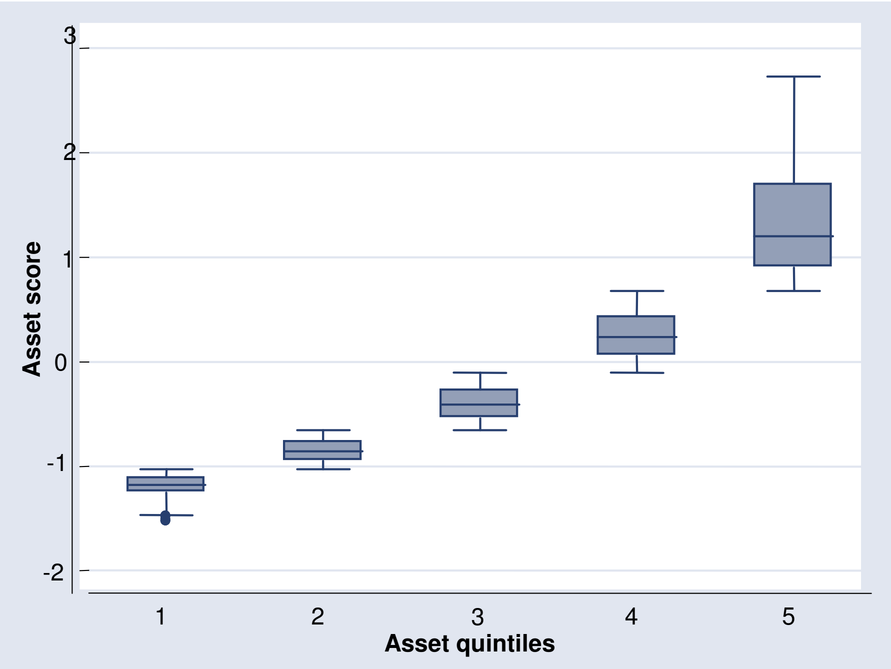
The pattern of the relationship between wealth quintiles and neonatal mortality from the NFHS 2 data is fairly much what would be expected, with poorer quintiles experiencing higher mortality (although the neonatal mortality rate for quintile 2 is very slightly lower than for quintile 3, see Table 27). This differs from the findings in Chapter 3 for Bangladesh, where the pattern was much less clear. One possible reason suggested why no clear pattern was discernable for Bangladesh (even when quintiles were calculated separately for urban and rural dwellers) was the lack of variation in asset score for quintiles 1-4. This was particularly marked for rural dwellers, who made up the vast majority of the sample. The pattern for India also shows a much greater variation for quintile 5, but scores for quintiles 1-4 do show some variation (see Figure 31). Because expected patterns are shown in relation to mortality, the quintiles have been used as defined by Macro International, and not disaggregated into rural/urban as done in the Chapter 3 for Bangladesh (which produced only relatively limited benefit anyway).

Table 27: Neonatal and early neonatal mortality rate (per 1000 live births) by socio-economic characteristics

Socio-economic characteristic	% of total sample	NMR
Asset index quintile		**
Quintile 1 (lowest)	23.3	47.2
Quintile 2	22.3	39.8
Quintile 3	20.1	41.6
Quintile 4	19.1	34.3
Quintile 5 (highest)	15.1	24.8
Asset index tertile		**
Tertile 1 (poorest)	39.8	43.8
Tertile 2	32.0	41.7
Tertile 3 (richest)	28.3	27.7
Urban /Rural residence		**
Urban	22.5	31.8
Rural	77.5	40.5
Highest level of maternal education		**
No education	54.4	46.0
Primary education	15.7	32.8
Secondary education	22.1	30.6
Further education	7.9	21.1

**Chi- squared test significant at 1%

Figure 31: Distribution of asset scores by asset quintile



To take account of the India-specific context two further variables, religion and caste are also included.

4.4.5 Biodemographic variables

Biodemographic variables for first birth, birth interval and maternal age reflect those used in Chapter 3, and are listed in Appendix 12.

4.4.6 Maternal health variables

Unfortunately, the data collected on maternal complications is poor. Unlike many DHS that collect data designed to reflect major complications around the time of birth (convulsions, excessive bleeding, prolonged labour and infection) the Indian NFHS only collects on a wider and somewhat more nebulous range of antenatal problems: night blindness, blurred vision, convulsions, swelling of legs, body or face, excessive fatigue, anaemia and vaginal bleeding. The problems of self reported morbidity have been discussed extensively in Chapter 3, but this data present a further problem in that while these variables may be a sign of serious complications, some (*e.g.* tiredness, swollen ankles) are difficult to differentiate from normal pregnancy symptoms. Table 28 shows reported incidence of these symptoms, as well as the NMR associated with each symptom. Night blindness, or xeropthalmia, is a symptom of vitamin A deficiency. The role of vitamin A in reducing maternal and perinatal morbidity and mortality is still under research, and while some evidence exists that deficiency causes poorer pregnancy outcomes it is inconsistent. In addition, studies suggest that self reporting of night blindness may be a poor predictor of vitamin A deficiency (Wedner *et al* 2004). However, despite these uncertainties, self reporting of night blindness was associated with increased neonatal mortality. Blurred vision, convulsions and swelling can be symptoms of eclampsia or pre-eclampsia, but this data suggests that these symptoms are much more widely reported than the global incidence of pre-eclampsia (which is estimated at around 3.2%). However, once again they were associated with increased mortality. Nearly half of all women reported excessive fatigue, and there was no association with neonatal mortality. There was no increased mortality for women who reported vaginal bleeding or anaemia, both of which are symptoms or conditions which can have important impact on outcomes, but which may also be mild and relatively benign.

Table 28: Proportion of sample reporting antenatal complications, with related NMR

Reported symptom/complication	% all births in sample	NMR
Night blindness	12.1	46.6**
Blurred vision	21.8	44.1**
Convulsions	14.4	43.0*
Swelling	28.2	41.0**
Excessive fatigue	43.6	35.4
Anaemia	27.1	35.7
Vaginal bleeding	3.1	41.9
Composite variable for complication (reports any complication except excessive fatigue)	53.2	43.0**
No complication reported	46.8	33.5**
Total	100	35.1

** Difference between NMR for women reporting the complication and those who did not significant at 1% level
* Difference between NMR for women reporting the complication and those who did not significant at 5% level

As these variables tend to be quite nebulous, it was uncertain how they could best be used. A decision was made to develop a composite variable of all complications, but not include the variable for excessive tiredness as such a high proportion of women reported it and it was not correlated with increased NMR. Based on these criteria over half of all women were included as having reported antenatal complications, and this composite variable was associated with increased neonatal mortality.

4.4.7 Health care variables

Antenatal care (ANC) has been divided into three categories: those who have received the WHO recommended regime of at least four visits commencing before the end of the fourth month of pregnancy, those who received some, but not the recommended regime, and those who received no ANC. Tetanus toxoid immunisation (TT) has been classified as either two or more doses (which provides protection for the pregnancy) or less than two doses. However, as discussed in Chapter 3, the variable is not able to ascertain whether those who have not received the recommended number of doses have received sufficient in previous pregnancies to produce lifetime immunity.

When care at delivery was considered, there was a significant proportion of women claiming to have had home deliveries attended by professional personnel. This was included as a category, along with home birth without professional attendant, delivery in a government institution and delivery in a private/NGO institution. However, as discussed in the previous chapter, it is often difficult for women to distinguish professional from untrained or semi-skilled personnel. In particular, it was also uncertain as to whether deliveries by ANMs should be included in this category: while they are a key provider within the Indian health care systems with a clear remit for carrying out normal deliveries, it is uncertain as to whether they should really be included as skilled attendants (although the NFHS 2 final report places them in this category). It was decided that they should be included, but the term "skilled attendant" will not be used as it is impossible to determine from the DHS data those who fulfil the WHO criteria for this category (it is also uncertain whether the nurses and doctors also included in this category will have received adequate training to ensure they are skilled attendants). The term "professional attendant" will be used instead. Caesarean section was also included in the regressions.

4.4.8 Biological variables

Sex of the child and whether the child was a twin was included. However, in addition the Indian NFHS 2 had data on birth weight, based on the mother's self-reported estimate. It was unclear whether this should be included as an independent variable within the regression for several reasons: firstly birth weight is itself an outcome as well as a determinant, and is influenced by many of the same determinants as mortality. Secondly, maternal estimates of infant size have been shown to be unreliable (Channon 2004). It was therefore decided to include this variable in the regressions, but it was added separately so it could be ascertained whether its addition significantly changed the coefficients of other determinants (in reality its addition did not create any marked changes in any other variables, so it was included in the final model).

4.4.9 Women's autonomy

The strong correlation between infant survival and antenatal care found in Chapter 3 raised issues as to whether this variable was actually measuring a particular characteristic of the mother rather than the impact of health care. The Indian NFHS 2 attempts to provide some information on women's autonomy by asking questions on involvement in household decision making, and it was decided to include some of these measures within the regression analysis to further investigate this issue. Initially the possibility of developing a composite index based on these questions was considered. However it was decided that a more appropriate approach would be to choose several variables that would intuitively appear to have the most bearing on a woman's ability to support and care for herself and her child. The variables chosen were involvement in decision to obtain health care for herself, ability to visit family and opportunity to put aside money for herself. The limitations of these variables will be considered when discussing the results.

4.5 Development of comparison groupings

4.5.1 Socio-economic groups

Because of concerns about sample size, the data on asset indices were recalculated to provide wealth tertiles rather than quintiles (using the existing asset scores determined by Macro). The disadvantage of this is that the differences between lowest and highest group will obviously not be so great, but it was felt that the advantage of increased sample size in each group outweighed this. Obviously the limitations of asset scores as a method of measuring inequality have been discussed extensively in Chapter 3, which concluded that in countries where much of the population is extremely poor, lack of variation in asset scores may fail to adequately differentiate outcomes. The clear monotonic relationship between wealth index tertile and neonatal mortality suggest that this may not be the case in India, and so tertiles were used, but may be interpreted with caution.

Because of the possible limitations of the asset index method of measuring wealth, mother's level of education has also been used as a comparison grouping. This also shows a strong monotonic gradient for neonatal mortality (see Table 27), and has the added advantage that it does not change over time (except possibly for a very small group of very young mothers who further their education after the birth of their child). Because the number of women receiving further/higher education is so low, this category has been amalgamated with secondary education for the purpose of comparison grouping. There is obviously going to be a correlation between education and wealth quintile: Table 29 demonstrates that the majority of mothers with secondary/further education will be from wealth tertile 3. However, there are some major differences: for instance nearly a fifth of women in the richest tertile actually received no education.

Table 29: Cross tabulation of level of education by wealth tertile (% all births)

Tertile	No education	Primary education	Secondary/ further education	Total
First	80.4	12.5	7.1	100
Second	53.3	21.8	25.0	100
Third	18.8	14.4	66.9	100
Total	50.8	16.2	33.0	100

4.5.2 Grouping by access to professional attendant at birth

As this study intends to establish how determinants may differ in relation to differing access to health care services, it was decided to also group mothers based on the state percentage of professional attendants at delivery. Three categories were created: states with attendance rates of over 60%, states with 35-60% and those with under 35%. An analysis of the characteristics of the groupings can be found in Appendix 13. This includes a full analysis of the associations between these groups and coverage levels of ANC and TT immunisation, and suggests that states with higher rates of coverage for attendance at birth generally have higher rates of coverage for ANC and TT. Appendix 13 also attempts to examine aspects of quality of care. While DHS data does not offer any real indicator of quality, it does provide information on the number of women who received a range of key interventions during their antenatal care, which may provide some indicator of quality. Again, it finds an association between the state level of attendance and number of ANC interventions received. Women in the group of states with the highest proportion of professional care at delivery also received the greatest number of interventions, and women in the group with the lowest proportion of professional care received the lowest number of interventions. While it cannot be claimed that these groupings in any way represent quality of care or access to other aspects of care, these findings do suggest that there are strong associations.

Appendix 13 also examines the relationship between state level per capita GDP and coverage of professional care, and finds there is a correlation, but with much variation. The correlation suggests that higher rates of professional attendance could be a function of greater wealth within states. However, further analysis finds that states with over 60% attendance have a smaller differential for professional attendance between asset quintiles suggesting that a relatively higher proportion of poor women use services in this group. Appendix 13 also describes a correlation between level of professional attendance and health care spending (both public and total spending), but again there is much variation.

4.5.3 Urban and rural residence

Because there is also a sharp divide in health care access between urban and rural areas, comparisons will also be made on these for the bivariate analysis and logistic regression. As the data needed for the 2SLS regression using IV variables only covers rural areas this differentiation cannot be made for this aspect of the study.

5.0 <u>Results</u>

5.1 Descriptive analysis

This section uses bivariate analysis (cross tabulations with chi-squared tests) to develop a greater understanding of the health care variables used in this study and their relationship with neonatal mortality. It addresses the following questions:

- How are tetanus toxoid immunisation, antenatal care and place of delivery associated with neonatal mortality?
- How does uptake of tetanus toxoid immunisation, antenatal care and institutional delivery vary by socio-economic group (wealth quintile/tertile and mother's education) and access to services (state level of professional attendance at delivery and urban/rural residence)?

- How do the associations between tetanus toxoid immunisation, antenatal care and institutional delivery and neonatal mortality differ when mothers are disaggregated by socio-economic group (wealth quintile/tertile and mother's education) and access to services (state level of professional attendance at delivery and urban/rural residence)?
- Does the degree of socio-economic inequality vary as a result of level of access to services (state level of professional attendance at delivery and urban/rural residence)?

5.1.1 The association between antenatal care/tetanus toxoid immunisation and neonatal mortality

Table 30 shows how neonatal outcomes vary based on use of antenatal care/TT. As can be seen, women who received no antenatal care had higher neonatal mortality than those who received some antenatal care, but those who received recommended antenatal care had the lowest rate of mortality: indeed it was considerably less than half that of women who received no antenatal care. For the small proportion of women where data was missing, mortality rates were very high. However, the difference between those who received recommended and no antenatal care was still significant at the 1% level if this group was discarded. The table also shows that women who had two or more TT immunisations had a neonatal mortality rate nearly half that of those who had none or one, which was also significant at the 1% level.

Table 30: Cross tabulation of NMR by level of Antenatal Care/Tetanus Toxoid immunisations

	% of sample	NMR
Level of ANC		**
No ANC	34.4	52.8
Some ANC (but not WHO recommended level)	53.1	30.0
Recommended level of ANC	11.9	21.3
Neonatal mortality by TT immunisation		**
Less than 2 TT immunisations	32.3	54.1
Two or more TT immunisations	67.2	28.1

** Difference between NMR significant at 1% level
* Difference between NMR significant at 5% level

5.1.2 Variation in level of uptake for antenatal care/tetanus toxoid immunisation by socio-economic groups/access to services

Table 31 shows coverage of ANC and TT immunisation disaggregated by socio-economic group, state level of professional attendance and urban rural residence. As might be expected, there is a strong socio-economic gradient for the use of both these services, with more wealthy and educated women having much higher levels of TT coverage and ANC: indeed women in tertile 3 are ten times more likely to receive recommended levels of ANC than those in tertile 1. Those in states with higher levels of professional attendance are also much more likely to receive these services as already discussed, as are those in urban rather than rural locations.

Table 31: Percentage of mothers using antenatal services disaggregated by wealth quintile, maternal education, level of state professional attendance and urban/rural residence

	Recommend-ed ANC	Some ANC	No ANC	Two or more TT	Less than two TT
Wealth tertile 1	2.7	44.6	52.2	60.4	39.6
Wealth tertile 3	28.4	59.4	12.0	93.8	6.3
No maternal education	3.3	46.1	51.0	62.9	37.1
Secondary/ further maternal education	29.1	61.0	9.9	94.4	5.6
Professional attendance over 60%	26.7	65.1	8.0	91.5	8.5
Professional attendance under 35%	3.0	38.9	57.3	62.8	37.2
Urban	25.6	60.2	13.9	90.0	10.0
Rural	8.0	51.5	40.2	71.6	28.4

N.B. Rows do not add up to exactly 100% because of a small amount of missing data

5.1.3 Association between antenatal care/tetanus toxoid immunisation and neonatal mortality disaggregated by socio-economic group/access to services

Table 32 demonstrates how the association between neonatal mortality and TT/ANC differs within subgroups. When tertiles are examined separately there is still a marked difference for all groups between those who have and have not received TT. This suggests that the difference in mortality for women who do or do not receive TT is not just due to socio-economic differences between the two groups. Indeed, the highest rate of mortality was in women with secondary/further education who did not receive 2 or more TT (although the sample size was small: only 5.6% of women with the highest educational level did not receive TT coverage). When the sample is disaggregated by urban/rural and percentage of professional attendant at birth at state level there are still marked differences between those who received or did not receive recommended TT immunisation, and these are all significant at the 1% level. A similar pattern is found when ANC is considered. When the data are disaggregated by tertile, urban/rural and state level of professional attendance, a higher level of antenatal care is associated with reduced mortality in all groups except tertile 1, where those who received some antenatal care had lower rates of neonatal mortality than those who received recommended levels. This could be just because the sample size is small (and therefore confidence intervals are large), or because poorer people have different patterns of ANC attendance, and frequent attendance in this group could indicate complications in pregnancy.

Table 32: Cross tabulation of NMR by level of Antenatal Care/Tetanus Toxoid immunisations dissagregated by tertile/rural urban and level of professional attendance

	Tertile 1	**Tertile 3**	**No education**	**Secondary/ further education**
Tetanus toxoid immunisation	**	**	**	**
Less than two TT	57.7	47.2	57.2	70.6
Two TT or more	29.6	25.0	35.9	24.0
Antenatal care	**	**	**	**
No ANC	52.7	38.0	53.7	50.1
Some ANC	27.4	28.6	33.4	27.9
Recommended levels of ANC	39.2	18.8	41.9	17.6
Total	**39.8**	**28.3**	**54.3**	**29.2**
	Professional attendance over 60%	**Professional attendance under 35%**	**Rural residence**	**Urban residence**
Tetanus toxoid immunisation	**	**	**	*
Less than two TT	54.1	58.5	59.0	46.5
Two TT or more	27.1	33.9	30.2	28.5
Antenatal care	**	**	**	**
No ANC	51.2	53.2	53.5	46.4
Some ANC	30.3	29.3	29.9	30.4
Recommended ANC	21.5	24.1	19.0	23.7
Total	**30.4**	**45.4**	**40.4**	**31.8**

** Difference between NMR significant at 1% level
Difference between NMR significant at 5% level

It is interesting to note that when only women who have received two or more TT immunisations are considered, there is no difference in mortality between tertiles 1 and 3 (and indeed the usual socio-economic gradient is reversed for maternal education). A similar pattern is found for women who have received some ANC (although a strong socio-economic gradient still exists when women who had recommended ANC are considered, possibly because of different patterns of usage). This may suggest that provision of TT and to some extent ANC actually promote greater socio-economic equity.

5.1.4 The association between place of delivery and neonatal mortality

Table 33 shows the neonatal mortality rate by place of delivery. As can be seen, the majority of women delivered at home without a professional attendant. When the whole sample is included there is little difference between those who delivered at home without professional attendance, and those who delivered in government institutions. The difference in mortality between those who delivered at home without professional attendance and those who delivered in a private/NGO institution was significant at the 5% level but not 1% level. The difference between those delivering at home with or without professional attendance was not significant.

Table 33: Cross tabulation of NMR by place of delivery

Place of delivery	% sample	NMR
		*
Home: not attended by professional personnel	57.5	39.4
Home: attended by Dr/Nurse/Midwife/ANM	8.1	31.3
Government facility	16.2	37.8
Private/NGO facility	17.5	29.1

* Difference between NMR significant at 5% level

5.1.5 Differences in use of delivery services between groupings

When use of delivery services is disaggregated by wealth tertile, maternal education, percentage professional attendance and urban/rural residence (Table 34), as would be expected greater disparities exist. While 80% of women in tertile 1 did not have a professional attendant, this figure is only 24% for tertile 3. Large differentials are also seen between women with no education and those with secondary education, and urban and rural residents. Levels of home delivery with professional attendance are low for all subgroups (6-10%). Deliveries are more frequent in government than private/NGO institutions for women in tertile 1, with no education, and those in rural areas, whereas for the other groups private/NGO institutions are more popular (though only by a very small margin for those in states with professional attendance under 35%).

Table 34: Percentage of women using types of delivery care disaggregated by wealth tertile, maternal education, level of state attendance and urban/rural residence

	Home delivery – no professional attendance	**Home delivery – professional attendance**	**Government institution**	**Private/NGO institution**
Wealth tertile 1	80.3	5.7	7.5	4.5
Wealth tertile 3	26.0	10.5	29.8	33.4
No maternal education	76.4	7.1	9.3	6.5
Secondary/further maternal education	25.7	9.5	26.1	38.3
Professional attendance over 60%	30.7	8.7	24.3	35.8
Professional attendance under 35%	75.7	7.1	7.9	8.3
Urban	26.4	8.0	29.1	36.0
Rural	66.5	8.3	12.5	12.1

Rows do not add up to exactly 100% because of a small amount of missing data

5.16 The association between neonatal mortality and type of delivery disaggregated by socio-economic groupings

When tertiles were examined separately (Table 35) tertile 1 has higher rates of mortality for all places of delivery than tertile 3, but within each tertile rates of mortality for home deliveries and institutional deliveries were similar. It might be hypothesised that poorer women would experience a greater increase in mortality if they used institutions as they would be more likely to be using them when complications arose, and may wait longer until seeking skilled care. However, there is no evidence of this: in fact there appears to be a greater rise in mortality for births in Government institutions compared to at home without skilled care for tertile 3 than tertile 1 (although it is not significant). This may be partly because women in tertile 3 who have home deliveries without a professional attendant appear to have achieved quite low levels of neonatal mortality (24 per 1000 live births), while those giving birth unattended in tertile 1 have an NMR of nearly double this.

Table 35: Cross tabulation of NMR/place of delivery disaggregated by wealth tertile, maternal education, level of state attendance and urban/rural residence

	Tertile 1	Tertile 3	No education	Secondary/ further education
Place of delivery			**	
Home delivery, no professional attendant	41.1	24.2	42.7	29.5
Home delivery, professional attendant	28.4	21.0	31.1	25.3
Government institution	45.3	31.5	58.8	29.2
Private/NGO institution	42.3	26.2	50.8	23.8

** Difference between NMR significant at 1% level

Conversely, when the data is disaggregated by maternal education, there is a marked and significant increase in mortality among women with no education who use government or private/NGO facilities compared to those who give birth at home, whereas rates are very similar for those with secondary education. This seems to be somewhat at odds with the findings for tertile groups, but as the difference for both tertile groups and secondary/further education is not significant it may just indicate large confidence intervals. However, as mentioned before while wealth quintile and education are correlated there are marked differences, so these findings may reflect specific factors related to important distinctions between the these two socio-economic indicators.

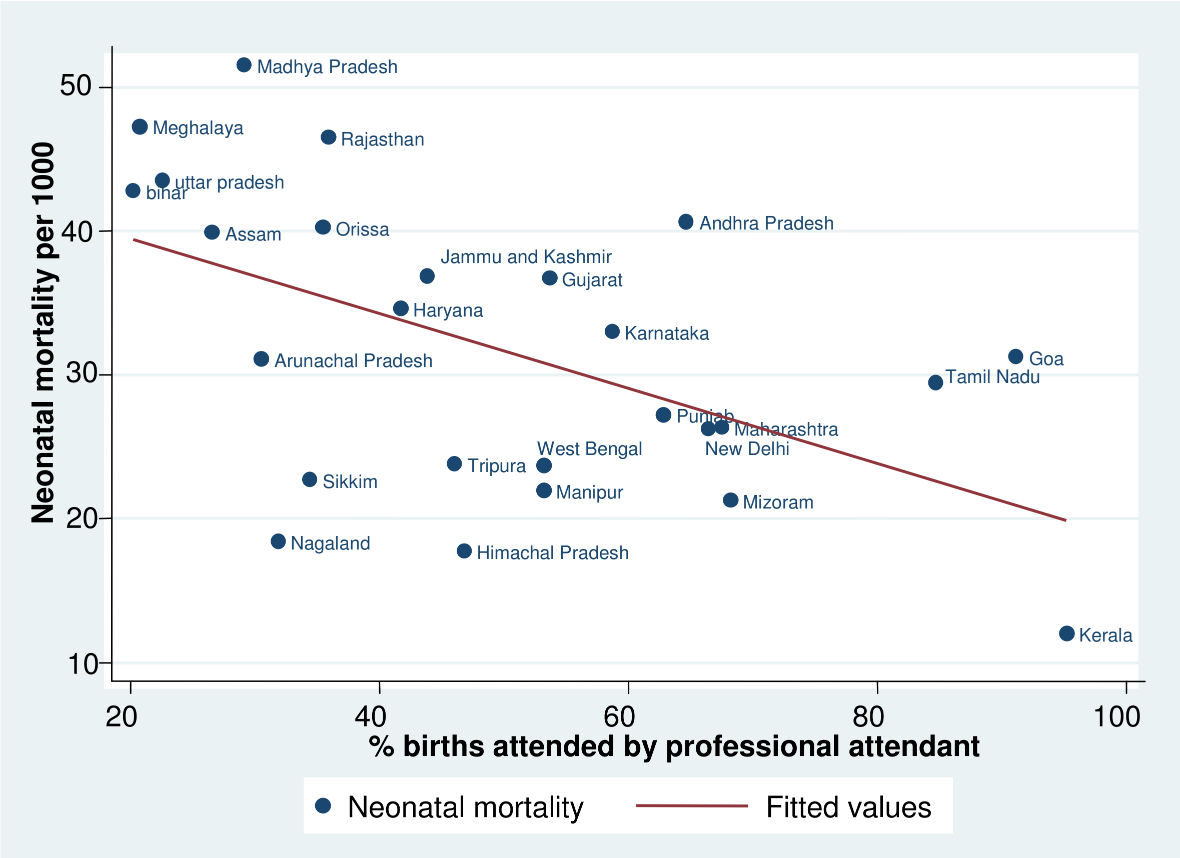
5.1.7 The association between state level of professional attendant at delivery and state level of NMR

Table 36 shows the mean NMR and range for neonatal and early neonatal mortality, disaggregated by level of state professional attendant at delivery. As can be seen, higher rates of professional attendants are, on average, associated with lower mortality, but the range is considerable. This is probably more clearly demonstrated as a scattergram (Figure 32), which shows a weak linear relationship between neonatal mortality and level of professional attendant, but much variation around the fitted line.

Table 36: Mean average (unweighted) neonatal mortality by level of state trained attendance (range in brackets)

	Professional attendance over 60%	**Professional attendance 35 - 60%**	**Professional attendance over 60%**
Neonatal mortality (rate per 1000 deaths)	27 (12 - 41)	36 (17 - 47)	43 (18 – 52)

Figure 32: Scatterplot of neonatal mortality by state level of trained attendance



5.18 The association between neonatal mortality and type of delivery disaggregated by level of access to services

When the sample is disaggregated by levels of professional attendant, states with a level of professional attendance over 60% had levels of neonatal mortality for deliveries in government institutions slightly lower those who delivered at home without professional attendance, and somewhat lower again (although not significantly so) for those who gave birth in private/NGO facilities. Rates were higher for those who delivered at home with a professional attendant, but the sample size was very small for this group. For states where attendance was below 35%, neonatal mortality was markedly higher (but only significant at the 5% level) for those who delivered in government institutions than those who delivered at home without a professional attendant, and was similar for those who delivered in private/NGO institutions. These differing patterns probably reflect that a greater proportion of women without complications have planned deliveries in institutions in the states with attendance above 60% than the states with below 35%, therefore resulting in good outcomes.

Table 37: Neonatal mortality by place of delivery, disaggregated by state level of professional attendants and urban/rural residence

	Professional attendants over 60%	**Professional attendants under 35%**	**Rural residence**	**Urban residence**
Place of delivery		*		
Home delivery, no professional attendant	33.1	42.9	40.0	34.5
Home delivery, professional attendant	43.4	24.4	32.2	28.0
Government institution	29.2	54.1	41.3	32.5
Private/NGO institution	23.6	43.6	31.8	25.9

* Difference between NMR significant at 5% level

When urban and rural mothers are disaggregated, those who delivered at home had similar rates of neonatal mortality to those who delivered in government institutions (although the overall rates for both places of delivery were lower for urban areas). Rates for professional attendance at home and private deliveries were somewhat lower, but the difference was not statistically significant.

5.1.9 Does level of professional attendance affect socio-economic inequities?

Table 38 shows neonatal mortality rate for each grouping based on level of professional attendance disaggregated by tertile, maternal education and urban/rural divide. It is very noticeable that when tertiles are examined the mortality gradient increased as level of attendance decreases: indeed while the differences in mortality by tertile are significant at the 1% level for states with attendance levels of 35-60% and under 35%, they are not significant in states with attendance over 60%. Women in tertile 3 appear to have very similar rates of NMR regardless of state grouping, but mortality increased markedly as level of professional attendant declines for the other two tertiles. It could therefore be tentatively suggested that socio-economic inequities are greater where service provision is weaker. A less marked pattern is found when the data is disaggregated by maternal education. When urban and rural residence is examined, there is no real difference in mortality in states with professional attendance over 60%, but more marked differences exist in the groups with lower levels of state attendance (although only significant at the 5% level for 35-60% and not significant for under 35%).

Table 38: Neonatal mortality rate in each state grouping disaggregated by tertile, highest education and urban/rural residence

	State level of professional attendance over 60%	State level of attendance 35-60%	State level of attendance under 35%
Tertile		**	**
Tertile 1 (poorest)	36.6	41.1	47.6
Tertile 2	26.5	41.5	44.4
Tertile 3 (richest)	27.1	26.1	26.8
Education	*	**	**
No education	35.5	42.8	48.0
Secondary/further education	24.9	23.5	32.9
Urban/Rural residence		*	
Urban	27.7	28.6	35.0
Rural	29.1	38.2	43.9

** Difference between NMR significant at 1% level
* Difference between NMR significant at 5% level

These findings could suggest that increased access to services leads to a decrease in socio-economic inequalities. However, the fact that the pattern is less marked for maternal education may suggest that it is actually at least partly increased level of education rather than access to services that results in greater equity in mortality (the analysis in Appendix 13 found that states with higher levels of attendants also had higher levels of maternal education).

5.1.9 Summary of key findings from bivariate analysis

- Women who received some ANC or TT immunisation had markedly and significantly lower NMRs than women who did not. When ANC is considered, women who received recommended ANC had the lowest NMR.
- There is a strong socio-economic gradient in use of ANC and TT immunisation. Women in states with higher rates of professional attendants and who live in urban areas are also more likely to utilise these services.
- When the sample is disaggregated by socioeconomic group, there is still a significant difference in NMR between women who did and did not receive TT immunisation.

This is also the case with ANC, except when women from asset tertile 1 are examined: those who had recommended ANC actually had higher NMR than those with lower levels of ANC. This may reflect patterns of service use among poorer women.

- When only women who received 2 or more TT or some antenatal care are examined, there is no (or little) socio-economic mortality gradient. This may suggest that both ANC and TT have a role in improving equity of outcomes.
- There is a weak linear relationship between NMR and state level of professional attendant, but much variation around the regression line.
- For the whole sample, there is no real difference in NMR between those who delivered at home without professional attendance, and those who delivered in government institutions. The difference in mortality between those who delivered at home without professional attendance and those who delivered in a private/NGO institution is modest.
- When the sample is disaggregated by socio-economic groups and state level of professional attendants, there is a marked and significant increase in mortality among women with no education who use government or private/NGO facilities, and for women in states with less than 35% attendance who use government facilities. Rates between home and institutional births in the other groups are not significantly different.
- Inequalities in NMR are greater for wealth quintiles urban/rural residence and (to a lesser extent) maternal education in the state grouping with the lowest levels of professional attendance. This may suggest that greater access to care at delivery reduces inequalities in mortality outcomes.

5.2 Results of regression analysis

This section describes a series of logistic regressions. As previously discussed, multivariate regression is needed in addition to bivariate analysis to provide a clearer picture on the impact of health care determinants of neonatal mortality without confounding from correlated socio-economic and other "distal" variables. Initially a logistic regression model is built up using groups of variables based on the model in figure. Once the full model is established, a series of further regressions are run using specific sample groups only:

- tertiles 1 and 3
- no maternal education and secondary further education
- State level of professional attendant below 35%/over 60%
- Rural/urban residence

5.2.1 Logistic regression for whole sample

Appendix 14 shows the regression for the whole sample, with models 1-9 building up the regression by adding more groups of variables based loosely on the theoretical framework developed in Chapter 3. There are a few exceptions to this: firstly sex and multiple births (biological variables) are added in early in the equation as while they are proximal variables in the theoretical model, the fact that they are innate characteristics not amenable to change suggests they should be adjusted for in all models. However, mother's perception of size of infant at birth (also a biological variable) was added in last. This was because of the concern that as it can be viewed as both an outcome as well as a determinant of mortality, it was important to ascertain whether its addition markedly affected other determinants in a way that could be viewed as skewing the results. Measures of maternal autonomy, which would be classified as socio-economic determinants were also added in later than the model would suggest (after health service variables) as the study hypothesised that these could be confounding factors for ANC, and therefore it was important to see whether they changed the OR for ANC when added.

- Model 1 includes only biological variables and state groupings.
- Model 2 includes socio-economic variables
- Model 3 includes environmental variables
- Model 4 includes biodemographic variables
- Model 5 includes maternal health and nutrition variables
- Model 6 includes preventive (ANC/TT immunisation) variables
- Model 7 includes all health care variables (ANC/TT and place of delivery variables were added separately in order to ascertain any interaction between the two groups)
- Model 8 includes measures of maternal autonomy

- Model 9, which is the full model, includes mother's perception of infant size at birth.

5.2.2 Results from regression for health care variables

The results for maternal health and health care variables are summarized in Table 39, and the full model can be found in Appendix 14.

Among the health care variables, two or more tetanus toxoid vaccinations, recommended levels of antenatal care and some antenatal care were all significant at the 1% level and associated with reduced ORs for neonatal mortality. The decrease in odds ratio for recommended antenatal care was greater than for some antenatal care (0.48 as opposed to 0.65). The ORs for ANC do not change markedly when variables are added into the regression for place of delivery or women's autonomy, suggesting that it is not acting as a proxy for preventative pre-natal care.

Delivery in a government institution was associated with an increased risk of mortality at the 5% level. Delivery in a private or NGO facility, or delivery by a professional attendant at home were not significant variables. There was also no significant change in OR for births by Caesarean section.

Table 39: Results for full regression (model 9) for neonatal mortality: maternal health and health care variables only

	Health and health care variables	Neonatal mortality (model 9)
Maternal health and nutrition	**Antenatal complications**	
	No antenatal complications reported (ref)	
	Mother reported antenatal complication	1.144
		(1.64)
Use of health care services	**TT immunisations**	
	Less than 2 TT (ref)	
	2 or more TT	0.671
		(3.74)**
	ANC	
	No ANC (ref)	
	Received recommended ANC	0.488
		(3.51)**
	Received some (but not recommended) ANC	0.665
		(3.64)**
	Place of delivery	
	Home delivery – no professional attendant (ref)	
	Home delivery with professional attendant	1.005
		(0.03)
	Delivery in Government institution	1.354
		(2.42)*
	Delivery in private/NGO institution	1.114
		(0.71)
	Data on place of delivery missing	2.323
		(1.33)

5.2.3 Results for other key variables

When the complete model (model 9) is examined, preceding birth interval of less than 18 months and first birth order are both associated with large increased ORs which are significant at the 1% level.

The addition of the variables that measure women's autonomy (involvement in health seeking decisions, ability to save money and ability to visit relatives with or without permission) did not bring about any changes in the health care variables. This would suggest that antenatal care and tetanus toxoid are not acting as a proxy for women's autonomy and empowerment as first hypothesised. Two of the women's autonomy variables (involvement in health care decisions and ability to save money) had a significant negative association with neonatal mortality in the final models.

When biological variables are examined, the child being a twin carries a very large increased OR neonatal mortality (ORs 4.5-4.9). Mother's estimate of size at birth was also a significant variable: a mother estimating her child was very small was associated with increased OR for neonatal mortality, and estimation of the baby being smaller than average was associated with significant but smaller changes in OR.

Maternal education variables (primary, secondary and further) were associated with a reduction in neonatal mortality, as was being of the Muslim religion. However, no other socio-economic or environmental variables were significant.

5.2.4 Results of regression by asset tertile

The results of the full regression models disaggregated by tertile, maternal education, state level of professional attendance and urban/rural residence can be found in Appendix 15, and a summary comparing significant health service variables can again be found in Table 40. For tertile 1 (*i.e.* the poorest), two or more tetanus toxoid vaccinations are associated with reduced mortality for neonatal mortality and receiving some antenatal care is associated with a reduced OR (but only at the 5% level). Receiving recommended ANC is not associated with significantly reduced ORs. This is interesting and reflects the bivariate analysis, and could either be because of a very small sample size, or indicate that poorer women only make frequent use of ANC services during complicated pregnancies which may have a poor outcome. Place of delivery or delivery by Caesarean section were also not significant.

Table 40: Comparison of health care determinants on neonatal mortality disaggregated by tertile, maternal education, state % trained attendance and urban/rural residence.

	Full sample	Tertile 1	Tertile 3	No education	Further/ secondary education	State % trained attendance over 60%	State % trained attendance under 35%	Urban only	Rural only
TT immunisations									
Less than 2 TT (ref)									
2 or more TT	_**	_**		_**	_**		_**		_**
ANC									
No ANC (ref)									
Received recommended ANC	_**		_*		_*				_**
Received some (but not recommended) ANC	_**	_*		_**			_**		_**
Place of delivery									
Home delivery – no trained attendant (ref)									
home delivery with trained attendant									
Delivery in Government institution	+*		+*	+**			+**		+**
Delivery in private/NGO institution				+*					

When tertile 3 is considered, two or more tetanus toxoid immunisations are not significant, and recommended antenatal care is only significant at the 5% level (some ANC is not significant). Place of delivery in a public institution is associated with a large and significant increase in mortality (but only at the 5% level) but birth in a private/NGO institution was not significant.

One interesting observation is that when tertile 3 (richest) is considered first birth order is not significantly associated with increased mortality, whereas when tertile 1 was analysed it was (although only at the 5% level). It is also significant in the full sample.

5.2.5 Results of regression for sample disaggregated by level of maternal education

Two or more immunisations are associated with reduced ORs for neonatal mortality for both women with no education and those who received secondary/further education. Some ANC is associated with significantly reduced ORs for women with no education, but not recommended level of ANC. When women with secondary/further education are considered the opposite is found: receiving recommended levels of ANC is associated with a reduced OR (although only at the 5% level), but some ANC is not significant. This mirrors the pattern found for wealth quintiles, where recommended ANC (but not lower levels of ANC) was associated with reduced mortality for wealthier women only, but the converse was the case for women in the lowest quintile.

When place of delivery is examined for women with no education, birth in either a private/NGO or government institution is associated with an increased OR (although only at the 5% level for private/NGO institution). Place of delivery was not significant for women with secondary/further education. This is the reverse of what was found when asset quintiles were examined, where only more wealthy women experienced increased mortality from delivery in government institutions.

When biodemographic variables are considered, women with no education have marked and significant increases in OR for first births and birth intervals of less than 18 months for neonatal mortality. When women who have received secondary or further education are considered, neither variable is significant.

5.2.6 *Results of regression for sample disaggregated by state level of professional attendance*

When data is analysed for only those living in a state with over 60% coverage of professional attendants (see Appendix 16 for full regressions), few variables are significant at the 1% level, and no health care variables are significant. The situation is markedly different for those living in states with levels of professional attendance below 35%. When health variables are considered two or more TT immunisations and some antenatal care are significantly associated with reduced mortality at the 1% level. Birth in a public institution is associated with a marked increase in mortality.

First births are significantly associated with increased mortality, but birth intervals less than 18 months are only significantly associated with increased ORs at the 5% level.

5.2.7 *Results of regression disaggregated by urban/rural residence*

When regressions for urban and rural populations are compared the most striking differences are for antenatal and delivery care. In urban areas antenatal and delivery care variables are not significant (with the exception of delivery data missing at the 5% level), whereas in the rural sample two or more TT, and recommended or some antenatal care are all significantly associated with reduced mortality. In rural areas delivery in a public institution is associated with increased mortality, but this is not found for urban populations.

5.2.8 *Summary of key points from logistic regression analysis*

- For the whole sample, two or more tetanus toxoid vaccinations, recommended levels of antenatal care and some antenatal care were all significantly associated with reduced ORs for neonatal mortality. Delivery in a government institution was associated with an increased risk of mortality at the 5% level.
- When disaggregated by socio-economic group, TT immunisation is no longer associated with reduced mortality for women in asset tertile 3. There seems to be a pattern that in lower socio-economic groups there is an association between reduced

mortality and some ANC but not recommended ANC, whereas those from higher socio-economic groups only have an association with recommended ANC. TT and ANC are associated with reduced mortality in states with less than 35% attendance and rural areas, but not in states with over 60% attendance and urban areas.

- When disaggregated by socio-economic group and state level of professional attendance, delivery in a government institution is only significant for women in asset tertile group 3, with no education, who live in states with less than 35% professional attendants or who live in rural areas.

5.3 Results of regression using IVs

As previously discussed, this study uses IVs as a means of overcoming the problems of endogeneity when examining the impact of professional attendants/institutional deliveries on neonatal mortality. This section describes a series of regressions with distance from health facility used as the IV for place of delivery. The IV regressions only use rural data, as information on distance from a health facility is not available for urban residents. The IV models are also run for the same disaggregated sample groups as above (except rural/urban residence).

Appendix 17 shows the results of the regressions using IV variables. The instrumental variable of distance was treated in four ways: firstly it was categorised into dummy variables. Secondly it was treated as a continuous variable, thirdly it was squared and fourthly it was cubed. Only the regressions with the instrumental variables treated as dummies are reported as these were the regressions that appeared to yield the most consistent results, and the other treatments did not result in any major differences. The instrumented variables were also treated in two ways: broken down into four categories by place of delivery and as a binary variable for professional and non-professional attendance. Only the first treatment is reported as the second approach made no difference to the results.

Model 1 in Appendix 17 shows an ordinary least square regression run on the sample of all rural dwellers using the full model developed in the previous section. This acts as the comparison when the place of delivery variables are instrumented in model 2 using two-stage least square regression. In model 1, where the delivery variables are not instrumented, birth in a government institution is associated with an increased risk of mortality which is significant at the 5% level. When the delivery variables are instrumented in model 2, the coefficient changes from a positive to a negative, but is not significant (see Table 41). However, the size of the coefficient for institutional delivery is in fact seven times as great as for the OLS regression in model 1. This actually produces a probability of mortality outside the range of 0-1, which as discussed is one of the problems when using OLS regression for binary outcomes. A Hausman test confirmed the hypothesis that the differences in the coefficients in models 1 and 2 were not systematic (p=<0.001), supporting the hypothesis that the variables for place of delivery are endogenous.

Table 41: Results from IV regression analysis (rural population only): place of delivery (instrumented) variables only

	Neonatal deaths: Full sample. Delivery variables **not instrumented**	Neonatal deaths: Full sample. Delivery variables **instrumented**	Neonatal deaths: wealth tertile 1 only. Delivery variables **instrumented**	Neonatal deaths: wealth tertile 3 only. Delivery variables **instrumented**
Place of delivery				
Home delivery – no professional attendant (ref)				
Home delivery with professional attendant	0.00 (0.00)	-0.128 (1.11)	-0.545 (1.64)	-0.016 (0.10)
Delivery in Government institution	0.01 (2.46)*	-0.072 (0.83)	-0.217 (0.89)	0.032 (0.24)
Delivery in private/NGO institution	0.01 (1.38)	-0.053 (0.56)	-0.014 (0.05)	-0.047 (0.40)
Data missing	0.01 (0.38)	-0.964 (0.58)	-0.330 (0.21)	-0.427 (0.20)
	Neonatal deaths: no education only. Delivery variables instrumented	Neonatal deaths: secondary/ further education only. Delivery variables instrumented	Neonatal deaths: State attendance over 60% only. Delivery variables instrumented	Neonatal deaths: State attendance below 35% only. Delivery variables instrumented
Place of delivery				
Home delivery – no professional attendant (ref)				
Home delivery with professional attendant	-0.016 (0.09)	0.024 (0.10)	-0.171 (1.27)	-0.281 (1.11)
Delivery in Government institution	0.006 (0.04)	0.032 (0.17)	-0.064 (0.84)	-0.141 (0.53)
Delivery in private/NGO institution	-0.195 (1.09)	0.022 (0.17)	0.068 (0.58)	-0.071 (0.47)
Data missing	0.210 (0.12)	-1.884 (0.99)	0.958 (0.74)	-0.853 (0.46)

* significant at the 5% level

When population subgroups are examined, the coefficient for delivery in a government institution is negative for most of them (tertiles 1 and 3, no education and percentage professional attendance under 35%) but none are significant even at the 5% level. However in many cases the negative coefficient is extremely large, and again often results in the probability of mortality being outside the 0-1 range.

Similar patterns can be seen for home delivery with professional attendant and delivery in a private/NGO institution. In model 1 (OLS regression without instrumenting place of delivery variables) delivery in a private/NGO institution has a positive coefficient, but in model 2 this has changed to a negative. The coefficient is negative for a number of the subgroups. When delivery at home with a professional attendant is examined, it has a coefficient of 0.0 in model 1, but the coefficient becomes negative for the full sample instrumented (model 2) as well as a number of the population subgroups (again with a large coefficient when tertile 1 is examined) although none is significant.

As with delivery in a government institution, some of the newly-negative coefficients for home delivery with professional attendance and delivery in private/NGO institution produce probabilities outside the range 0-1. A number of other coefficients that are large in the logistic regressions also produce similar results in the IV regressions (*e.g.* mother estimates child is very small, child is a twin) suggesting this is not just an anomaly related just to the instrumented variables. Obviously interpretation needs to be cautious, but the size of the coefficient, and the fact that it consistently changes to negative in most of the subgroups is certainly worth noting, even if significance is not reached.

6.0 Discussion

6.1 Why is there little evidence that professional attendance reduces neonatal mortality?

While the use of IV variables results in a change from a positive to a (sometimes large) negative coefficient, it does not result in the equation showing a significant reduction in mortality as a result of births from professional attendants. This could be partly as a result of methodological difficulties. As discussed earlier, regression using IV variables results in larger standard errors, so coefficients are less likely to reach significance. In addition, IV methodology is only able to detect changes in mortality among the "marginal group": in this case it would be infants who would have survived delivery with a professional attendant (but not at home without a professional attendant), but did not receive such care as a result of distance from health facility/road. As mentioned earlier, there are many other reasons within the Indian context for mothers not to receive skilled attendance, so this group may be relatively small. A further issue is that some of the excess mortality resulting from lack of care at birth will actually be from stillbirths rather than neonatal deaths. DHS does not routinely collect data on these, so these cannot be included in the "marginal group". Other limitations with the choice of IV have also been discussed: in particular the fact that some women return to the natal home to deliver, so the IV may not be an accurate reflection of distance from hospital when the woman goes into labour. Another issue mentioned previously is the large standard errors with instrumented variables, which are also likely to contribute to the fact the variables do not reach significance.

However, the very large negative coefficients for some of the regressions, while not statistically significant, may suggest that this technique warrants further exploration. Beck *et al* (2003) point out that the fact that findings are not statistically significant does not mean they are not clinically significant, and in order to corroborate findings, IV methodology needs to be tested in different settings. This would be an area for further research, ideally involving use of large datasets in countries where women do not traditionally return to the natal home to give birth. In the absence of suitably sized datasets it may be possible to combine countries (ideally with similar levels of NMR/professional attendance), although this may obviously limit the ability to draw country-specific conclusions.

A further potential explanation for these findings is that there is indeed limited advantage to newborn survival from professional attendance within the Indian context. The most likely reason for this would be poor quality of care. This hypothesis may be partly supported by data showing that the reduction in neonatal mortality between the two DHS in 1992/3 and 1998/9 was mostly among home deliveries (Gardiner 2006), although this could indicate greater use of institutional care by mothers with complications (and therefore less deaths at home). Previous studies from other countries have demonstrated how poor quality care can reduce the potential benefit of maternal and neonatal care. A study from the Dominican Republic (Miller *et al* 2003) is a particularly good example: although nearly 100% of women give birth with professional attendants in institutions, the maternal mortality ratio is still relatively high (150 per 100,000 live births) and the NMR of 19 is similar to a number of Latin American countries with much lower rates of professional attendance (*i.e.* Guatemala and Nicaragua, where professional attendance is 41% and 56%, respectively) (WHO 2005).

Miller *et al*'s study found the quality of care to be extremely poor: in particular, emergencies were not dealt with in a timely fashion, complications were not managed appropriately and normal deliveries were over-medicalised. The paper concluded that access to professional attendance and emergency obstetric care was not enough to lower mortality, and quality of care was a vital determinant of impact.

Generalisations about quality of care in India are difficult because of the wide variations found between states and indeed between individual institutions (including public and private/NGO). However, there is evidence of widespread and deep-rooted problems throughout the country, including inadequate staffing levels and training, poor infrastructure, insufficient attention to basic hygiene procedures and poor management of the sick newborn (*e.g.* Hulton *et al* 2007, Sen *et al* 2005, Biswas *et al* 2004).

6.2 Differences in outcomes for place of delivery/professional attendance

The findings for place of delivery/professional attendance by socio-economic group were initially somewhat surprising. Results from the Bangladesh study in Chapter 3 suggested that poorer women experienced greater levels of increased risk of neonatal mortality related to use of institutional facilities for delivery. This would appear to be intuitively correct, as these women may be more likely to only use professional care in the event of complications, may wait longer before using services and may experience lower quality care because of inability to pay. However, this study appears to demonstrate the opposite: increased neonatal mortality based on the regression findings is only associated with delivery in public facilities for the third tertile (wealthiest) rather than the first (poorest). However, the reverse is found if regressions disaggregated by education are examined: women with secondary or further education do not experience increased risk, whereas those with no education do. This may suggest that education may be a more important factor than wealth in the appropriate use of professional attendance.

The reason why more wealthy women appear to have increased risks as a result of use of government facilities (despite relatively high rates of professional attendance) may be the results of the relatively low mortality in the reference category (*i.e.* delivery at home without professional attendant). Based on the bivariate analysis the NMR for unattended home deliveries in the richest tertile is 24 per 1000, which is about half that in the poorest tertile. More wealthy women in Bangladesh have not managed to reach such low rates (NMR for women in quintile 5 delivering at home are 28 per 1000 for urban areas and 34 per 1000 for rural areas), which may partly explain the differing findings between the two chapters: the Bangladesh study found a marked and significant increase in mortality among poorer women using Government delivery care. However, it is also probable that these differences also reflect in some way differences in the way women access and use care. It is also worth noting that the proportion of women receiving institutional deliveries in India is over three times that of Bangladesh (34% compared with 9%), so the care context is very different.

Possible explanations for the relatively low rate of mortality among home deliveries from higher socio-economic groups in India include that the majority of women who deliver at home have uncomplicated pregnancies and deliveries, and have also managed to further reduce risk by effective use of antenatal and postnatal care. It is also worth noting that much fewer first births (which are associated with greater risk) occur unattended at home in this tertile than in institutions (approx 16% first births are without professional attendance, compared to 32% of subsequent deliveries), so some women may choose a home delivery only after they have had an attended delivery without complication. It would be interesting to carry out further research to investigate how aspects of home-based newborn care and health seeking behaviour differ between more wealthy and poor. An alternative (or additional) explanation is that a proportion of wealthy women also tend to only use institutional services in the event of complication or emergencies, or that they are subjected to poor care, possibly as a result of over-medicalisation.

However, it is important to bear in mind that women with the highest level of education appear to have also achieved relatively low levels of mortality for home deliveries without professional attendance, but also do not experience an increased risk as a result of institutional delivery. This suggests that education may have a stronger influence on use of services than asset quintile. This may make some intuitive sense, particularly when richer women are considered. If a woman is wealthy but has received no education it may indicate an innate conservatism within the family, which may also influence use of modern health care.

Maternal education and wealth have never been differentiated in studies which examine service usage, and this may be an interesting area for further research.

The findings are more straightforward when the impact of place of delivery/professional attendance is disaggregated by access to professional attendance/urban and rural residence. As would probably be expected, increased risk is associated with poorer access to services, probably because in places where professional attendance is low a higher proportion are likely to be using them only when complications arise. It is also highly likely that quality of care is better in places where levels of use are higher. However, it is interesting to note that even where attendance is over 60%, there is still no evidence of significant reduction in mortality in the uninstrumented models, and it would be interesting to examine at what level of professional attendance mortality actually becomes lower with, rather than without, professional attendance. A larger, cross national study examining how risk of neonatal mortality changes with varying levels of professional attendance would be interesting and useful, and highlight which countries appear to be getting the best results from strategies to promote institutional and professional deliveries.

6.3 The role of antenatal care

As with the Bangladesh study in Chapter 3, there is clear evidence that women receiving antenatal care and tetanus toxoid experienced lower neonatal mortality. The most obvious interpretation of this would be that these interventions have a direct impact on reducing mortality, but this is not easy to demonstrate. It is difficult to provide a general estimate for tetanus in India: the greatest number of neonatal tetanus deaths globally occur in India (estimated at 50,000 in 1999) (Unicef 2001), but this is a relatively small percentage of the overall 1.2 million neonatal deaths that are estimated to have occurred within the country in 2000 (approximately 4%). As with many other aspects of Indian health care, there are also gross disparities between regions: a number of states (*e.g.* Kerala, Gujarat and Andhra Pradesh) are believed to have achieved elimination (*i.e.* a rate below 1 per 1000 live births) (WHO 2007), whereas in other states it is still a major public health issue, particularly in rural areas. A reduction in OR of 0.7 seems quite large based on these assumptions.[48] A previous study (which finds an association between TT immunisations and early childhood mortality) suggests that tetanus toxoid immunisation can be a good indicator of health seeking behaviour (Luther 1998), so this could be a confounding factor. This hypothesis is also supported by the finding in Chapter 3 that two or more TT immunisations reduced the risk of post-neonatal mortality, where tetanus is rarely ever a problem.

The findings on antenatal care also raise interesting questions. Previous studies which have found a correlation between antenatal care and reduced mortality have generally attributed this to a direct effect. Undoubtedly there is evidence that some antenatal interventions can directly improve neonatal outcomes (*e.g.* treatment of malaria and STIs) (Shulman *et al* 1999, Gichangi *et al* 1997), but the data on quality of ANC does raise issues as to whether such a marked reduction in OR (approx 0.6 for some antenatal care and 0.4 for recommended level of antenatal care) could be achieved within the Indian context. The Bangladesh study in Chapter 3 found an interaction between ANC and outcomes from institutional deliveries, suggesting that part of the mechanism for improved survival may be more effective and appropriate use of delivery services. However, no such interaction is found with the Indian FHS data, suggesting this is not the case in this study.

The Bangladesh study in Chapter 3 hypothesised that ANC could be acting as a proxy for women's autonomy, which was not represented in the model in that study. The addition of variables included in the Indian FHS designed to measure the mother's level of autonomy did not support this: while a few were significant in some models they did not change the coefficients of the ANC variables when they were added to the equation. However, this may reflect limitations with the variables, rather than a real lack of association. For instance ability to visit family may be limited by distance as much as level of autonomy, or the apparent "freedom" that involvement in decision-making provides could be explained by a lack of presence or support from male relatives (*i.e.* female-headed households) rather than reflect gender balance. In addition, a number of studies suggest that these measures of

[48] As previously mentioned, regressions were originally run for early neonatal mortality only, but were not reported. These found a reduction in OR for tetanus toxoid immunisation of approximately the same for early neonatal as for overall neonatal mortality. This is also somewhat unexpected as studies suggest that the mean and median age of death for neonatal tetanus is outside the early neonatal period (*e.g.* Eregie and Ofovwe 1993).

“autonomy” may not reflect the complex and multi-dimensional nature of gender relations, where women may gain power through influencing male relatives rather than through direct decision-making. Research also suggests these variables may not be comparable across communities (Mason and Smith 2001): a factor that is of particular pertinence in India, which is home to vast cultural and ethnic diversity.

It is possible that use of ANC may, like TT immunisation, be a proxy for health seeking behaviour, which is possibly influenced by, but not synonymous with, autonomy. Other aspects of health seeking behaviour or family influence may be important.

6.4 Are the effects of antenatal care different for specific sectors of the population?

The evidence is somewhat inconclusive as to whether antenatal preventive care (*i.e.* TT and ANC) benefits the poor more than the wealthy. There is certainly a suggestion that TT has a greater impact on neonatal mortality for the poorest tertile (although there is little difference when mothers are grouped by education). However, the lack of significant impact for the wealthier tertile may be related to the fact that the number within these groups who had not received two or more TT was very small (about 6% of those within that tertile), and lack of significance may just be a result of wide confidence intervals. The fact that the regressions for the higher socio-economic groups tend to still show a marked, though statistically non-significant, decrease in OR for women who have received two or more TT may support this, as does the cross-sectional analysis that show high rates of mortality among the neonates of women in the wealthiest and most educated groups who did not receive TT coverage. This study has already questioned whether the association between TT coverage and neonatal mortality is really related to the impact of the actual intervention itself; if so, one might expect the effect would be different. Tetanus is essentially a disease of extreme poverty and therefore immunisation is likely to have the greatest impact on those most at risk. It would be interesting to rerun this analysis using data from a variety of countries, including those where TT coverage was lower (and incidence of neonatal tetanus higher). Again, TT immunisation is found to have a significant effect in states with attendance below 35% and rural areas, but not for those above 60%, and in urban areas, and the same possibilities apply: it could be because those in urban areas/states with high level of professional attendance have low numbers of unimmunised women, or because the risks differ between the groups. An alternative explanation could be that the improved health seeking behaviours for which TT immunisation may be a proxy have greater impact where services are weaker.

The pattern for ANC is somewhat more complex. When neonatal mortality is considered, some (but not recommended level) of ANC alone is found to result in statistically significant reduction in mortality for the poorest tertile and women with no education, but only recommended level ANC is associated with reduced mortality for mothers from the wealthiest tertile or with secondary/further education. Part of the explanation could lie in the fact that only a very small proportion of women from the poorest quintile or with no education received recommended level of ANC (and therefore confidence intervals are large), but the bivariate analysis may suggest a different explanation. When the cross tabulations are examined it is found that women from the lowest socio-economic groups who receive recommended levels of ANC actually experience higher levels of neonatal mortality, while those from higher groups experience markedly lower. This could be because of differing patterns in health care usage: poorer or less educated women may only make multiple visits to health care providers prenatally when they are experiencing complications (which impact on neonatal survival) whereas those who are more wealthy or educated may make more extensive use of services even when all is well.

There appears to be some evidence that ANC has more impact in situations where access to professional attendance is reduced (*i.e.* in states where rates are lower, or in rural areas). This is somewhat surprising in the light of analysis that suggests that quality is often poorer in these environments. It is also interesting to note that there does not appear to be an interaction between ANC and place of delivery, as found in the Bangladesh study in Chapter 3, so a link between use of ANC and patterns of usage for professional attendance is unlikely to be the key. Possible explanations could include the fact that access to information on danger signs and healthy behaviours is scarcer in these scenarios, so therefore has a greater impact. However, a more probable explanation is that, as previously discussed, use of ANC is actually acting as a proxy for some unmeasured characteristic in those women that use them such as health seeking behaviour. It is possible that in areas where use of services is rarer, the impact of such personal characteristics may be greater as women need to be more knowledgeable and proactive to access appropriate care.

6.5 The problem of inequity

Inequity, both at the individual and community level, is a clear concern within India. The initial descriptive analysis shows large differences in access to both prenatal and delivery care based on socioeconomic group and urban/rural residence. There are also marked differences in mortality rate. What is less clear is the degree to which improved equality of access to services would reduce inequities in neonatal mortality. This is an important area for further research, but there is some preliminary suggestion that this may be the case. Levels of inequity for neonatal mortality between wealth tertiles were markedly lower in states where professional attendance is higher (and where there is some evidence that antenatal care is more comprehensively used and of better quality). This could be suggesting that higher levels of services lead to reduced inequalities in mortality (possible as a result of greater numbers of poor women being able to access services). Obviously other socio-political factors could be influential in determining this situation, in particular the level of female education. The fact that the pattern is less obvious when maternal education rather than quintiles is considered suggests this could indeed be a contributing factor, and that higher levels of maternal education are a catalyst for reducing inequality. Kunst and Houweling (2001) also support this hypothesis as they found that when the examined the association of inequality of delivery care with three national characteristics (GDP, public expenditure on health as percentage of GDP and female literacy rates), the strongest correlation was with female literacy. Further research using methodologies that adjust for education and coverage levels both within India and using cross national data would be valuable.

It is also interesting to note that the bivariate analysis suggested that if only women who have received TT or some ANC are considered, there appears to be no or little socio-economic gradient for mortality (although this is not the case when recommended ANC is examined, possibly because again poorer women only tend to have intensive ANC for complicated pregnancies). This could suggest that TT and ANC have an impact in reducing inequalities, or indeed the factors or personal qualities for which they are proxies can override socio-economic disadvantage. Obviously much more work is needed in this area before any clear conclusions can be made, but it would be a fruitful area for further research. Improving equity of access to maternal health care and, in particular, delivery care will require major changes to the way services are delivered and financed. Some of these issues are currently being considered by the Indian Government as outlined in Section 2 of this chapter in the RCH II. It will be important that the more innovative developments (such as payment for low income women to have institutional deliveries) are rigorously evaluated, particularly as it is possible that their effectiveness could be limited by other factors such as transport problems or cultural barriers.

6.6 The role of socio-economic status and access to services in mitigating the risk of first births

One interesting finding from this study is that the increased risk associated with first birth appears to be mitigated both by higher socio-economic status or improved access to delivery services. There is very little existing data on this area. Much of the increased risk of first births in caused by a higher incidence of pre-eclampsia and obstructed labour. While there may be some link between poverty and obstructed labour due to increased risk of maternal stunting, these conditions are generally not associated with socio-economic factors. However, they are to a great extent amenable to prompt and effective treatment and the risk can be ameliorated by access to health care, particularly at delivery. This would suggest that while poverty alone may not actually influence risk, the ability to access health care (which in most developing countries, is strongly affected by socio-economic status) would. One study (Swailem *et al* 1988) which compares perinatal mortality from a Saudi maternity hospital with Swedish data found that the risk posed by first birth order was very much greater in Saudi Arabia, where marked shortcomings in obstetric services were noted.

A review of data from a number DHS surveys (Mahy 2003) also shows marked differences in relative risk (RR) for infants who were first or subsequent births between countries and regions. While the unweighted mean average for the RR of neonatal mortality for the 29 Sub-Saharan African countries was 1.47, the RR for the nine Latin American countries was only 1.16. Countries where skilled attendance is over 80% (*e.g.* Kazakhstan, Turkmenistan, Brazil, Columbia, Armenia) generally appeared to have low or no increased risk, whereas those with very low rates of skilled attendance (*i.e.* below 20%: Bangladesh, Ethiopia, Nepal), had much higher relative risks (*e.g.* RR for neonatal mortality in Bangladesh is 1.93). This very cursory observation of available data is, of course, by no means conclusive, and anomalies do exist (for instance the Kyrgyz Republic has high rates of skilled attendance and also high relative risk).

Mahy suggests much of the variation may result from differences in age of first pregnancy (ibid.), but as the regressions in this study adjust for maternal age this is not likely to be the sole reason. This could again be an interesting area for further inter-country studies to ascertain in particular how increased risk of first birth is related to use and availability of health care services. There does not appear to be any difference in risk from short birth intervals for women from different socio-economic backgrounds or with different levels of access to services.

7.0 Conclusion

The results of this study open an interesting debate on the possibility of different outcomes from health care, and suggest a number of areas for further research. In the case of antenatal care and tetanus toxoid immunisation, there is little real evidence of differences in outcomes based on socio-economic factors, but some evidence that these services have greater association with mortality in situations where access to services are scarcer. However, measuring outcomes is likely to be undermined by the fact that the variables may be actually acting as a proxy for the mother's health seeking behaviour. The apparent paradox that wealthier women appear to experience a greater risk than their poorer counterparts when delivering in institutions (as compared to home deliveries without a professional attendant) whereas women with a high level of education experience less than those with no education is an interesting area for further research. It raises questions about the role of education in promoting appropriate use of delivery services and suggests the need for further research on health seeking behaviours. Increased risk of neonatal mortality from institutional deliveries is, as would be expected, greater where services are less utilised.

The use of IV variables to ascertain the impact of professional attendance while attempting to control for endogeneity produced a marked negative coefficient, but this did not reach statistical significance. However, despite limitations the findings do suggest that further work that utilises the methodology in different scenarios could be a valuable avenue for further research.

CHAPTER 5: CONCLUSIONS

1.0 The use of DHS data for analysing trends in NMR

This study provides a comprehensive review of data quality, and suggests that national level DHS estimates for neonatal mortality are generally of sufficient quality to provide valuable information, but data from some countries may be significantly flawed. It is probably not suitable for tracking changes over relatively short periods of time for individual countries, and is more appropriate for ascertaining general regional trends (or individual level analysis). The main reason for this is large standard errors. Probably the greatest non-sampling error is that of data heaping. This has been previously documented at seven days (which makes the desegregation of early and late neonatal mortality difficult), but this study also carries out new analysis that suggests for the first time that heaping may also occur at 28 days/one month. A further possible problem is the back-dating of deaths to over five years prior to the survey to prevent the need for in-depth questioning.

The best method of obtaining accurate mortality data is through comprehensive vital registration systems, but in reality this is unlikely to happen in the short term in many developing countries. DHS data is likely to remain one of the most important and accurate methods of collecting country level data for many countries. One possible option to reduce standard errors would be to either increase the sample size (which is probably not financially or practically viable) or introduce a shortened child mortality module that could be administered to a larger group of clusters than the full survey. The main source of non-sampling errors (data heaping and back-dating) could probably be ameliorated by better training of data collectors, and encouraging them to probe more fully when ascertaining exact age of death.

2.0 Global trends in NMR

While results should be treated with caution, there is evidence that neonatal mortality has indeed fallen at a slower rate than post neonatal or early childhood mortality. This appears to be the case in nearly all countries analysed, and this study is unusual in that it provides data from a large number of individual countries. In many countries, further progress is likely to be very limited unless neonatal mortality is addressed as the rate of mortality in older age groups is already relatively low, and the proportion of deaths occurring in the neonatal period is very high.

A finding of particular concern that has not been highlighted in previous studies is that in more recent years a number of African countries appear to be experiencing a marked increase in neonatal mortality. It has been recognised for some time that overall child mortality is increasing in many parts of Sub-Saharan Africa, but it has not been noted that this trend now includes neonatal deaths (which historically seem to be less affected by economic downturns and shocks). This phenomenon requires ongoing monitoring and research.

3.0 The role of socio-economic factors in reducing neonatal mortality

While the association between child mortality and GDP is well documented, Chapter 2 provides the first clear evidence that national level changes in GDP have a weaker association with neonatal mortality than post-neonatal and early childhood mortality. This may well provide some indication as to why progress in the neonatal period has been less marked than for older age groups. It also has important implications for future progress: in many countries further gains in reducing child mortality will not be made without addressing neonatal mortality, and this study suggests that reliance on improving overall socio-economic conditions will have a limited effect in achieving this. It points to the need for focussed, widespread and accessible maternal and newborn health programmes that provide a continuum of care before, during and after delivery.

The analysis of individual-level data from Bangladesh in Chapter 3 somewhat supports the hypothesis that wealth may be a more important determinant for post-neonatal than neonatal mortality, but the findings are far less compelling. This may be due to study limitations (*e.g.* sample size) but could also be the result of shortcomings in the way that wealth is measured at the family level through the asset index and quintiles. In particular, it appears that this methodology is unable to clearly differentiate between groupings in countries such as Bangladesh where there is little variation in wealth across the population.

4.0 The association between institutional deliveries and neonatal mortality

Knowledge of the association between delivery care and neonatal mortality has been limited by the endogenous nature of the relationship between professional attendance at delivery and neonatal mortality. In developing countries, many women will only seek care in hospitals once complications have arisen, making it difficult to compare outcomes with women who gave birth at home. As expected both the bivariate and multivariate regression in Chapter 3 found higher rates of neonatal mortality for births in government institutions compared with home births. Further bivariate analysis provided new findings that this excess mortality appeared to be greater among women from lower socio-economic groups, those who reported complications or who had little or no antenatal care. Multivariate regression using composite variables confirmed that delivery in a government institution was associated with an increase in mortality for women who were of poorer economic status (wealth quintiles 1-4 or no education) or had received either not the recommended level or no antenatal care.

Interestingly, in Chapter 4 excess mortality from deliveries in government institutions compared to home births appeared to be greatest amongst the wealthier. This needs to be considered within the context of relatively low levels of mortality for women in the richest tertile who have home deliveries. It suggests that only relatively straightforward deliveries are attempted at home, and complications are referred to hospital (though possibly not promptly enough to avoid poor outcomes).

Chapter 4 uses IV methodology for the first time in an attempt to overcome the endogeneity of the association between variables recording place of delivery and neonatal mortality. It instruments place of delivery with distance from place of residence to government health facilities (using rural data only). While this method brings about a change from a positive association between neonatal mortality and delivery in a government institution to a negative, the instrumented variables do not reach significance. However, the size of the positive coefficients in the instrumented models is often extremely large. This, and the consistency of the change from negative to positive, suggests that further evaluation of this technique would be useful even if significance wasn't reached in this study.

The high rate of mortality among institutional deliveries suggests that emphasis needs to be placed on improving both demand and supply factors for maternal health services. The extremely high rates of mortality in some groups in both the Indian and Bangladeshi studies suggest than many women leave it too late to get to hospital after the appearance of complications, resulting in poor outcomes. However, quality of care is also likely to be an issue, and there is plenty of existing evidence that suggests that this may limit the benefits of hospital births.

5.0 The role of antenatal care and tetanus toxoid in reducing neonatal mortality

The studies in both Chapters 3 and 4 found that antenatal care and tetanus toxoid immunisation were associated with marked decreases in neonatal mortality. On the surface this would appear to point to their value as antenatal preventive measures, and this is normally the explanation given in previous studies. However, it could be argued that the decrease is too great to be solely a direct result of their efficacy as a health intervention. It is also worth noting than tetanus toxoid immunisations were associated with a similar reduction in mortality for post-neonatal mortality in Chapter 3: tetanus is almost never a cause of death for this age group. It is possible that these variables are acting as proxy indicators for some other unmeasured maternal characteristic. It was hypothesised in Chapter 3 that this characteristic could be women's empowerment and autonomy. The study in Chapter 4 included three indicators designed to measure levels of autonomy in the model, but this did not affect the results. This may be because of the difficulties in developing meaningful indicators of autonomy, or could mean that the characteristic in question (*e.g.* health seeking behaviour) is not necessarily strongly correlated with levels of autonomy. This issues would be a useful area for further research, as would further investigation on the impact of particular aspects of antenatal care in different scenarios.

The findings are inconclusive when the question of how association between antenatal care and tetanus toxoid differs between women from higher or lower socio-economic groups. This study does, however, provide some new evidence that the impact of antenatal care is greater when access to health services is more limited (even after adjusting for other socio-economic factors). In some ways this seems counter-intuitive, as ANC in states with poor coverage of services appears to be of lower quality. This could be because the overall level of knowledge regarding pregnancy, delivery and neonatal health is lower, so health promotion opportunities such as antenatal visits have a greater impact. If ANC is acting as a proxy for some unmeasured maternal characteristic, it could be that this factor is more important where resources are scarce. Bivariate analysis in Chapter 4 also indicates that provision of both ANC and tetanus toxoid appears to reduce socio-economic inequalities in neonatal mortality.

6.0 The role of biodemographic variables

In both of the studies in Chapters 3 and 4 short birth intervals were associated with one of the greatest increases in odds for neonatal mortality. This is important as it highlights the role of family planning, and in particular child spacing, in reducing newborn deaths. There is no strong evidence that the impact of birth intervals is greater for different socio-economic groups or communities with different levels of access to health care.

One original and interesting finding from Chapter 4 is that the increased risk associated with first birth appears to be mitigated by higher socio-economic status and access to services. Differentials between countries for increased risks for first births have previously been explained by variations in maternal age, but as this study controls for age this is unlikely to be the reason. Most of the underlying causes for increased risk in first-born children can be managed effectively with appropriate diagnosis and treatment, so it is probable that the difference at least partially results from differing access to treatment.

7.0 Limitations of the study

7.1 Limitations in modelling the determinants of neonatal mortality

The introductory chapter of this thesis outlines the determinants of neonatal mortality, and describes the development of a conceptual framework that has been used as a basis for regressions in Chapters 3 and 4. This model draws on Mosley and Chen's (1984) concept of distal and proximal determinants, whereby the distal determinants only have an impact on the outcome through influencing the proximal determinants. However, in the empirical model used in the regressions, some of the distal variables are still significant once all the proximal variables have been added, which suggests that either the model is incomplete or variables are either missing or not capturing the phenomenon of interest. There is certainly clear evidence for the latter: for instance DHS does not provide information of family practices, and the quality of other variables (*e.g.* maternal complications) is poor. This somewhat undermines the comprehensiveness of the model, but it is not feasible to expect that any empirical model can include all determinants of mortality.

7.2 Lack of data on stillbirths

An important limitation in this study is that DHS do not usually record data on stillbirths, so these could not be included in the analysis. Ideally any trend analysis of neonatal mortality would also include trends in stillbirths, as there is often some uncertainty about how deaths around the time of birth are categorised. In addition many deaths resulting from lack of medical intervention at birth occur *in utero*, so the efforts in Chapters 3 and 4 to identify the potential impact of professional care are limited by the lack of stillbirth information. Contradictory research exists as to whether mothers can reliably report stillbirth, and further research is needed to both clarify this and ascertain how such information can most dependably be attained. In addition, for any study looking at impact of delivery care it would really be necessary to differentiate fresh from macerated stillbirths (*i.e.* those that occur during, as opposed to before, the commencement of labour), as those that occur prior to labour may have very different aetiology.

7.3 Difficulties in identifying "higher" and "lower" risk births

One of the major limitations of these studies was that it was not possible to identify women who had planned to delivery in institutions from those who only attended once complications arose. Efforts in Chapter 3 to identify groupings with "lower" or "higher" risk were not wholly successful. While it was possible to identify groups of women who had particularly high risks of neonatal mortality for institutional deliveries, it was not possible to identify any groups for whom the risk was lower than giving birth at home. This is probably because in the Bangladesh context, where the percentage of people who deliver in institution is extremely low, even wealthier, more educated women, who tend to make more use of such services, may only be doing so in an emergency. DHS do not include data in any of their surveys on planned place of delivery, which is unfortunate. Further analysis using the Bangladesh Maternal Health Services and Maternal Mortality Survey 2001 would offer some opportunity to examine rationale behind place of delivery and this may be worth considering, but it does not specifically ask if institutional delivery is planned.

7.4 Limitations to the IV methodology

As discussed previously, the use of IV methodology resulted in coefficients for institutional delivery/professional attendance changing from negative to positive, but did not reach significance. This could be because of limitations in the choice of IV (*i.e.* distance from the health facility) within the Indian context: in India many women return to their natal home to give birth to their first child. Further limitations could include a possible relationship between the IV and the outcome through another channel (*i.e.* distance from health facility will also affect ability to access care for a sick neonate) and the fact that data on distance was only available for rural dwellers, which reduces the sample size considerably.

8.0 Further research opportunities

8.1 Further analysis on non-sampling errors in neonatal mortality from DHS data

The analysis in Chapter 2 highlights for the first time the possibility that deaths are heaped at 28 days or a month, which would lead to under-reporting. This area needs further analysis before any clear conclusions can be reached. Developing a methodology to investigate this possible phenomenon is likely to be difficult and complex, but it might be possible to analyse data from other reliable sources (*i.e.* vital registration or ongoing demographic surveillance studies such as Matlab in Bangladesh) to establish whether a clear pattern emerges in the relationship between deaths in the late neonatal period, and at one and two months. This would probably differ between regions and between countries with differing overall infant mortality rates, so a series of models would probably need to be established. It may then be possible to compare the patterns found in DHS data to establish if they conform as expected. Finding high quality data for countries with IMR comparable to countries covered by DHS data would,however, be problematic.

Another potential source of non-sampling error is caused by the use of the mother as the primary sampling unit. If the mother dies, her child will automatically be excluded from the sample, and as there is a correlation between neonatal and maternal deaths, this may introduce bias. One previous study has examined whether the impact of AIDS is likely to lead to under-reporting of child mortality (Artzrouni and Zaba 2003), but no study has established if countries with high all-cause maternal mortality will suffer underestimations of neonatal mortality. Calculations would need to be based on the estimate of MMR and rate of mortality for newborns whose mothers have died (which will be markedly higher than for the general population) so any estimate will be country specific. Estimates of the mortality for neonates of mothers who have died are also likely to be difficult without extensive further primary research, as only a few studies exist in this area. However, analysis from population laboratories with ongoing demographic surveillance may be possible in some countries.

8.2 The relationship between level of skilled attendance and difference in mortality between neonates born with or without professional attendance

Chapter 3 showed that states with higher levels of professional attendance have lower differentials between women who gave birth in institutions and those who gave birth at home. This is probably because a greater proportion of uncomplicated pregnancies are delivered in states with higher overall coverage of professional attendance. It would be interesting to establish if this pattern was similar globally, and also at what level of national coverage mortality in institutions becomes lower than for home births. A study of this type would also enable the identification of countries which had managed to attain a good ratio of mortality for institutional to home deliveries compared to countries with similar overall coverage, and it would then be possible to identify and analyse factors that result in this (*e.g.* high quality of care, fast access to care for women experiencing complications, or, possibly in some cases heavy usage by woman from higher socio-economic groups with no complications and lack of use by poor women even when severe complications manifest).

8.3 The use of IV methodology to measure the impact of professional attendance at birth

The marked change in coefficient when IVs are used for place of delivery in the regression equation suggests this is a methodology that could be further developed for estimating the association between delivery care and neonatal mortality. Further research in this area could be valuable. In particular it would be interesting to rerun similar analyses for data from countries where women do not traditionally return to the natal home to give birth, as this would reduce one of the potential limitations of the IV. DHS surveys now routinely collect geographical data (including distance from health facilities) using global imaging systems, and this offers excellent opportunities for further developing this work. These studies would also have the advantage of providing geographical data for all mothers, not just those from rural area as with NFHS 2. Success would probably be partially reliant on large sample sizes, which will be assisted by the recent publication of a number of large-scale DHS surveys. Alternatively, successive surveys from one country could be appended, or surveys from a number of countries with similar maternal health care profiles could be amalgamated to increase sample size.

8.4 The association between professional delivery and neonatal mortality at national level

While a number of studies have examined the association between NMR and professional attendance rate at national level using cross-sectional data, none have done so using longitudinal data. The disadvantage of cross-sectional analysis is that it cannot allow for country-specific factors that may also influence the relationship between skilled attendance and neonatal mortality. The proliferation of DHS in recent years offers the opportunity to carry out longitudinal studies using countries with more than one survey. The development of a multivariate regression model (including such additional factors as changes in GDP, maternal education, ANC and TT coverage) would provide valuable information on the potential impact of increasing skilled attendance, and would also assist in defining the potential degree to which a number of factors often used as proxy indicators for neonatal mortality are actually associated with a reduction in deaths.

8.5 The relationship between service use and wealth and education

There is ample existing evidence that both wealth (usually measured through asset indices) and education is correlated with use of professional care at delivery. However, no previous study has ever comprehensively examined the differences in impact of wealth or education (or the combination of the two factors) on a woman's choice of place of delivery. Wealth and education are often viewed as synonymous, but while they are strongly correlated, Chapter 4 clearly demonstrates they are not. The Indian study provides some suggestion that education may actually be a more important factor than asset quintile in health seeking behaviour. This would certainly be an interesting area for further research. Use of health services could be separately disaggregated using compound variables for asset quintile/maternal education to ascertain, for instance, whether richer women without education have significantly different patterns in service use to their more educated counterparts or poorer women.

8.6 Qualitative studies on medical decision-making

This thesis highlights the importance of quality of delivery care, but one area that has never been examined is how the importance of the unborn foetus is perceived when medical decisions are being made. This is an area in which I was unable to find any existing literature, but felt would have informed the discussion on quality of care. In developed countries most interventions during labour (*e.g.* decisions to carry out instrumental delivery or Caesarean section) will be to ensure the safety of the foetus, whose condition usually deteriorates before that of the mother. There is no evidence for India and Bangladesh of how influential the wellbeing of the unborn foetus is in the clinical decision-making process, and this will clearly affect quality of care. There is clear evidence of delayed treatment, particularly for poor women (*e.g.* Pitchforth *et al* 2006) which may simply reflect shortcomings within the service, but may also suggest clinical decisions for major interventions are mostly based on the health of the mother and an inclination to take risks with the health of the foetus under certain circumstances. It would also be interesting to ascertain whether the health of the foetus is viewed differently in decision-making depending on the woman's socio-economic group and the perceived impact of the cost of treatment on the family (especially when catastrophic out-of-pocket payments would be needed). This would be a very valuable and original (albeit somewhat sensitive) area for further qualitative study, but results would probably be very context-specific.

8.7 The potential for maternal health services to reduce inequalities in mortality

While there is a significant body of research related to inequalities in maternal and child mortality and use of services, the literature is much less developed on how health care can reduce these inequalities. This would be a very valuable area for further work. This study indicates that both antenatal care and care at delivery may be important in reducing inequalities, but further, more rigorous research is needed. For instance, Chapter 4 suggest that Indian states with higher levels of professional care at delivery have lower socio-economic gradients for mortality, but this could be caused by other characteristics such as higher levels of maternal education. Any further research will need to adjust for such possible confounding factors.

8.8 Relationship between increased risk of first births and access to medical care

One unexpected and original finding from the Indian study was that the increased risk of mortality posed by first births is mitigated by increased access to professional attendance. Further cross-country analysis would be useful in this area to see if the pattern is universal, and would need to be adjusted for maternal age at delivery as this could confound the results.

9.0 Concluding comments

Addressing neonatal mortality is an important challenge for national governments and the international community if progress is to be made in reducing child mortality. While socio-economic growth is likely to have some positive impact, any real progress is likely to depend on the development of a continuum of interventions that promotes optimal birth spacing as well as providing equitable access to appropriate care to mother and baby during pregnancy, childbirth and the weeks following delivery.

Appendix 1: Bar graphs of distribution of neonatal mortality 0-31 days by day of reported death

Figure 33 (a-e) Distribution of neonatal mortality 0-31 days by day of reported death

Figure a: Sub-Saharan Africa (data from 30 surveys)

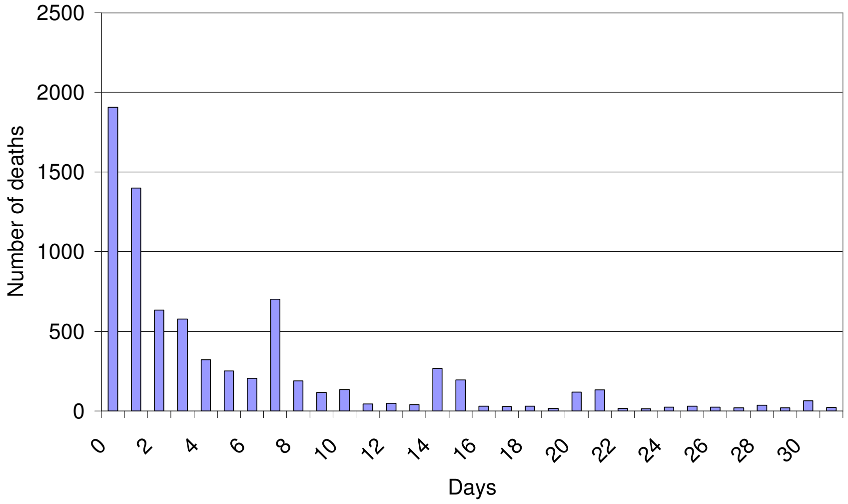


Figure b: South and South East Asia (data from 8 Surveys)

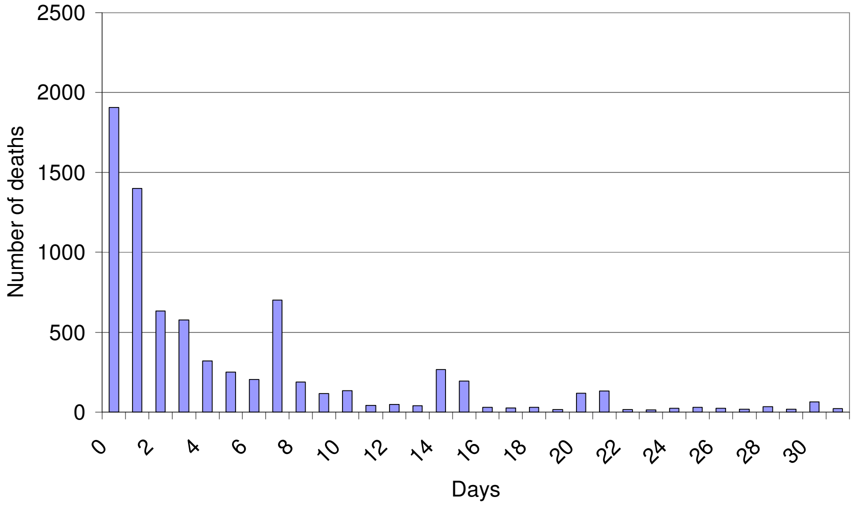


Figure c: North Africa and Western Asia (data from 6 surveys)

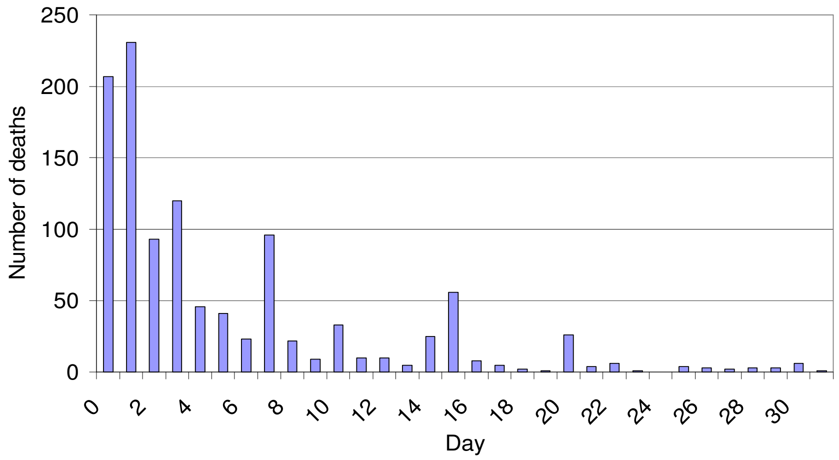


Figure d: Latin America and the Caribbean (data from 9 surveys)

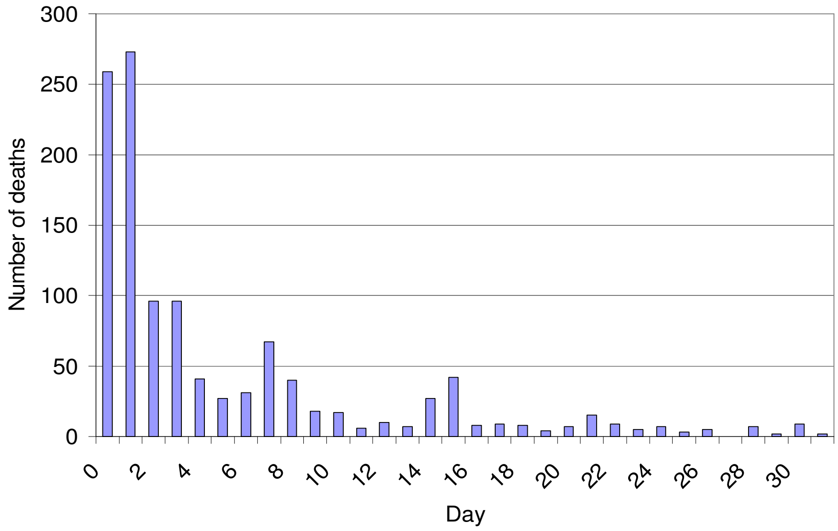
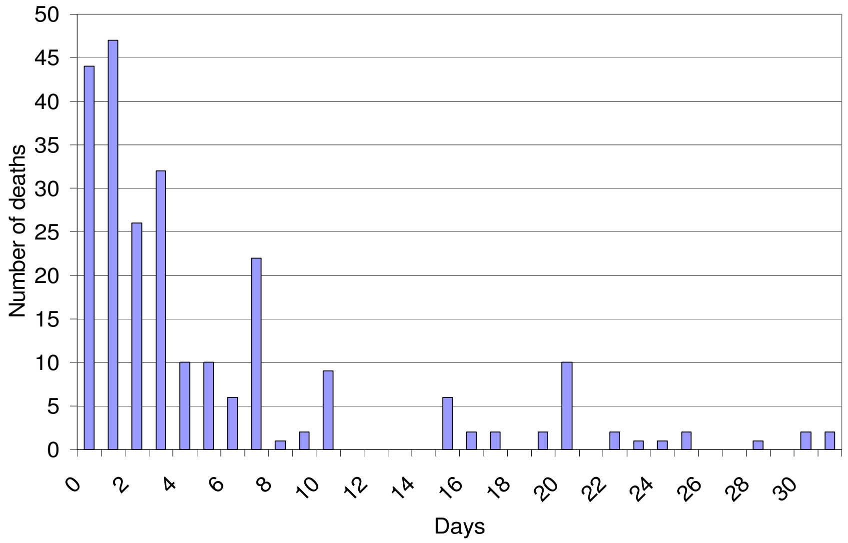


Figure e: Central Asia (data from 4 surveys)



Appendix 2: Bar graphs showing the distribution of infant mortality by month of reported death

Figure 34 (a-e) Distribution of infant mortality by month of reported death

Figure a: Sub-Saharan Africa (data from 30 surveys)

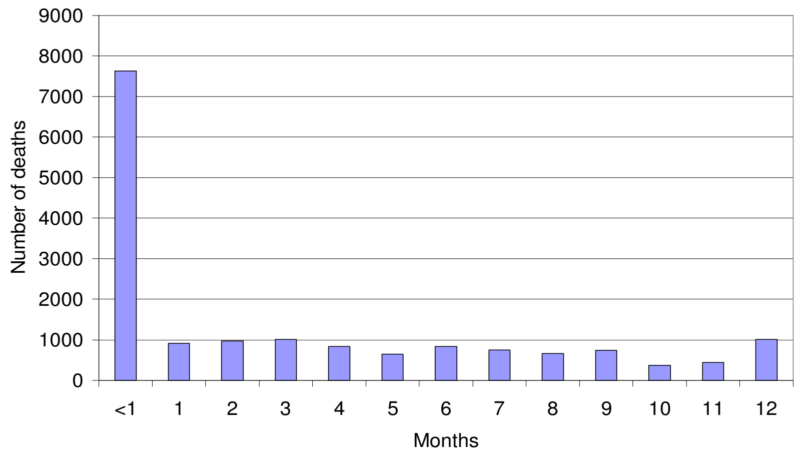


Figure b: South and South East Asia (data from 8 surveys)

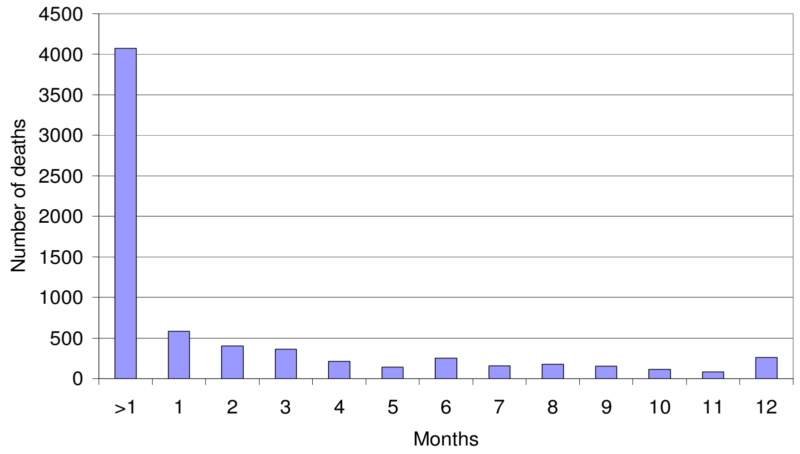


Figure c: North Africa and Western Asia (data from 6 surveys)

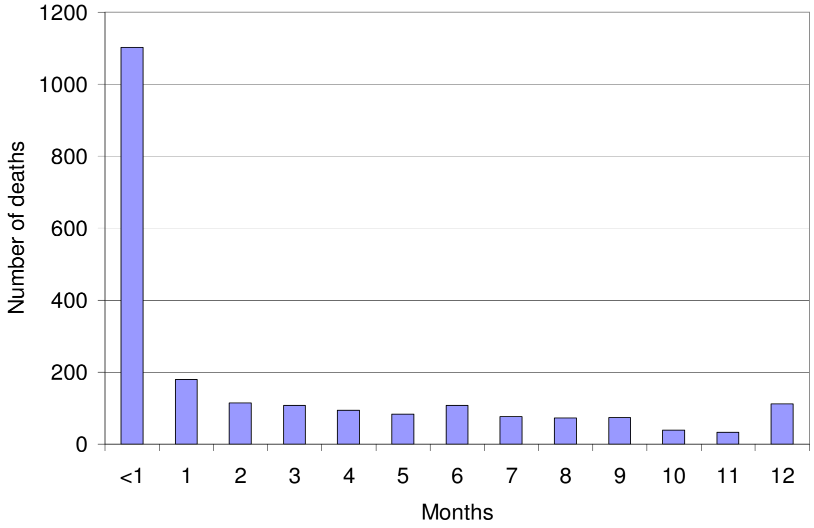


Figure d: Latin America and the Caribbean (data from 9 surveys)

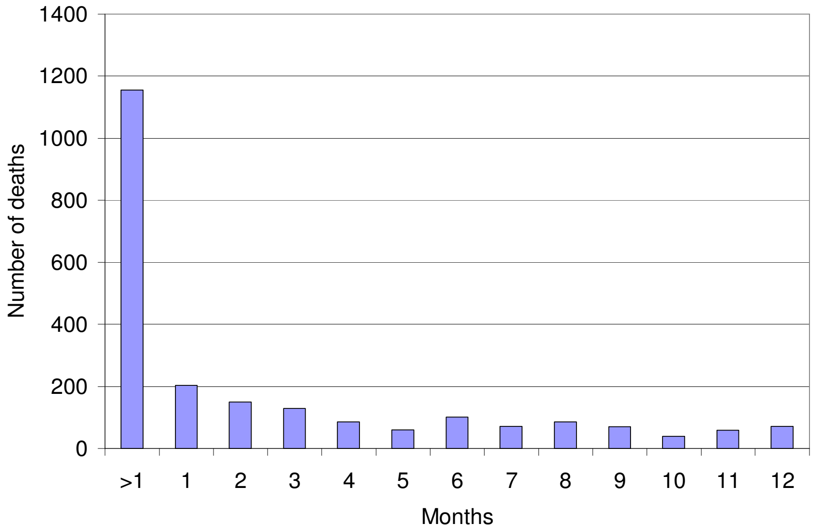
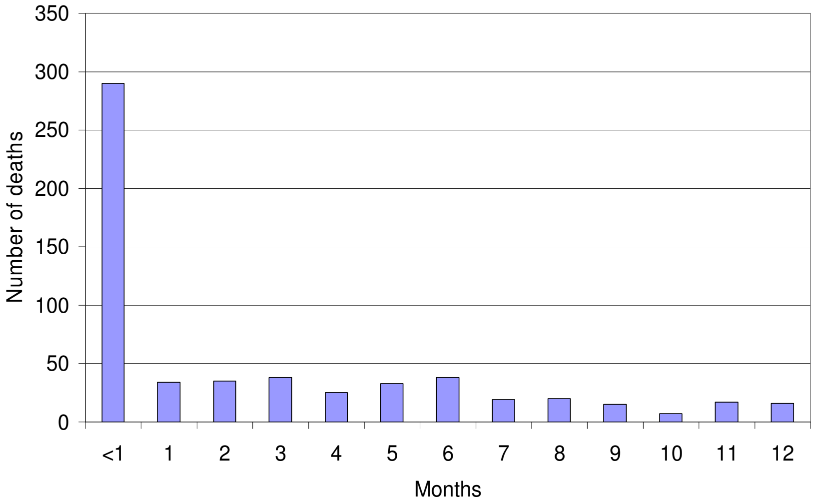


Figure e: Central Asia (data from 4 surveys)



Appendix 3: Standard errors for neonatal mortality estimates from DHS II surveys (5 year rates)

Country	NMR	Standard Error	Relative Standard error (S/E as proportion of NMR)	Date of later survey with available SEs (if any)	Relative Standard error of later survey
Burkina Faso	43.2	3.49	0.081		
Cameroon	33.1	4.20	0.127		0.097
Madagascar	38.9	3.27	0.084		
Malawi	41.2	3.56	0.087	2000	0.059
Namibia	31.5	3.16	0.100		
Niger	40.7	3.32	0.081		
Nigeria	42.2	2.90	0.069	1999	0.081
Rwanda	38.6	3.07	0.079		
Senegal	34.9	2.77	0.080		
Tanzania	37.9	3.65	0.096	1999	0.116
Zambia	43.5	2.91	0.068	2000	0.075
Egypt	32.8	2.46	0.075		
Indonesia	31.7	2.42	0.076		
Jordan	21.4	1.88	0.088		
Morocco	31.4	2.96	0.094		
Pakistan	48.9	4.19	0.086		
Yemen	40.9	3.00	0.073		
N E Brazil	26.1	3.76	0.144		
Columbia	10.8	1.66	0.153		
Dominican Republic	23.7	3.74	0.158		
Paraguay	19.4	2.48	0.128		
Peru	25.3	1.75	0.069	2000	0.081

Source: Curtis 1995, p.19
Note: DHS II surveys were carried out between 1990 and 1993.

Appendix 4: Child mortality rates by age group, and proportion of infant and child deaths occurring in the neonatal period

	NMR	PNMR	ECMR ($_4q_1$)	IMR	U5MR ($_5q_0$)	% under 5 deaths in the neonatal period	% infant deaths in the neonatal period (%)
Sub-Saharan Africa							
Cote d'Ivoire 1998/99	62.2	49.9	77.2	112.1	180.7	34.4	55.4
Mali 2001	57.1	56.4	130.5	113.5	229.1	24.9	50.4
Mozambique 1997	53.9	80.7	76.6	134.6	200.9	26.8	40.0
Ethiopia 2000	48.7	48.3	76.7	97.0	166.2	29.3	50.2
Guinea 1999	48.4	49.6	87.5	98.0	176.9	27.4	49.4
Mauritania 2000/01	44.4	25.5	36.8	69.9	104.2	42.6	63.5
Niger 1998	44.2	78.8	171.8	123.1	273.8	16.1	35.9
Chad 1996/97	43.9	58.7	102.1	102.6	194.2	22.6	42.8
Rwanda 2000	43.9	63.5	99.5	107.4	196.2	22.4	40.9
Sudan 1990	43.8	26.1	57.7	69.9	123.7	35.4	62.6
CAR 1994/95	42.1	54.6	67.3	96.7	157.5	26.7	43.5
Malawi 2000	41.8	62.0	94.6	103.8	188.6	22.2	40.3
Togo 1998	41.3	38.5	72.3	79.8	146.3	28.2	51.8
Burkina Faso 1998/99	40.8	64.6	127.1	105.4	219.1	18.6	38.7
Madagascar 1997	40.4	55.9	69.6	96.3	159.2	25.4	42.0
Tanzania 1999	40.4	58.7	52.7	99.1	146.6	27.6	40.8
Benin 2001	38.4	50.7	77.8	89.1	160	24	43.1
Comoros 1996	38.2	39.1	28.9	77.3	104	36.7	49.4
Senegal 1997	37.4	30.3	76.5	67.7	139.1	26.9	55.2
Cameroon 1998	37.2	39.8	79.9	77.0	150.7	24.7	48.3
Nigeria 1999	36.9	38.1	70.3	75.0	140.1	26.3	49.2
Zambia 2001/02	36.7	58.3	80.8	95.0	168.2	21.8	38.6
Uganda 2000/01	33.1	55.3	69.3	88.4	151.5	21.8	37.5
Namibia 1992	31.5	25.2	28.9	56.7	83.9	37.5	55.7
Gabon 2000	30.1	27.2	33.2	57.3	88.6	34.0	52.5
Ghana 1998	29.7	27.0	53.9	56.7	107.6	27.6	52.4
Zimbabwe 1999	28.9	36.2	39.6	65.1	102.1	28.3	44.5
Kenya 1998	28.4	45.3	40.8	73.7	111.5	25.5	38.5
Eritrea 1995	24.8	40.7	75.7	65.5	136.3	18.2	37.8
South Africa 1998	19.8	25.6	14.7	45.4	59.4	33.3	43.6
Average	**39.6**	**47.0**	**72.3**	**86.6**	**152.2**	**27.2**	**46.5**
North Africa/West Asia							
Yemen 1997	33.6	41.7	31.9	75.3	104.8	32.1	44.6
Morocco 1992	31.4	25.9	20.0	57.3	76.1	41.3	54.8
Turkey 1998	25.8	16.9	9.8	42.7	52.1	49.5	60.4
Egypt 2000	24.0	19.6	11.3	43.5	54.3	44.2	55.2
Armenia 2000	19.5	16.7	3.0	36.1	39.0	50.0	54.0
Jordan 1997	19.0	9.6	5.9	28.5	34.2	55.6	66.7

	NMR	PNMR	ECMR ($_4q_1$)	IMR	U5MR ($_5q_0$)	% under 5 deaths in the neonatal period	% infant deaths in the neonatal period (%)
Average	**25.6**	**21.7**	**13.7**	**47.2**	**60.1**	**45.5**	**56.0**
Central Asia							
Turkmenistan 2000	33.8	40.1	22.0	73.9	94.3	35.8	45.7
Kazakhstan 1999	33.6	28.3	10.1	61.9	71.4	47.1	54.3
Kyrgyz Republic 1997	31.6	29.7	11.7	61.3	72.3	43.7	51.5
Uzbekistan 1996	22.8	26.3	10.7	49.1	59.3	38.4	46.4
Average	**30.5**	**31.1**	**13.6**	**61.6**	**74.3**	**41.3**	**49.5**
South & Southeast Asia							
Pakistan 1990/91	48.9	37.1	28.8	86.0	112.3	43.5	56.9
India 1998/99	43.4	24.2	29.3	67.6	94.9	45.7	64.2
Bangladesh 1999/2000	42.0	24.3	29.8	66.3	94.1	44.6	63.3
Nepal 2001	38.8	25.6	28.6	64.4	91.2	42.5	60.2
Cambodia 2000	37.3	57.8	32.5	95.1	124.4	30.0	39.3
Indonesia 1997	21.8	23.9	13.1	45.7	58.2	37.5	47.7
Vietnam 1997	18.4	10.1	9.2	28.5	37.5	49.1	64.6
Philippines 1998	17.8	17.3	13.8	35.1	48.4	36.8	50.7
Average	**33.6**	**27.5**	**23.1**	**61.1**	**82.6**	**41.2**	**55.9**
Latin America & Caribbean							
Bolivia 1998	33.8	33.5	26.2	67.3	91.7	36.9	50.2
Haiti 2000	32.2	48.1	41.7	80.3	118.6	27.2	40.1
Guatemala 1998/99	23.3	21.7	14.3	45.0	58.7	39.7	51.7
Paraguay 1990	19.4	14.1	9.3	33.5	42.5	45.6	57.9
Brazil 1996	19	20.3	9.9	39.3	48.8	38.9	48.3
Peru 2000	18.3	15.0	13.9	33.3	46.7	39.2	55.0
Nicaragua 1997/98	17.1	22.4	10.6	39.5	49.7	34.4	43.3
Colombia 2000	14.9	6.5	3.5	21.4	24.9	59.8	69.6
Dominican Republic 1999	14.1	8.2	8.4	22.3	30.4	46.4	63.5
Average	**21.3**	**21.1**	**15.3**	**42.4**	**56.9**	**40.9**	**53.3**

Source: ORC Macro, 2003. MEASURE DHS+ STATcompiler. http://www.measuredhs.com August 30 2003

Appendix 5: NMRs for trend analysis (with confidence intervals where available): Long term trends

Country	Date 1st survey	NMR for first survey (CIs in brackets where available)	Date 2nd survey	NMR for second survey (CIs in brackets where available)
Sub-Saharan Africa				
Benin	1981-2	49.7	2001	38.4 (32.5-44.2)
Cote d'Ivoire	1980-1	54.0	1998/9	62.2
Ghana	1979	38.0	1998	29.7
Kenya	1977	38.8	1998	28.4
Mauritania	1981/2	47.8	2001/2	44.4
Nigeria	1981-2	45.1	1999	36.9
Senegal	1978	49.6	1997	37.4
North Africa/West Asia				
Egypt	1980	58.7	2000	24.0
Jordan	1976	27.5	1997	19.0
Turkey	1978	63.0	1998	25.8 (19.9-31.8)
Yemen	1979	58.4	1997	33.6
South & Southeast Asia				
Bangladesh	1975/6	73.7	1999/2000	42.0
Indonesia	1976	47.3	1997	21.8
Nepal	1976	75.4	2001	38.8
Philippines	1978	24.5	1998	17.8
Latin America & Caribbean				
Colombia	1976	33.5	2000	14.9
Peru	1977/8	43.8	2000	18.3

Neonatal mortality data taken from DHS statcompiler. Confidence intervals, where available, taken from individual country final report (Sampling Error annex).

Appendix 6: NMRs for trend analysis (with confidence intervals where available): Short term trends

Country	Date 1st survey	NMR for first survey (CIs in brackets where available)	Date 2nd survey	NMR for second survey (CIs in brackets where available)
Sub-Saharan Africa				
Benin	1996	38.2	2001	38.4 (32.5 -44.2)
Burkina Faso	1992/3	43.2	1998/9	40.8
Cameroon	1991	32.8	1998	37.2 (30.0-34.4)
Cote d'Ivoire	1994	42.0	1998/9	62.2
Ghana	1993	40.9	1998	29.7
Kenya	1993	25.7	1998	28.4
Madagascar	1992	39.2 (32.8-45.6)	1997	40.4
Malawi	1992	41.2 (34.3-48.1)	2000	41.8 (36.9-46.7)
Mali	1995	60.4 (54.8-66.0)	2001	57.1
Niger	1992	40.7 (34.2-47.2)	1998	44.2
Nigeria	1990	42.2 (36.5-47.9)	1999	36.9 (31.0-42.9)
Rwanda	1992	38.6 (32.6-44.6)	2000	43.9
Senegal	1992	34.9 (29.5-40.3)	1997	37.4
Tanzania	1992	37.9 (30.7-45.1)	1999	40.4 (31.4-49.8)
Uganda	1995	27.0 (22.0-31.9)	2000	33.2 (27.8-38.5)
Zambia	1992	42.5 (48.2-36.8)	2000	36.7 (31.2-42.3)
Zimbabwe	1994	24.4 (18.6-30.2)	1999	28.9 (21.3-36.4)
North Africa / Western Asia				
Egypt	2000	32.8	2000	24.0
Jordan	1990	21.4 (17.8-25.0)	1997	19.0
Turkey	1993	29.2	1998	25.8 (19.9-31.8)
Yemen	1991/2	40.9 (35.0-46.8)	1997	33.6

Country	Date 1st survey	NMR for first survey (CIs in brackets where available)	Date 2nd survey	NMR for second survey (CIs in brackets where available)
Central Asia				
Kazakhstan	1995	19.5	1999	33.6
South and South East Asia				
Bangladesh	1993/4	52.4	1999/2000	42.0
India	1992/3	48.6 (46.1–51.1)	1998/9	43.4 (41.1-45.6)
Indonesia	1991	31.7	1997	21.8 (18.3-25.3)
Nepal	1996	49.9	2001	38.8 (32.8-44.7)
Philippines	1993	17.7	1998	17.6 (13.5-21.8)
Latin America / Caribbean				
Bolivia	1994	36.3	1998	33.8
Colombia	1990	10.2 (7.1-13.4)	2000	14.9
Dominican Republic	1991	23.5	1999	14.1
Haiti	1994/5	31.2 (24.7-37.7)	2000	32.2 (25.6-38.9)
Peru	1992	25.3 (21.9-28.7)	2000	18.3 (15.3-21.3)

Appendix 7: Methodology for calculating wealth quintiles

Choice of indicator variables

The selection of indicator variables was the same as those used by Macro International. They use a broad criterion of almost all household assets and utility services (including country specific items) in order to maximise the distribution of households. The items used were:

Type of roof	Type of toilet facilities
Type of floor	Type of water source
Land	Electricity
Cot	TV
Table	Radio
Almirah (cupboard)	Bicycle

Construction of the index

The index is constructed using principal component analysis (as recommended by Filmer and Pritchett 2001) to assign indicator weights using the same process as used by DHS/Macro. Principal component analysis (PCA) is a procedure that transforms a number of potentially correlated variables into a smaller number of uncorrelated variables. The procedure standardises the indicator variable (calculating z-scores) then calculates the factor coefficient scores. It then multiplies the indicator values by the loadings and adds them together to create the index wealth value for each child. The resulting sum is a standardised score with a mean of zero and a standard deviation of one. Whereas DHS calculated scores for the sample as a whole, I calculated them separately for urban and rural dwellers, giving two separate indices.

Quintiles were then constructed based on the scores. Whereas Macro/DHS calculate quintiles at the household level, I calculated them at the level of the individual child, thus creating an equal 20% in each quintile.

Appendix 8: Results of bivariate analysis for Bangladesh data

1.0 The relationship between asset quintiles and neonatal/post-neonatal mortality

When the cross tabulations were carried out using the original quintiles calculated by Macro the relationship between neonatal mortality and asset quintiles was not clear. Children born to mothers in the lowest wealth quintile have higher rates of mortality than those in highest two wealth quintiles but the pattern between quintiles and mortality is not a clear monotonic relationship, with the highest rate of mortality found in quintile three (see Table 42). As the survey measures the level of assets at time of survey rather than at the time of birth, bivariate analysis was also carried out to see if a clearer gradient was found when only children born two years or less before the survey were included. A similar pattern was found (Table 42), suggesting that possible changes in wealth between the time of the child's birth and the survey are not major contributing factors to this lack of clear pattern. Post-neonatal mortality tends to show a clearer gradient.

Because of this lack of clear association asset scores were recalculated separately for urban and rural dwellers, as it was believed that the lack of linear association may be related to the failure of the asset index to capture differences in rural and urban ownership (see Appendix 7 for methodology used). The results in Table 43 show mortality by separately calculated quintiles for urban and rural dwellers. The pattern for rural dwellers is nearer to what would be expected, and while an improvement, neither urban nor rural quintiles provide a clear monotonic relationship between assets and mortality for neonatal mortality, and the differences between quintiles are not significant for urban areas (see Figures 35 and 36). The pattern for post-neonatal mortality is even less monotonic, although there is a significant difference between the richest and poorest quintiles for both urban and rural areas.

Table 42: Bivariate analysis of mortality by quintile (DHS original analysis)

Wealth index quintiles (based on original DHS analysis)	% of total sample	NMR **	PNMR **
Quintile 1 (lowest)	23.0	45.6	37.4
Quintile 2	21.0	46.0	30.3
Quintile 3	19.25	53.1	26.3
Quintile 4	17.8	38.5	26.9
Quintile 5 (highest)	19.1	30.2	22.7
Wealth index quintiles (children born 24 months or less before the survey only)		**NMR** **	
Quintile 1 (lowest)		50.6	
Quintile 2		50.6	
Quintile 3		54.1	
Quintile 4		39.6	
Quintile 5 (highest)		33.5	

* Denotes chi-squared tests showed differences were significant at the 5% level

** Denotes chi-squared tests shower differences were significant at the 1% level

Table 43: Bivariate analysis of mortality by quintile (recalculated separately for urban/rural)

Wealth index quintiles (recalculated separating urban and rural dwellers	% of total sample	NMR	PNMR
Urban only	15.5		**
Quintile 1 (lowest)	2.9	44.6	35.1
Quintile 2	2.9	50.4	46.5
Quintile 3	3.1	41.1	23.9
Quintile 4	3.2	34.2	28.5
Quintile 5 (highest)	3.5	25.7	0.85
Rural only	84.5	**	*
Quintile 1 (lowest)	16.6	51.3	40.8
Quintile 2	17.4	44.9	27.1
Quintile 3	17.3	48.3	25.7
Quintile 4	16.7	41.8	28.9
Quintile 5 (highest)	16.6	33.8	23.8
Total	**100**	**42.9**	**29.2**

* Denotes chi-squared tests showed differences were significant at the 5% level

** Denotes chi-squared tests shower differences were significant at the 1% level

Figure 35: Distribution of neonatal mortality by quintile: urban (asset score for urban and rural recalculated separately)

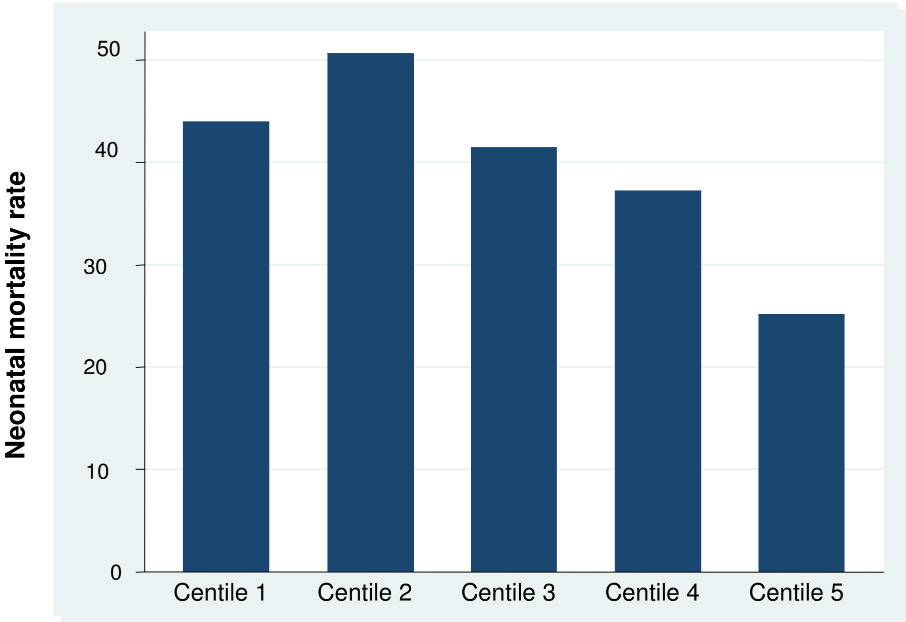
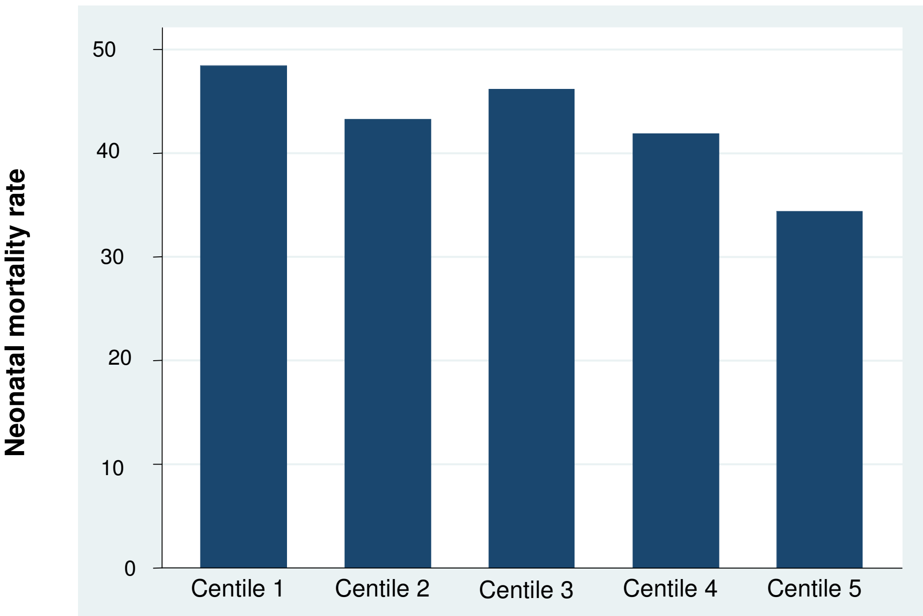
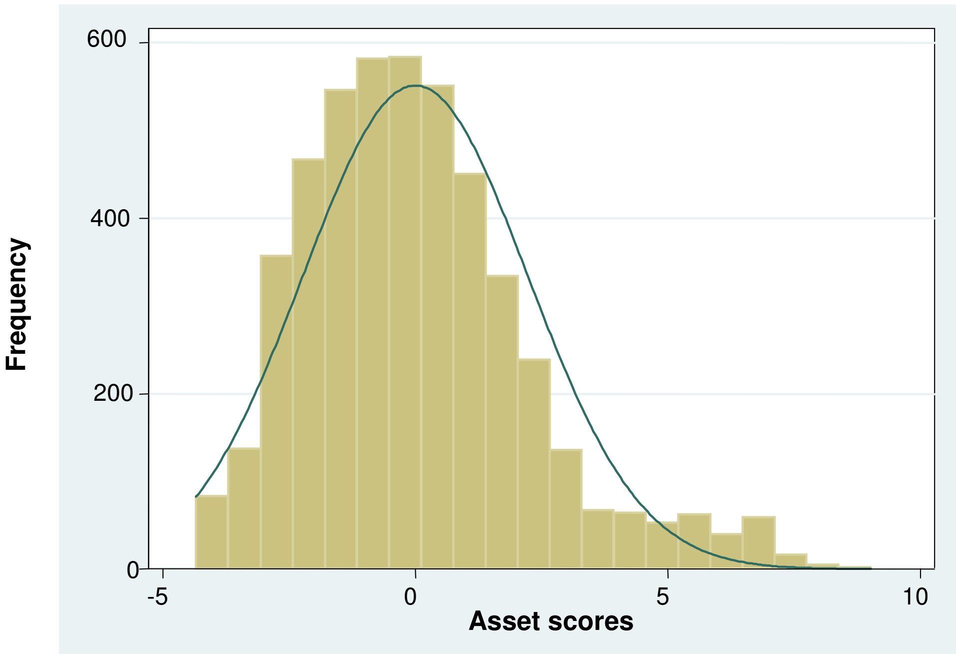


Figure 36: Distribution of neonatal mortality by quintile: rural (asset score for urban and rural recalculated separately)



Further analysis of the asset scores themselves (as recalculated by myself) in figures 37 and 38 show the distribution disaggregated by urban and rural dwellers for the 2004 survey[49], which presents very different patterns. While the rural pattern overall distribution is clustered around the median, the pattern for urban dwellers is bimodal, with a much greater spread. This could indicate the differing socio-economic status of slum-dwellers and migrants in large cities, and the more wealthy "established" urban population. The boxplots in Figures 39 and 40 show the asset scores by quintile for rural and urban dwellers (based on 1996/7 survey data). The data for rural dwellers shows that there is very little variance in asset score either within or between quintiles 1-4, suggesting there is little difference in wealth as measured by the asset score. The boxplot for urban dwellers shows a greater degree of variance. This lack of variance in the rural population (which makes up the bulk of the sample) may well reduce the ability to demonstrate differences in mortality by asset quintile, as in reality the difference in asset scores between the first four quintiles is small.

Figure 37: Distribution of asset scores: rural only (2004 survey)



[49] As the asset scores (as opposed to the quintiles) are not comparable between different surveys, analysis must be carried out separately. The other two surveys show similar patterns.

Figure 38: Distribution of asset scores (with normal distribution superimposed: urban only (2004 survey)

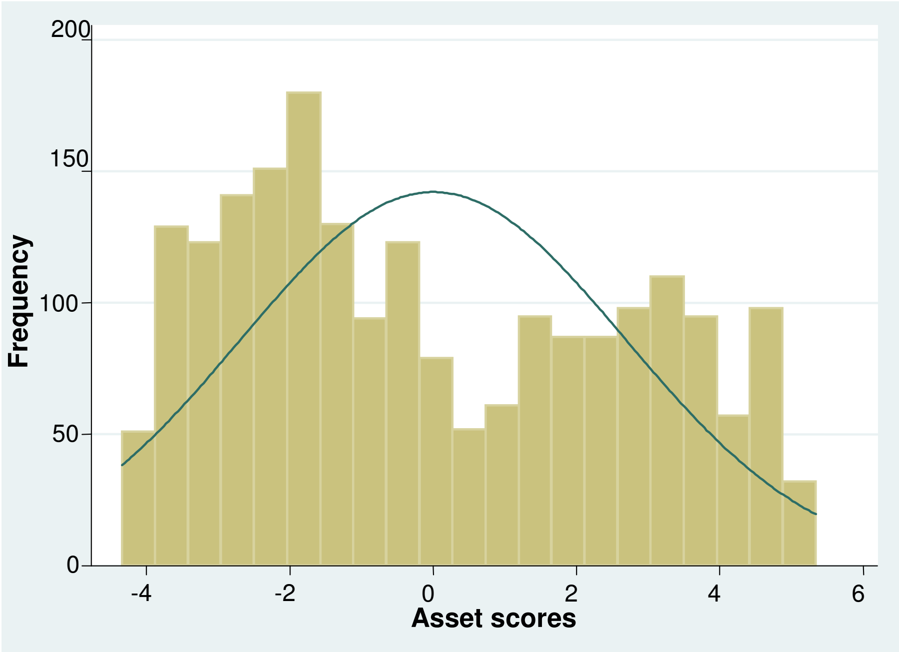


Figure 39: Asset index score by quintile: rural (1996 survey only)

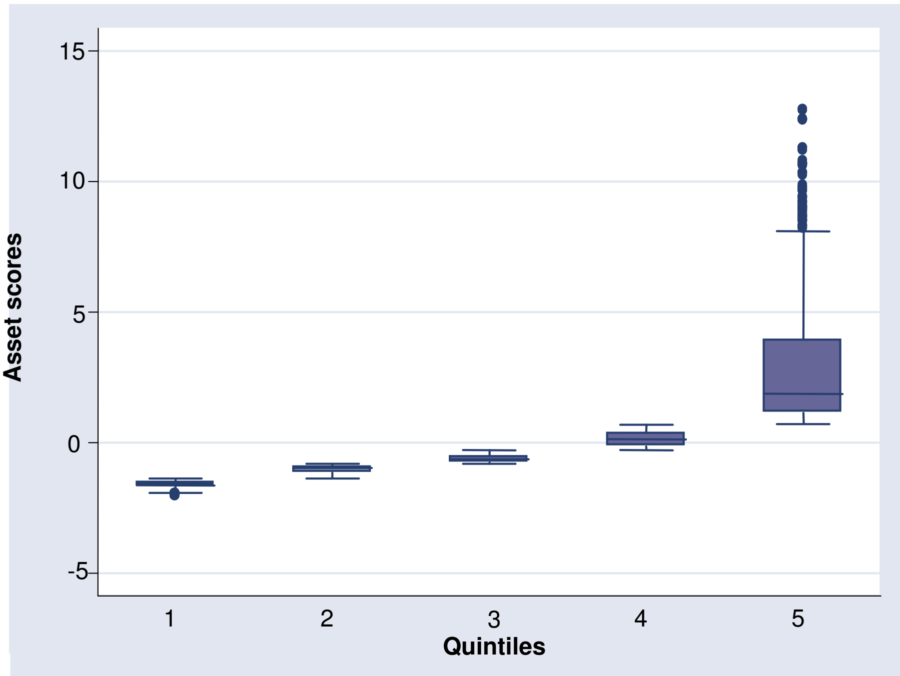
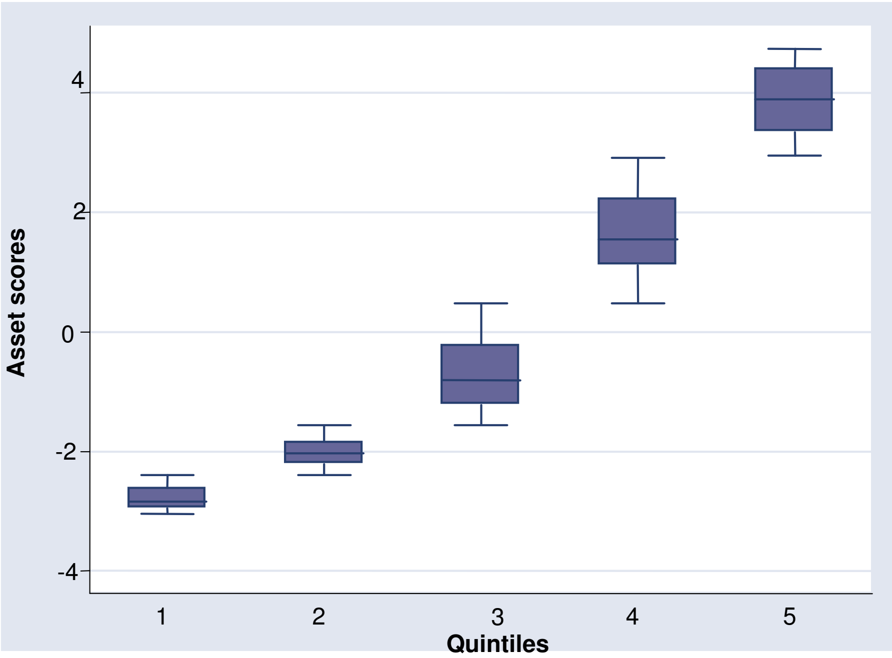


Figure 40: Asset score by quintile: urban only (1996 survey)



2.0 <u>Maternal education</u>

Levels of maternal education showed a clearer pattern with levels of mortality decreasing with increased educational level for both NMR and PNMR (Table 44). However, it was clear that mortality did not drop to any great degree for NMR until the level of further education was reached (although this was a very small sample with very few neonatal deaths): with PNMR the decrease was more evenly distributed, and there were marked differences in rates for children born to mothers with no schooling, primary education and secondary education.

While there did appear to be slightly lower NMR for children born in urban areas, this was not statistically significant. The analysis was repeated removing all children who had moved within the last 5 years in order to see whether recent migration may be affecting these figures, but the difference was still not significant for either neonatal or post-neonatal mortality. An examination of mortality by place of residence found mortality within the capital or large cities to be the highest, with mortality in the countryside the second highest.

Mortality was lowest in towns, but again a chi-squared test did not find the differences significant.

Table 44: Bivariate analysis of mortality by other socio-economic factors

Socio-economic variables	**% of total sample**	**NMR**	**PNMR**
Mother's education		**	**
No education	47.5	46.2	35.7
Primary	29.0	40.4	26.1
Secondary	20.0	39.6	17.7
Higher	3.6	20.5	14.7
Urban/rural			
Urban	15.6	39.2	32.1
Rural	84.5	42.9	28.1
Urban (those migrated within last 5 years removed)	13.0	35.9	28.3
Rural (those migrated in last 5 years removed)	53.4	39.1	28.4
Place of residence			
Capital/large city	4.0	44.8	33.1
Small city	2.6	35.4	27.9
Town	16.5	37.7	32.5
Countryside	76.7	42.9	28.7
Total	**100**	**42.3**	**28.7**

** Denotes chi-squared tests were significant at the 1% level

The lack of significant difference in neonatal mortality for urban/rural residence in the bivariate analysis is an interesting and unexpected incidental finding. This could be due to a number of reasons, including possible under-reporting of rural deaths. However, the probable key to this issue is the very high neonatal mortality found in Dhaka and other large cities seen in the bivariate analysis. Large scale rural/urban migration has led to a massive proliferation of slums: indeed the slum population of Dhaka has doubled in a decade and is estimated to have reached 3.4 million in 2006 (One World Asia 2006), with approximately 30% of the population now slum-dwellers (ICDDR(B) website). Increased child mortality within slum areas has been widely reported, and is normally mostly attributed to the poor environmental and housing experienced (Huq-hussain 1996).

2.0 Environmental factors

Significant differences were found in mortality when analysed by sanitation facilities (Table 45). Mortality was much lower in families that had flush toilets or a septic tank, and highest among those who had no sanitation. Source of drinking water was only significant for neonatal mortality, with lower mortality among those who had piped water, and very high among those who used surface water. However, it is worth noting that the vast majority of people used well water, so the sample sizes for other water sources are extremely small. This may explain the apparent lack of difference for PNMR, but another factor to consider is that piped water could indicate a wealthy family with high quality housing, or could also be the source of water for a slum dwelling served by communal piped water supply.

Table 45: Bivariate analysis of mortality by environmental factors

Water and sanitation variables	% of sample	NMR	PNMR
Sanitation		**	*
Flush toilet, septic tank	8.0	28.6	20.4
Latrine	72.2	42.1	28.6
No sanitation	19.8	48.2	32.3
Visitor/other/data missing	0.02	18.8	120.2
Total	**100**	42.3	28.8
Source of drinking water		**	
Water piped	4.9	34.0	35.3
Well	94.1	42.4	28.4
Surface	0.8	81.1	25.5
Visitor/other/missing	0.2	37.8	0
Total	**100**	**42.3**	**29.1**

* Denotes chi-squared test shows differences significant at 5% level.
** Denotes chi-squared test shows differences significant at 1% level.

3.0 Biodemographic variables

Data from cross tabulations with chi-squared tests for biodemographic variables generally conformed to expected patterns (Table 46). Neonatal mortality was very high for first order births (62 per 1000), and then showed a U-shaped curve declining for birth orders two to four, before increasing again for five and six. A chi-squared test showed the differences to be significant. There was very little increase in mortality for first births in the post-neonatal analysis, but again a marked increase for births of fifth order or greater.

Table 46: Bivariate analysis of biodemographic variables

Biodemographic variables	**% of total sample**	**NMR**	**PNMR**
Birth order		**	*
1st order birth	28.8	62.2	27.8
2nd order birth	24.6	32.6	24.5
3rd order birth	16.8	32.6	22.5
4th order	10.9	32.0	25.8
5th order	7.0	41.0	37.6
6th order or more birth	12.0	43.2	48.5
Total	**100**	**42.9**	**29.1**
Preceding birth interval		**	**
Preceding birth interval <24m	17.0	55.7	47.9
Preceding birth interval 24-35m	27.1	35.5	33.4
Preceding birth interval 36-47m	21.8	27.2	21.6
Preceding birth interval 48m+	34.1	34.6	22.3
Total	**100**	**42.9**	**29.1**
Mother's age		**	**
10-15	7.1	75.8	33.8
16-20	31.4	50.2	25.5
21-30	48.1	33.8	28.3
31-40	12.4	40.4	35.3
41 and over	1.1	47.6	66.3
Total	**100**	**42.9**	**29.1**

A preceding birth interval of less than 24 months is associated with a significantly marked increase in mortality for both neonatal and post-neonatal age groups, with mortality then decreasing in inverse proportion to length of birth interval until over 48 months, when there is a slight increase. The association between maternal age and neonatal mortality showed a U-shaped distribution, with very high rates of mortality for newborns of mothers aged 10-15 and increased mortality in the 31-40 and over 40 age group. Post-neonatal mortality showed a much smaller increase for mothers aged 10-15, but a very large increase for mothers 41 and over (although numbers were extremely small).

4.0 Family care practices

No discernible pattern was seen for time of initiation of breastfeeding and mortality for any age group (Table 47). Only 2.4% of infants were never breastfed, but there was extremely high NMR (711 per 1000 births) among this group. This is likely to be because in a country where initiation of breastfeeding is almost universal, those who were never breastfed are likely to have been unable to do so because of prematurity or sickness at birth. The link between mortality and failure to breastfeed is therefore likely to be endogenous. Markedly increased PNMR is also found among infants never breastfed, which may be related to poor condition at birth, or may be as a more direct result of poor feeding practices.

Table 47: Bivariate analysis of mortality by time of initiation of breastfeeding

Initiation of breastfeeding	% total of ever-breastfed sample	NMR	PNMR
Under 1 hour	20.4	21.9	24.7
1-6 hours	47.4	21.5	23.7
7-12 hours	3.6	16.4	22.6
13-24 hours	0.3	20.8	0
On day 1	9.2	22.6	18.7
On day 2 or 3	17.7	13.8	22.3
Day 4 or later	1.4	12.4	37.8
Total	**100**	**20.0**	**23.3**
	% total sample		
Never breastfed / data missing	2.4	711.3**	154.9

**Chi-squared test significant between never breastfed and breastfed infants at the 1% level.

5.0 Biological variables

The 1.7% of children who were either twins or higher multiple births had a massively increased rate of neonatal mortality (NMR 255 per 1000), and this was significant at the 1% level when compared to singleton births (Table 48). This vastly increased risk continued into the post-neonatal period. Males also had a significantly increased risk for neonatal mortality, but not for PNMR.

Table 48: Bivariate analysis of mortality by biological variable

Biological variables	**% of total sample**	**NMR**	**PNMR**
Multiple birth		**	**
Twin/multiple birth	1.7	255.2	167.5
Singleton	98.3	39.1	27.1
Sex		*	
Male	50.8	45.9	29.3
Female	49.2	40.0	28.9
Total	**100**	**42.9**	**29.1**

** Chi-squared tests were significant at the 1% level for association between twin/singleton for NMR/PNMR
*Chi-squared tests were significant at the 5% level for association between male/female for NMR

Appendix 9: Multivariate logistic regression with neonatal mortality as the dependant variable (reported as ORs)

		(1) Socio-political/ socio-economic	(2) Environmental added	(3) Bio-demographic/ maternal health added	(4) Maternal health care added	(5) Biological added
Socio-political environment	**Year of survey**					
	1996 (ref)					
	2004	0.85	0.83	0.99	0.62	0.64
		(0.08)	(0.08)	(0.10)	(0.07)**	(0.07)**
	2000	0.884	0.890	0.970	0.569	0.59
		(0.082)	(0.083)	(0.093)	(0.063)**	(0.066)**
	State					
	Barisal (ref)					
	Chittagong	0.99	1.01	0.99	0.89	0.90
		(0.16)	(0.16)	(0.16)	(0.15)	(0.15)
	Dhaka	1.23	1.22	1.20	1.16	1.16
		(0.19)	(0.19)	(0.19)	(0.18)	(0.18)
	Khulna	1.14	1.12	1.10	1.05	1.03
		(0.19)	(0.19)	(0.19)	(0.19)	(0.19)
	Rajshahi	1.18	1.17	1.14	1.17	1.20
		(0.18)	(0.19)	(0.19)	(0.19)	(0.20)
	Sylhet	1.78	1.80	1.69	1.47	1.45
		(0.28)**	(0.28)**	(0.27)**	(0.24)*	(0.24)*
Socio-economic	**Wealth quintile**					
	Quintile 1/4/rural (ref)					
	Quintile 1/4 urban	0.99 (0.10)	1.01 (0.57)	1.01 (0.11)	1.10 (0.12)	1.05 (0.12)
	Quintile 5/urban	0.68	0.90	0.99	0.90	0.77
		(0.16)	(0.27)	(0.30)	(0.28)	(0.26)
	Quintile 5/rural	0.75	0.82	0.84	0.87	0.86
		(0.10)*	(0.10)	(0.11)	(0.12)	(0.12)
	Maternal education					
	No education (ref)					
	Primary education	0.94 (0.09)	0.95 (0.09)	0.83 (0.08)	0.90 (0.09)	0.88 (0.09)
	Secondary education	0.99 (0.12)	1.02 (0.12)	0.81 (0.10)	0.95 (0.13)	0.91 (0.12)
	Further education	0.54	0.58	0.44	0.44	0.45
		(0.17)*	(0.18)	(0.14)*	(0.16)*	(0.16)*
Environmental	**Water and sanitation**					
	No sanitation (ref)					
	Flush toilet		0.60	0.61	0.64	0.67
			(0.14)*	(0.15)*	(0.16)	(0.16)
	Latrine		0.89	0.87	0.91	0.92
			(0.10)	(0.10)	(0.10)	(0.10)
	Surface water (ref)		1.0	1.0	1.0	1.0

		(1) Socio-political/ socio-economic	(2) Environmental added	(3) Bio-demographic/ maternal health added	(4) Maternal health care added	(5) Biological added
	Well		0.61 (0.23)	0.59 (0.22)	0.65 (0.24)	0.73 (0.27)
	Piped		0.54 (0.17)	0.52 (0.16)*	0.56 (0.17)	0.60 (0.19)
Bio-deomographic	**Birth order**					
	Second or subsequent					
	First birth			1.74 (0.22)**	1.64 (0.22)**	1.84 (0.25)**
	Preceding birth interval					
	24-35 months (ref)					
	< 24 months			1.51 (0.20)**	1.47 (0.20)**	1.49 (0.21)**
	36-47 months			0.77 (0.12)	0.78 (0.12)	0.79 (0.12)
	48 months +			0.78 (0.11)	0.86 (0.12)	0.82 (0.12)
	Maternal age					
	Under 16 (ref)					
	16-20			0.86 (0.11)	0.85 (0.11)	0.85 (0.11)
	21-30			0.77 (0.12)	0.74 (0.12)	0.74 (0.12)
	31-40			0.97 (0.19)	1.02 (0.20)	0.96 (0.19)
	41 and over			0.93 (0.40)	1.03 (0.45)	0.89 (0.39)
Maternal health and nutrition	**Maternal height**					
	Over 145cm (ref)					
	Less than 145cm			1.31 (0.12)**	1.30 (0.12)**	1.29 (0.13)**
	Maternal complication					
	No complication (ref)					
	Complication			1.56 (0.12)**	1.67 (0.14)**	1.60 (0.13)**
Maternal health care	**Tetanus toxoid /ANC**					
	No ANC/TT (ref)					
	ANC only				0.76 (0.14)	0.79 (0.14)
	TT only				0.61 (0.07)**	0.61 (0.07)**
	TT and ANC				0.43 (0.06)**	0.45 (0.06)**

		(1) Socio-political/ socio-economic	(2) Environmental added	(3) Bio-demographic/ maternal health added	(4) Maternal health care added	(5) Biological added
	Data missing				2.65 (0.30)**	2.33 (0.27)**
	Place of delivery					
	Home (ref)					
	Government facility				1.96 (0.33)**	1.70 (0.30)**
	Private or NGO facility				2.09 (0.48)**	1.77 (0.46)*
Biological	**Child is a twin**					7.08 (1.39)**
	Sex of child					
	Female (ref)					
	Male					1.16 (0.09)
	Constant (logit form)					-2.67
	Pseudo r-squared	0.019	0.011	0.035	0.078	0.100
	Observations	19321	19293	18950	18950	18950

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%.

Appendix 10: Results of multivariate logistic regression with neonatal mortality as the dependant variable and composite variables added (reported as ORs)

Model:	(6) **Composite** Maternal education/ place of delivery	(7) **Composite** Quintile/ place of delivery	(8) **Composite** ANC/place of delivery	(9) **Composite** Recommended ANC/place of delivery	(10) **Composite** Complication / place of delivery
Year of survey					
Ref: 1996					
2000	0.60	0.60	0.58	0.57	0.60
	(0.07)**	(0.07)**	(0.06)**	(0.06)**	(0.07)**
2004	0.635	0.632	0.614	0.585	0.685
	(0.072)**	(0.071)**	(0.069)**	(0.066)**	(0.082)**
State					
Ref: Barisal					
Chittagong	0.91	0.90	0.91	0.92	0.90
	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)
Dhaka	1.16	1.16	1.15	1.16	1.14
	(0.19)	(0.18)	(0.18)	(0.19)	(0.18)
Khulna	1.03	1.03	1.03	1.06	1.01
	(0.19)	(0.19)	(0.19)	(0.19)	(0.18)
Rajshahi	1.20	1.18	1.17	1.19	1.17
	(0.20)	(0.20)	(0.19)	(0.20)	(0.19)
Sylhet	1.47	1.45	1.47	1.49	1.43
	(0.25)*	(0.24)*	(0.25)*	(0.25)*	(0.24)*
Asset quintile					
Ref: Quintile 1-4 /rural					
Quintile 1-4/urban	1.04		1.01	1.01	1.05
	(0.12)		(0.12)	(0.11)	(0.12)
Quintile 5/urban	0.74		0.86	0.85	0.77
	(0.26)		(0.29)	(0.26)	(0.26)
Quintile 5/rural	0.86		0.86	0.87	0.86
	(0.12)		(0.11)	(0.11)	(0.12)
Maternal education					
Ref: no education					
Primary education		0.89	0.86	0.85	0.88
		(0.09)	(0.09)	(0.08)	(0.09)
Secondary education		0.96	0.89	0.88	0.91
		(0.13)	(0.11)	(0.11)	(0.12)
Further education		0.58	0.48	0.49	0.44
		(0.20)	(0.16)*	(0.17)*	(0.15)*
Sanitation					
Ref: no sanitation					
Flush toilet, septic tank	0.65	0.79	0.66	0.64	0.67
	(0.16)	(0.17)	(0.16)	(0.16)	(0.17)
Latrine	0.92	0.95	0.91	0.91	0.91
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Water source					
Ref: open					
Well	0.74	0.81	0.74	0.75	0.72
	(0.28)	(0.30)	(0.28)	(0.28)	(0.27)
Piped	0.60	0.61	0.61	0.60	0.59
	(0.19)	(0.19)	(0.20)	(0.19)	(0.19)

Model:	(6) **Composite** Maternal education/ place of delivery	(7) **Composite** Quintile/ place of delivery	(8) **Composite** ANC/place of delivery	(9) **Composite** Recommended ANC/place of delivery	(10) **Composite** Complication / place of delivery
Birth order					
Ref: second or subsequent					
First birth	1.81 (0.24)**	1.85 (0.25)**	1.73 (0.23)**	1.78 (0.24)**	1.88 (0.25)**
Preceding birth interval					
Ref: 24-35 months					
Less than 24 months	1.49 (0.21)**	1.49 (0.21)**	1.48 (0.21)**	1.49 (0.21)**	1.48 (0.21)**
36-47 months	0.79 (0.12)	0.78 (0.12)	0.77 (0.12)	0.79 (0.12)	0.79 (0.12)
48 months +	0.82 (0.12)	0.82 (0.12)	0.79 (0.11)	0.80 (0.11)	0.83 (0.12)
Mother's age					
Ref: less than 16 years					
16-20	0.84 (0.11)	0.85 (0.11)	0.83 (0.11)	0.86 (0.11)	0.85 (0.11)
21-30	0.72 (0.11)*	0.75 (0.12)	0.73 (0.12)	0.77 (0.12)	0.74 (0.12)
31-40	0.93 (0.18)	0.97 (0.19)	0.98 (0.19)	1.02 (0.20)	0.97 (0.19)
41 and over	0.87 (0.38)	0.90 (0.40)	0.96 (0.43)	0.99 (0.45)	0.92 (0.40)
Maternal height less than 145cm	1.29 (0.13)**	1.29 (0.13)**	1.27 (0.12)*	1.28 (0.12)**	1.28 (0.12)*
Reported complication	1.61 (0.13)**	1.58 (0.13)**	1.60 (0.13)**	1.54 (0.13)**	
Antenatal care and TT					
Ref: no ANC or TT					
AN only	0.78 (0.14)	0.80 (0.15)			0.80 (0.15)
TT only	0.61 (0.07)**	0.61 (0.07)**			0.61 (0.07)**
TT and AN	0.44 (0.06)**	0.46 (0.07)**			0.45 (0.06)**
Data missing	2.32 (0.27)**	2.34 (0.27)**	3.57 (0.94)**	3.49 (0.34)**	2.29 (0.26)**
Child is a twin	7.10 (1.40)**	7.38 (1.45)**	7.38 (1.45)**	7.08 (1.39)**	7.28 (1.42)**
Male	1.15 (0.09)	1.15 (0.09)	1.16 (0.09)	1.17 (0.09)*	1.16 (0.09)*
Maternal education/place of delivery					
Ref: No education, home delivery					
No education, government facility	1.92 (0.58)*				
No education, private/NGO facility	4.20 (3.21)				
Primary education, home delivery	0.90 (0.09)				

Model:	(6) **Composite** Maternal education/ place of delivery	(7) **Composite** Quintile/ place of delivery	(8) **Composite** ANC/place of delivery	(9) **Composite** Recommended ANC/place of delivery	(10) **Composite** Complication / place of delivery
Primary education, government facility	1.51 (0.46)				
primary education, NGO/private facility	1.61 (0.78)				
Secondary or further education, home delivery	0.93 (0.13)				
Secondary or further education, government facility	1.27 (0.35)				
Secondary or further education, private/NGO facility	1.23 (0.40)				
Quintiles/place of delivery					
Ref: rural 1-4, home					
Urban 1-4, home		1.00 (0.12)			
Urban 1-4, government		1.54 (0.42)			
Urban 1-4, NGO/private		2.24 (0.92)*			
Rural 1-4, government		2.83 (0.67)**			
Rural 1-4, NGO/private		1.53 (1.00)			
Rural 5, home		0.62 (0.26)			
Rural 5, government		0.35 (0.26)			
Rural 5, NGO/private		0.85 (0.39)			
Urban 5, home delivery		0.83 (0.12)			
Urban 5, government		0.49 (0.24)			
Urban 5, NGO/private		0.52 0.39)			
Recommended level of ANC,/Place of delivery					
Ref: Not recommended ANC, home delivery					
Not recommended ANC, delivery in government institution				1.67 (0.30)**	
Not recommended ANC, delivery in private/NGO institution				1.77 (0.52)*	
Recommended ANC, home delivery				0.62 (0.20)	
Recommended ANC, delivery in government institution				0.60 (0.32)	

Model:	**(6)** **Composite** Maternal education/ place of delivery	**(7)** **Composite** Quintile/ place of delivery	**(8)** **Composite** ANC/place of delivery	**(9)** **Composite** Recommended ANC/place of delivery	**(10)** **Composite** Complication / place of delivery
Recommended ANC, delivery in private/NGO institution				0.99 (0.45)	
ANC, Place of delivery					
Ref: Home delivery, no ANC					
Delivery in Government institution, no ANC			3.00 (0.81)**		
Delivery in private/NGO institution, no ANC			1.51 (1.20)		
Home delivery, some ANC			0.63 (0.08)**		
Delivery in government institution, some ANC			0.80 (0.23)		
Delivery in a private/NGO institution, some ANC			1.01 (0.37)		
Complications/place of delivery					
Ref: no complication, home delivery					
No complication, government institution					1.03 (0.32)
No complication, delivery in private/NGO institution					1.89 (0.63)
Complication, home delivery					1.44 (0.15)**
Complication, government institution					3.04 (0.61)**
Complication, private/NGO institution					2.61 (0.91)**
Constant (logit)	-2.65	-2.63	-2.58	-2.90	-2.90
Observations	18855		18855	18950	18855

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

Appendix 11: Results of multivariate logistic regression with post-neonatal mortality as the dependant variable (reported as ORs)

		(1) *Socio-political/ socio-economic*	(2) *Environmental added*	(3) *Bio-demographic /maternal health added*	(4) *Maternal health care added*	(5) *Biological added*
Broader socio-political	**Year of survey**					
	1996 (ref)					
	2004	0.69	0.69	0.74	0.51	0.52
		(0.08)**	(0.09)**	(0.09)*	(0.07)**	(0.08)**
	2000	0.697	0.699	0.716	0.464	0.482
		(0.084)**	(0.085)**	(0.089)**	(0.066)**	(0.069)**
	State					
	Barisal (ref)					
	Chittagong	0.82	0.82	0.79	0.73	0.75
		(0.16)	(0.16)	(0.16)	(0.15)	(0.15)
	Dhaka	1.05	1.02	1.04	1.02	1.02
		(0.19)	(0.18)	(0.19)	(0.19)	(0.19)
	Khulna	0.47	0.47	0.47	0.48	0.46
		(0.12)**	(0.12)**	(0.12)**	(0.12)**	(0.12)**
	Rajshahi	0.77	0.76	0.75	0.82	0.86
		(0.15)	(0.15)	(0.15)	(0.16)	(0.17)
	Sylhet	1.28	1.27	1.14	1.06	1.11
		(0.25)	(0.25)	(0.23)	(0.22)	(0.23)
Socio-economic	**Wealth quintile**					
	Quintile 1-4/rural (ref)					
	Quintile 1-4/urban	1.00	1.30	1.32	1.45	1.43
		(0.10)	(0.17)	(0.18)	(0.20)**	(0.21)*
	Quintile 5/urban	0.68	0.39	0.42	0.52	0.45
		(0.16)	(0.19)*	(0.20)	(0.27)	(0.23)
	Quintile 5/rural	0.76	1.01	1.03	1.01	1.10
		(0.10)*	(0.09)	(0.19)	(0.20)	(0.19)
	Maternal education					
	No education					
	Primary education	0.79	0.80	0.84	0.92	0.92
		(0.10)	(0.10)	(0.11)	(0.12)	(0.12)
	Secondary education	0.54	0.55	0.53	0.67	0.66
		(0.10)**	(0.10)**	(0.10)**	(0.13)*	(0.13)*
	Further education	0.44	0.45	0.43	0.63	0.61
		(0.17)*	(0.18)*	(0.17)*	(0.26)	(0.26)
Environmental	**Water and sanitation**					
	No sanitation (ref)					
	Flush toilet, septic tank		0.95	0.93	0.89	0.89
			(0.27)	(0.27)	(0.27)	(0.28)
	Latrine		0.96	0.93	0.95	0.97
			(0.13)	(0.13)	(0.14)	(0.14)
	Well		1.68	1.73	1.99	1.95
			(0.94)	(0.99)	(1.15)	(1.12)
	Open water source (ref)		1.0	1.0	1.0	1.0
	Piped		1.10	1.12	1.25	1.15
			(0.57)	(0.59)	(0.66)	(0.61)

		(1) *Socio-political/ socio-economic*	(2) *Environmental added*	(3) *Bio-demographic /maternal health added*	(4) *Maternal health care added*	(5) *Biological added*
Biodemographic	**Birth order**					
	Second or subsequent births (ref)					
	First birth			1.21 (0.21)	1.23 (0.22)	1.35 (0.24)
	Preceding birth interval					
	Less than 24 months			1.50 (0.24)*	1.49 (0.24)*	1.48 (0.24)*
	36-47 months			0.65 (0.12)*	0.67 (0.12)*	0.69 (0.12)*
	48 months +			0.71 (0.12)*	0.80 (0.14)	0.76 (0.13)
	Mother's age					
	Under 16 (ref)					
	16-20			0.83 (0.18)	0.85 (0.19)	0.87 (0.19)
	21-30			1.07 (0.24)	1.15 (0.27)	1.15 (0.26)
	31-40			1.33 (0.35)	1.50 (0.40)	1.45 (0.38)
	41 and over			2.82 (1.07)**	3.38 (1.32)**	3.29 (1.29)**
Maternal health and nutrition	**Maternal height**					
	Over 145cm (ref)					
	Less than 145cm			1.19 (0.15)	1.19 (0.15)	1.17 (0.15)
	Maternal complications					
	No reported complication (ref)					
	Complication			1.03 (0.11)	1.09 (0.12)	1.04 (0.12)
Health care	**Antenatal care/TT**					
	No ANC/TT (ref)					
	ANC only				0.56 (0.16)*	0.59 (0.16)
	TT only				0.62 (0.09)**	0.62 (0.09)**
	TT and ANC				0.38 (0.08)**	0.39 (0.08)**
	Data missing				1.98 (0.31)**	1.80 (0.28)**
	Place of delivery					
	Home (ref)					
	Government facility				1.47 (0.38)	1.26 (0.35)
	Private/NGO facility				0.72 (0.37)	0.62 (0.33)
Biological	**Child is a twin**					7.18 (1.76)**
	Sex					

		(1) *Socio-political/ socio-economic*	(2) *Environmental added*	(3) *Bio-demographic /maternal health added*	(4) *Maternal health care added*	(5) *Biological added*
	Female (ref)					
	Male					1.00
						(0.10)
	Pseudo r-squared	0.026	0.027	0.039	0.065	0.082
Constant (logit)						-2.88
	Observations	14949	14925	14681	14617	14617

Robust standard errors in parentheses
significant at 5%; ** significant at 1%

Appendix 12: Variables included in logistic and 2 stage least square logistic regression

Outcome variables

- Neonatal mortality

Distal Variables

Broader Socio-political:
- Region (BIMARUO, North, South, East, North east, West)

Socio-economic
- Urban/rural residence
- Wealth index (5 quintiles)
- Maternal education (none, primary, secondary, further)
- Caste (scheduled caste or tribe/non scheduled caste)
- Religion (Hindu, Muslim, other)
- Maternal autonomy:
    - involvement in seeking healthcare
    - ability to save money and
    - whether requires permission to visit natal kin

Environment
- Water supply (well, piped, pump, open)
- Sanitation facilities (none, latrine, flushed toilet)

Biodemographic
- Maternal age (10-15, 16-20, 21-30, 31-40, 41 and over)
- First birth order
- Birth interval (preceding interval less that 18 months, 18-23 months, 24-35 months, 36 months or over)

Maternal health and nutrition
- Maternal stunting (height under 145cm)

Use of preventive and curative health services
- Antenatal care
- Tetanus Toxoid immunisation
- Place of delivery/trained attendant
- Delivery by Caesarean section

Biological
- Multiple birth
- Sex
- Mother's estimate of size at birth (very small, small, average, large)

Appendix 13: An analysis of state groupings by level of professional attendant at birth

1.0 Relationship between state level of professional attendance and ANC/TT immunisation

Figures 41-46 examine the percentage of mothers receiving recommended level of ANC or two or more tetanus toxoid immunisations, and while there is still some variation within groups, particularly for the ANC, there is a marked gradient between the different groups. In the group where professional attendance is over 60%, the percentage of women who receive recommended levels of ANC ranges markedly from 75% (Kerala) to 16% (Punjab). While this range is large, nearly all states in this group have higher levels than in the group where professional attendance is 35-60% (the percentage of women receiving recommended antenatal care ranges from 21% to under 5%). In the group of states with professional attendant levels under 35%, less than 9% of women in all states received recommended antenatal care. When tetanus toxoid is considered, the percentage of women who received two doses in the group with over 60% professional attendance ranged from 88-99%, compared to 62-93% for states with between 35-60% professional attendance, and 46-68% for states with professional attendance rates below 35%.

Figure 41: Percentage of mothers receiving recommended level of ANC: States with over 60% professional attendance

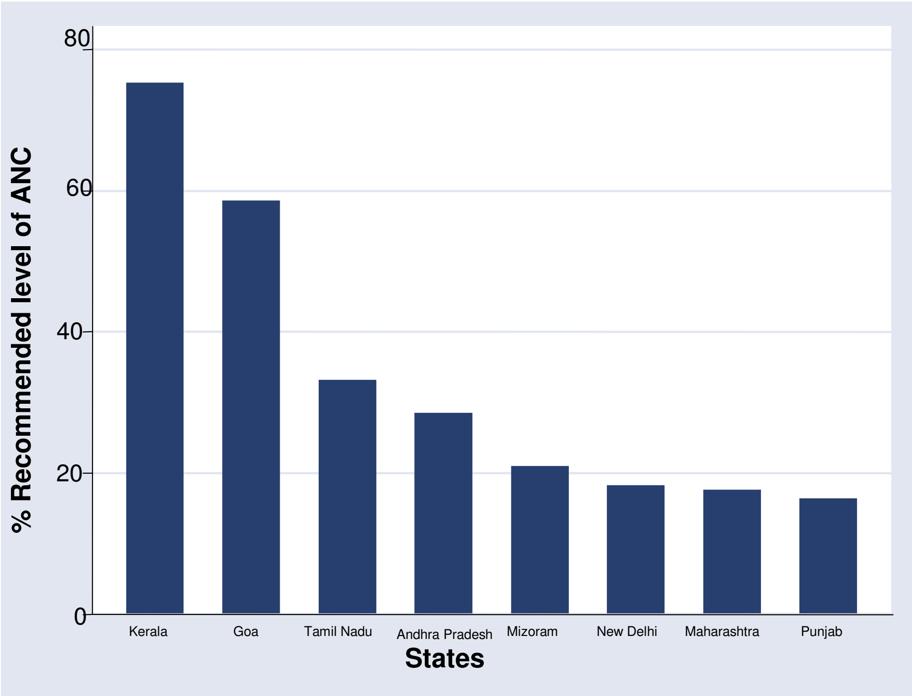


Figure 42: Percentage of mothers receiving recommended level of ANC: States with over 35-60% professional attendance

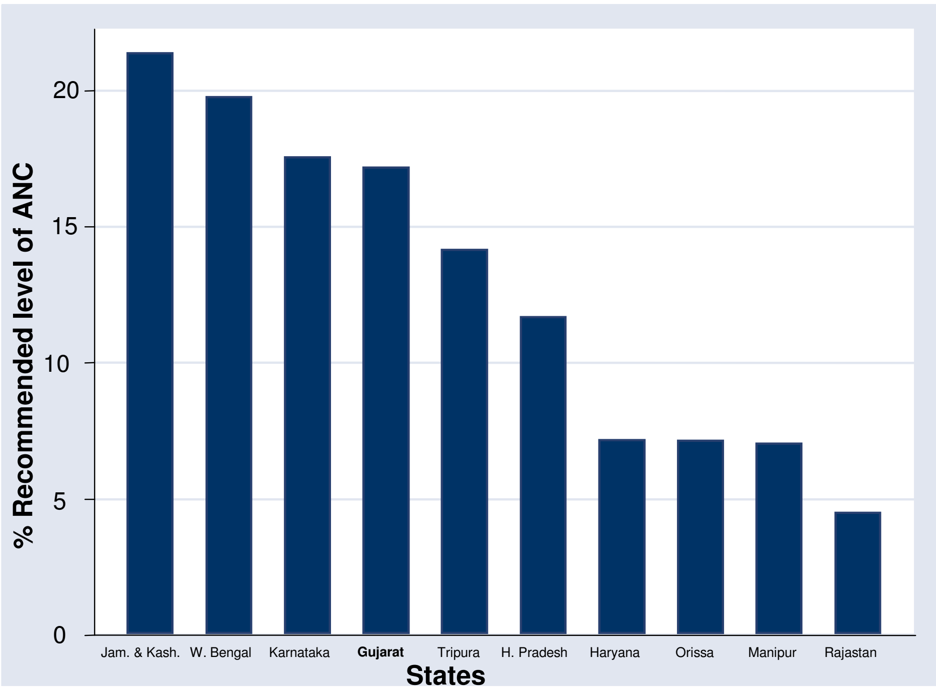


Figure 43: Percentage of mothers receiving recommended level of ANC: states with under 35% professional attendance

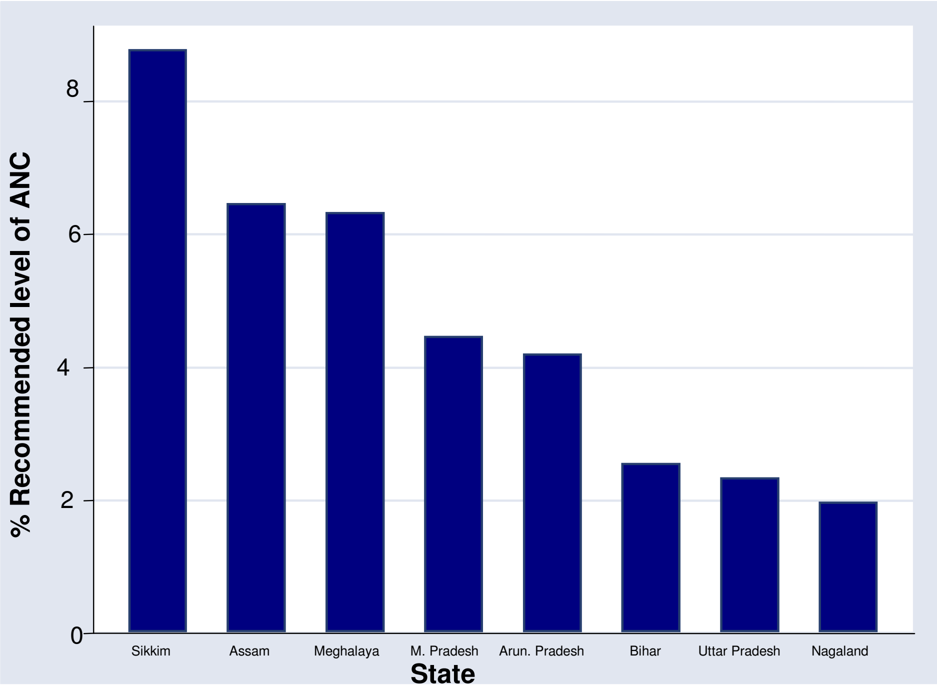


Figure 44: Percentage of mothers receiving two or more TT immunisations: states with over 60% professional attendance

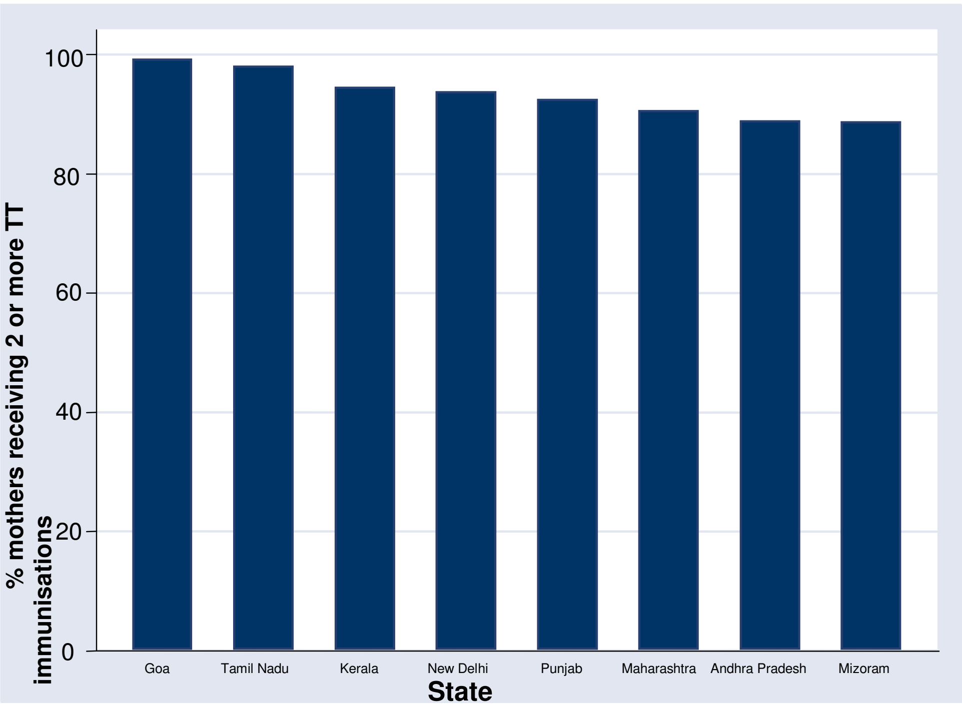


Figure 45: Percentage of mothers receiving two or more TT immunisations: states with between 35-60% professional attendance

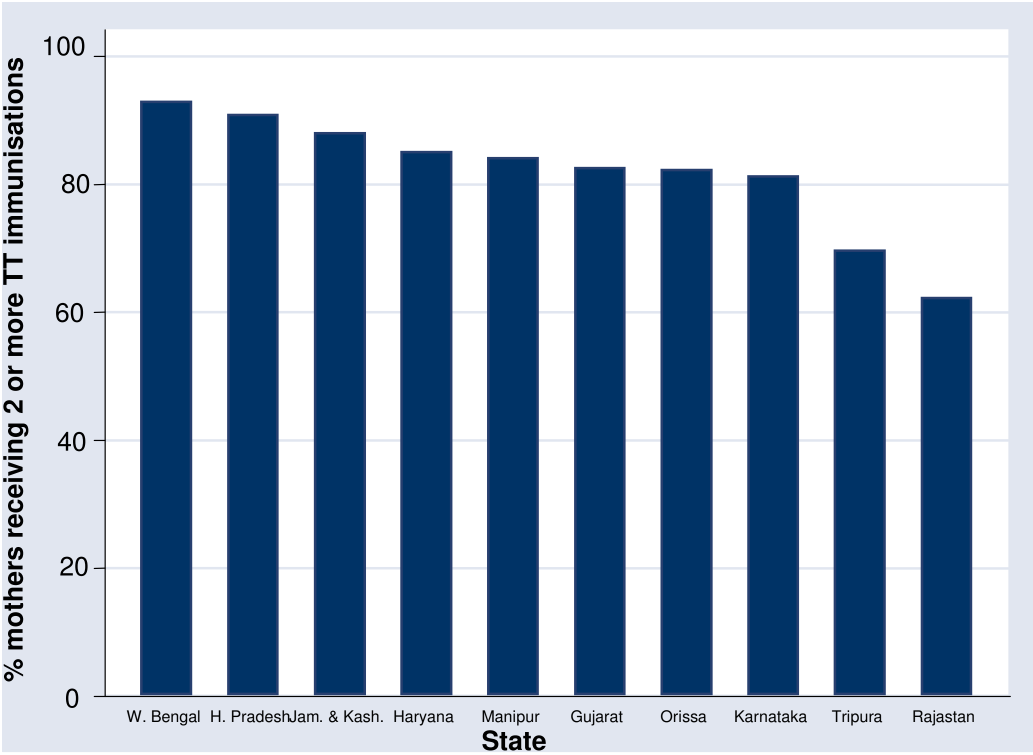
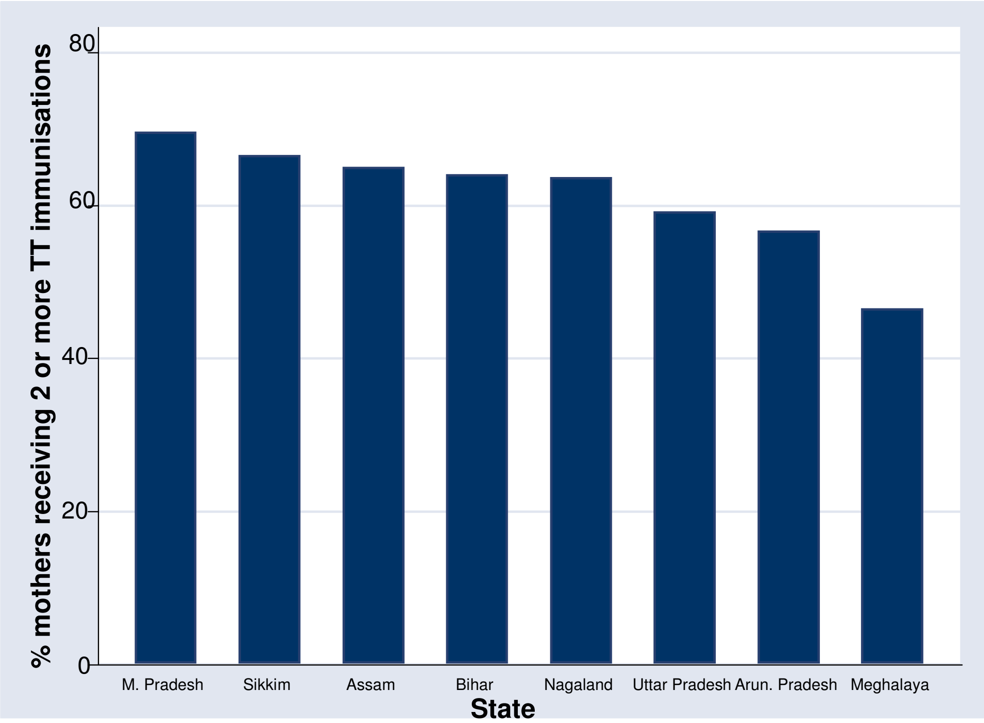


Figure 46: Percentage of mothers receiving two or more TT immunisations: states with under 35% professional attendance



2.0 The correlation between level of state professional attendance and quality of care

In addition to availability of services, quality of care is also an important issue. This is difficult to measure using DHS data. One possible way of examining potential quality of services is to look at the number of specific components of antenatal care women received (if they received ANC at all). Table 49 shows the number of women who received a number of components of antenatal care (based on responses to prompted questions). These specific components were chosen as they correlate with those identified as essential in the new WHO antenatal care model (WHO 2006), although obviously the quality and exact nature of the components cannot be accurately ascertained from the data. As can be seen, women in states where professional attendance is over 60% are systematically more likely to receive specific ANC interventions than those in states where attendance is lower. However, it is still worth noting that even in states where attendance is high, the proportion of women who reported receiving some of the interventions was extremely low: for instance in states with professional attendance over 60% only 42% of women attending ANC reported receiving information on danger signs in pregnancy. It must be remembered that it is possible that there is marked under-reporting as women may not remember the care they received, but it does raise issues about the possible content and quality of ANC country-wide.

Table 49: Percentage of women receiving specific aspects of antenatal care by state level of skilled attendance

	% of women who received specific components of ANC (full sample of all women who received any ANC)	% of women who received specific components of ANC: skilled attendance over 60% only	% of women who received specific components of ANC :skilled attendance under 35% only
Urine test	55.4	74.1	39.1
Measurement of blood pressure	62.7	81.1	41.3
Information on danger signs of pregnancy	35.6	42.1	24.2
Information on safe delivery	41.2	53.7	30.2
% women who attended for first appointment in first trimester	52.2	58.3	44.7
Number of women who only received one antenatal visit	12.4	4.8	26.4

3.0 The correlation between state level of professional attendants and GDP per capita

As discussed earlier, there tends to be a correlation between level of services and state level of GDP, with poorer states experiencing poorer services. It is therefore important to examine the degree to which higher levels of professional attendance appear to be a function of greater state wealth. Table 50 shows state levels of net domestic product (NDP) and rankings for the Human Development Index (HDI) disaggregated by groups percentage state level professional attendance.[50] There is a clear gradient with per capital NDP increasing with groupings based on percentage of professional attendance. However, there is significant variation in some of the groups: for example, Kerala, which has one of the highest percentages of professional attendance, has a relatively modest level of NDP per capita, and is only classed as a middle income state. States with professional attendance below 35% tend to have relatively low NDPs and there is comparatively little variation (although Arunachal Pradesh has a markedly higher rate of NDP). Figure 47 is a scattergram of net GDP and percentage level of professional attendant by state. As can be seen, there is a marked gradient, but much deviation from the fitted line. When HDI is examined, a similar pattern can be seen. Those with higher rankings tend to be clustered in the group with professional attendance over 60%, and many with low ranking are found in the group with professional attendance under 35%, but there is still considerable variation.

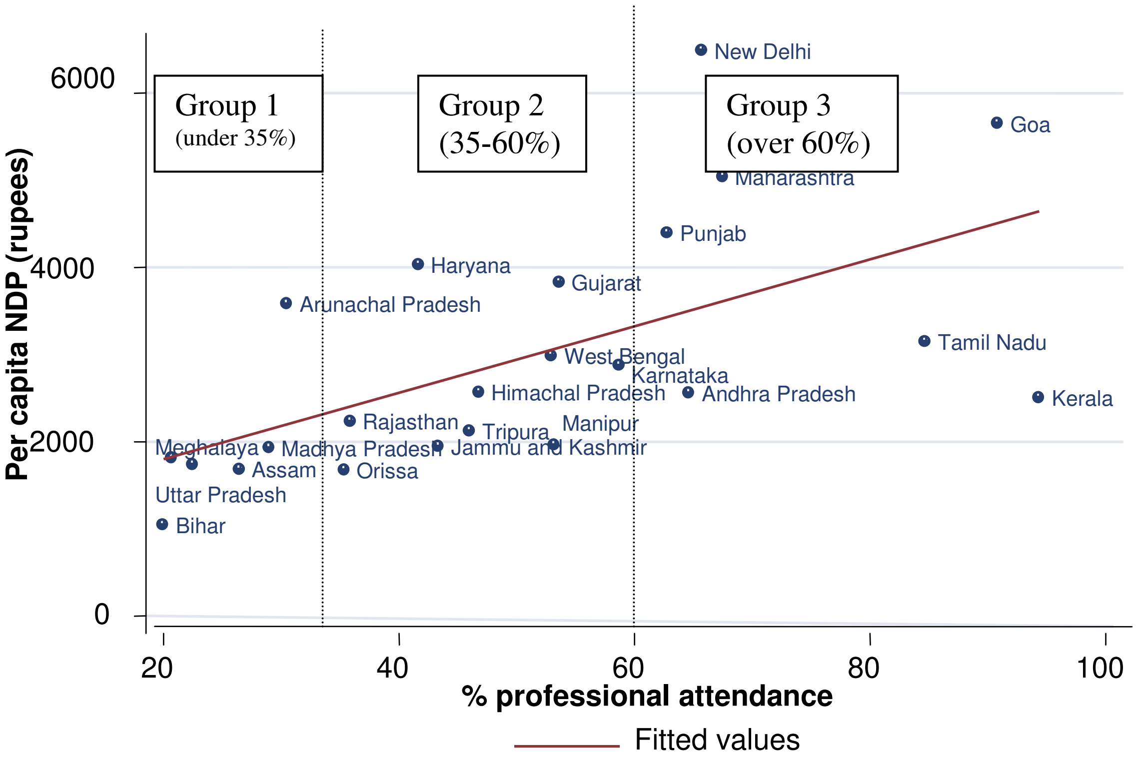
[50] The HDI is a composite of variables designed to capture attainment in economic development, education and healthcare. It incorporates monthly per capita expenditure adjusted for inequality, a measure of literacy rate and intensity of formal education and a combination of life expectancy and infant mortality rate.

Table 50: Per capita state domestic product and human development ranking

	State Income level	Per capita net state domestic product (in rupees)	Human development index 1991 ranking*
States with over 60% professional attendance			
Andhra Pradesh	Middle	2550	23
Goa	High	5640	4
Kerala	Middle	2490	3
Maharashtra	High	5032	15
Mizoram	-	-	7
Punjab	High	4389	12
Tamil Nadu	Middle	3141	14
New Delhi	-	6478	2
Mean average(unweighted)		*4245*	
States with professional attendance 35-60%			
Gujarat	High	3918	17
Haryana	High	4024	16
Himachal Pradesh	-	2556	13
Jammu and Kashmir	-	1932	21
Karnataka	Middle	2866	19
Manipur	-	1948	9
Orissa	Low	1666	28
Rajasthan	Low	2226	29
West Bengal	Middle	2977	20
Mean average(unweighted)		*2679*	
States with professional attendance below 35%			
Assam	-	1675	26
Bihar	Low	1038	32
Madhya Pradesh	Low	1922	30
Meghalaya	-	1804	24
Nagaland	-	-	11
Sikkim	-	-	18
Uttar Pradesh	Low	1725	31
Arunachal Pradesh	-	3571	29
Tripura	-	2117	22
Mean average(unweighted)		*1978*	

HDI rankings and per capita GDP taken from the Indian National Human Development Report 2001
http://planningcommission.nic.in/reports/genrep/nhdrep/nhdreportf.htm
*Rankings have been calculated to include union territories, which are not included in DHS data, therefore some rankings are not consecutive in this table.

Figure 47: Scattergram of percentage professional attendance against per capita net domestic product



The association between increased NDP and state grouping for professional attendance begs the question whether increased attendance at delivery is purely a result of a higher proportion of more wealthy individuals living in states with higher rates of attendance: the association between increased wealth and increased use of professional attendance is well documented, so does this fully explain the variation between states, or do other cultural or policy-related factors influence levels of uptake of care? Table 51 shows the uptake of professional attendance disaggregated by wealth quintile. As can be seen, when wealth quintile 5 (the richest) is examined, a relatively similar level of women receive professional attendance whether the state average is under 35% or over 60% (78% as opposed to 88%). However, while there is a clear wealth gradient for all three groupings for levels of state attendance, the inequality is less for women living in states with attendance over 60%: in this group 38% of women in quintile 1 (poorest) receive professional care, compared to under 8% in states where attendance is under 35%. This suggests that the differences in state level of professional attendance are not purely driven by an increased percentage of more wealthy women living in these states: poor women in states with high levels of professional attendants appear to stand a greater chance of receiving professional care than their counterparts in states with overall low levels of attendance.

Table 51: Percentage of mothers receiving professional attendance in each quintile group by state level of professional attendance

	States where skilled attendance over 60% only	States where skilled attendance is 35 – 60%	States where skilled attendance under 35% only
Wealth quintile 1 (poorest)	38.1	19.8	7.8
Wealth quintile 2	50.7	27.4	14.5
Wealth quintile 3 (middle)	66.7	37.3	24.1
Wealth quintile 4	76.3	53.5	44.4
Wealth quintile 5 (richest)	88.8	80.6	78.0

Access to health care is also likely to be linked to state levels of health spending, which, as discussed earlier, vary greatly within India. Table 52 shows level of health spending for each of the groupings for state level of professional attendance, and figure 48 is a scattergram showing the relationship between level of attendance and public spending. Initial calculations are somewhat skewed by relatively high state spending in some of the small (and often tribal) states, so figures have also been calculated for major states only (figure 49 is a scattergram of level of professional attendance and public spending for major states only)[51].

[51] The classification of a "major state" is based on the distinction used in the Indian National health accounts 2001-2.

Table 52: Health expenditure by state level of professional attendance (unweighted mean average with range for state grouping in brackets)

	Average public spending per head (rupees) **Maximum and minimum values in brackets.**	**Average public and private spending per head in rupees** **Maximum and minimum values in brackets.**	**Public expenditure as % of total expenditure** **Maximum and minimum values in brackets.**
Over 60% (all states in group)	402 (182-836)	1221 (846-1858)	30% (12.9-89.2)
35-60% % (all states in group)	195 (134-493)	896 (582-1570)	21% (10.4-53.7)
Under 35% % (all states in group)	339 (88-825)	941 (569-1344)	36% (11.8-80.1)
Over 60% (major states only)	205 (182-240)	1188 (846-1858)	17% (13-24)
35-60% (major states only)	222 (147-271)	1043 (597-1570)	21% (10-38)
Under 35% (major states only)	121 (84-176)	834 (569-1124)	15% (8-31)

If all states in the groups are included in the analysis, the scattergram (figure 48) shows a fairly weak correlation with much variation around the fitted regression line. The table demonstrates that states with over 60% professional attendance show the highest spending for both public and total (private and public), with states with 35-60% attendance showing the lowest. States with 35-60% professional attendance also have the lowest proportion of public expenditure as a proportion total expenditure. If only major states are included in the calculation the picture is somewhat different. The scattergram (figure 49) shows much less variation around the fitted regression line, although the slope is still fairly slight. Figures in the table show that the highest level of public spending is found in the group of states with professional attendance 35-60% (although it is not much higher than for states over 60%). States with under 35% professional attendance have the lowest level of public expenditure by quite some margin, as well as the lowest total expenditure (although the difference is not so great for this). This group also has the lowest proportion of public expenditure as a proportion of the total expenditure if only major states are considered. While an examination of major states does suggest that that low levels of health expenditure, and particularly state expenditure are associated with low rates of professional attendants, there are still very marked differences within groups. In particular, there is little to distinguish between the group of states with over 60% professional attendants at birth and those with 35-60%. While this is an extremely cursory examination of state level expenditure in relation to provision of professional attendance, it does seem to support previous studies suggesting that the effectiveness of health care expenditure varies greatly between states (*e.g.* Bhalotra 2007), and that levels of professional attendance are not simply a function of health care expenditure.

Figure 48: Scattergram of public health spending per capita (rupees) and percentage professional attendance by state (all states)

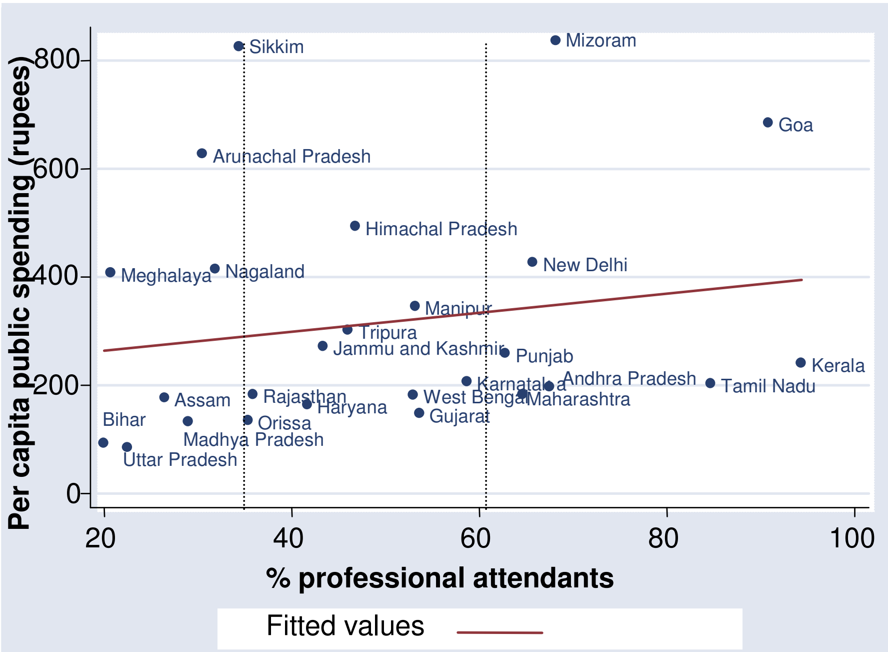
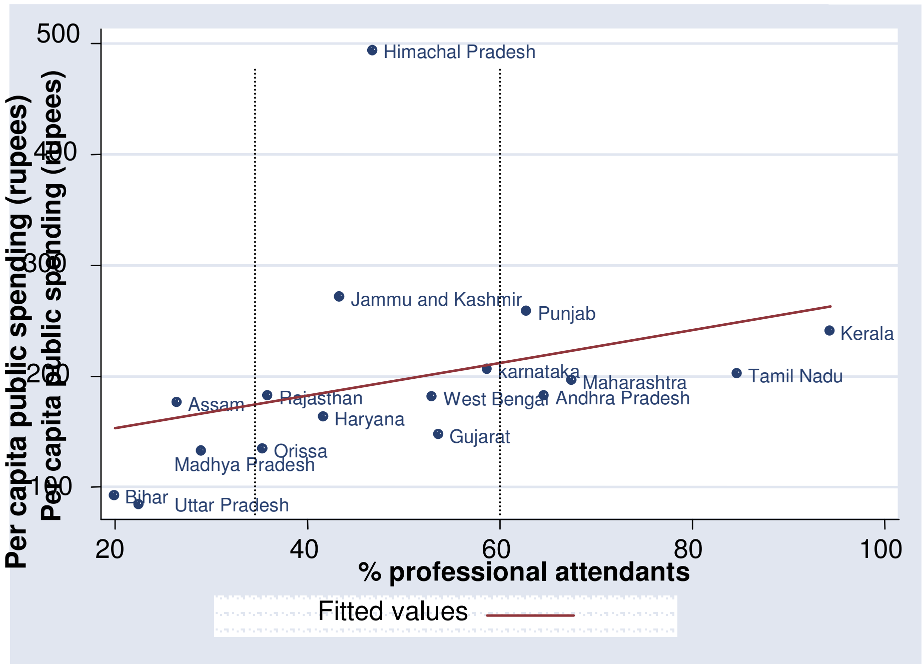


Figure 49: Scattergram of public health spending per capita (rupees) and percentage professional attendance by state (major states only)



Appendix 14: Results of logistic regression for whole sample with neonatal deaths as dependent variable.

	Model:	(1) *Biologic-al/state*	(2) *Socio-economic added*	(3) *Environ-mental added*	(4) *Biodem-ographic added*	(5) *Maternal health added*	(6) *ANC/ TT added*
Broader socio-political environ-ment	**State grouping**						
	Southern (ref)						
	BIMARUO	1.43 (3.41)**	1.243 (2.00)*	1.276 (2.12)*	1.323 (2.40)*	1.235 (1.77)	0.896 (0.83)
	Other Northern States	0.922 (0.59)	0.962 (0.27)	0.977 (0.15)	1.024 (0.16)	0.973 (0.18)	0.736 (1.86)
	Other Eastern States	0.83 (0.87)	0.808 (0.96)	0.836 (0.79)	0.862 (0.65)	0.835 (0.78)	0.726 (1.29)
	Northeast	1.19 (1.08)	1.206 (1.10)	1.315 (1.53)	1.348 (1.67)	1.306 (1.46)	1.010 (0.05)
	West	1.01 (0.04)	1.018 (0.12)	1.040 (0.25)	1.036 (0.23)	1.054 (0.34)	0.951 (0.32)
Socio-economic Factors	**Urban/rural**						
	Rural residence (ref)						
	Urban residence		1.023 (0.22)	1.060 (0.50)	1.065 (0.55)	1.042 (0.35)	1.058 (0.45)
	Caste						
	Scheduled or backward caste or tribe		1.038 (0.44)	1.042 (0.49)	1.047 (0.54)	1.053 (0.57)	1.026 (0.27)
	Religion						
	Hindu (ref)		1.0	1.0	1.0	1.0	1.0
	Religion: Muslim		0.789 (2.07)*	0.785 (2.10)*	0.765 (2.30)*	0.779 (2.01)*	0.747 (2.23)*
	Religion: other		0.838 (0.91)	0.842 (0.88)	0.847 (0.84)	0.795 (1.12)	0.759 (1.33)
	Wealth quintiles (quintiles 1-5 continuous)		0.962 (1.04)	0.972 (0.69)	0.964 (0.90)	0.978 (0.52)	1.059 (1.31)
	Education						
	No education (ref)						
	Primary education		0.771 (2.26)*	0.770 (2.28)*	0.747 (2.55)*	0.707 (2.93)**	0.766 (2.15)*
	Secondary education		0.763 (2.42)*	0.777 (2.26)*	0.736 (2.75)**	0.700 (3.08)**	0.794 (1.87)
	Further education		0.519 (3.33)**	0.547 (3.03)**	0.534 (3.10)**	0.538 (2.94)**	0.583 (2.42)*
Environ-mental factors	**Sanitation**						
	No sanitation (ref)						
	flush toilet			0.773 (1.77)	0.791 (1.61)	0.777 (1.66)	0.780 (1.58)
	latrine			1.006 (0.04)	1.022 (0.15)	0.994 (0.04)	0.980 (0.13)
	Water supply						
	Well (ref)						
	piped			1.203 (1.69)	1.193 (1.62)	1.182 (1.49)	1.211 (1.64)

	Model:	(1) *Biologic-al/state*	(2) *Socio-economic added*	(3) *Environ-mental added*	(4) *Biodem-ographic added*	(5) *Maternal health added*	(6) *ANC/ TT added*
	pump			1.128 (1.28)	1.117 (1.18)	1.127 (1.23)	1.148 (1.37)
	open			0.738 (1.38)	0.730 (1.43)	0.742 (1.28)	0.760 (1.16)
Biodemo-graphic Factors	**Mother's age**						
	16-20 (ref)						
	10-15				1.553 (2.30)*	1.583 (2.30)*	1.391 (1.58)
	21-30				0.828 (2.12)**	0.833 (1.98)*	0.828 (1.96)*
	31-40				1.044 (0.31)	1.050 (.33)	1.030 (0.19)
	41 and over				1.749 (1.58)	1.838 (1.64)	1.613 (1.20)
	Birth order						
	2 or more (ref)						
	First birth				1.403 (3.08)**	1.401 (2.95)**	1.453 (3.18)**
	Preceding birth interval						
	24-35 months (ref)						
	less than 18 months				2.041 (5.49)**	2.093 (5.41)**	2.045 (5.14)**
	18-23 months				1.271 (1.83)	1.322 (2.06)*	1.252 (1.62)
	36 months or over				0.782 (2.23)*	0.795 (1.99)*	0.754 (2.38)*
Maternal health	**Antenatal complications**						
	No antenatal complications reported (ref)						
	Mother reported antenatal complication					1.224 (2.57)*	1.206 (2.31)*
	Maternal height						
	145cm or over (ref)						
	Less than 145cm					1.124 (1.10)	1.118 (1.01)
Use of health services	**TT immunisations**						
	Less than 2 TT (ref)						
	2 or more TT						0.682 (3.66)**
	ANC						
	No ANC (ref)						
	Received recommended ANC						0.481 (3.67)**
	Received some (but not recommended) ANC						0.677 (3.56)**
Biological							
	Sex of child						
	Female (ref)						

Model:	(1) *Biological/state*	(2) *Socio-economic added*	(3) *Environ-mental added*	(4) *Biodem-ographic added*	(5) *Maternal health added*	(6) *ANC/ TT added*
Male child	1.09	1.096	1.097	1.104	1.109	1.088
	(1.18)	(1.29)	(1.31)	(1.39)	(1.40)	(1.10)
Multiple Birth						
Child is a twin	5.94	6.326	6.340	7.439	6.299	6.306
	(9.52)**	(9.77)**	(9.73)**	(10.66)**	(8.90)**	(8.89)**

Robust z statistics in parentheses
* significant at 5%; ** significant at 1%

	Model	(7)	(8)	(9)
		All health care variables added	*Maternal autonomy added*	*Weight added : full model for neonatal*
Socio-political environment	**State grouping**			
	Southern (ref)			
	BIMARUO	0.94	0.917	0.887
		(0.48)	(0.63)	(0.84)
	Other Northern States	0.779	0.787	0.829
		(1.48)	(1.40)	(1.08)
	Other Eastern States	0.72	0.708	0.668
		(1.31)	(1.39)	(1.61)
	Northeast	1.06	1.117	1.135
		(0.29)	(0.55)	(0.63)
	West	0.98	0.978	0.935
		(0.14)	(0.14)	(0.42)
Socio-economic	**Urban/rural**			
	Rural residence (ref)			
	urban residence	1.02	1.020	1.006
		(0.17)	(0.15)	(0.04)
	Caste			
	Scheduled backward caste or tribe	1.02	1.018	1.014
		(0.24)	(0.19)	(0.14)
	Religion			
	Hindu (ref)	1.0	1.0	1.0
	Religion: Muslim	0.76	0.757	0.760
		(2.13)*	(2.15)*	(2.09)*
	Religion: other	0.76	0.762	0.758
		(1.36)	(1.31)	(1.34)
	Wealth quintiles	1.05	1.051	1.046
		(1.15)	(1.12)	(1.00)
	Education			
	No education (ref)			
	Primary education	0.75	0.750	0.734
		(2.30)*	(2.31)*	(2.46)*
	Secondary education	0.77	0.761	0.757
		(2.09)*	(2.17)*	(2.21)*
	Further education	0.57	0.564	0.589
		(2.48)*	(2.53)*	(2.34)*
		(1.68)	(1.70)	(1.60)
Environmental factors	**Sanitation**			
	No sanitation (ref)			
	Flush toilet	0.77	0.767	0.779
		(1.68)	(1.70)	(1.60)
	Latrine	0.98	0.981	0.997
		(0.12)	(0.12)	(0.02)
	Water			
	Well (ref)			
	Piped	1.20	1.206	1.233
		(1.57)	(1.60)	(1.79)
	Pump	1.15	1.144	1.208
		(1.39)	(1.33)	(1.86)
	Open	0.76	0.762	0.795
		(1.14)	(1.15)	(0.97)

	Model	(7)	(8)	(9)
		All health care variables added	*Maternal autonomy added*	*Weight added : full model for neonatal*
Bio-demog-raphic	**Mother's age**			
	16-20 (ref)			
	Mother's age 10-15	1.41	1.402	1.355
		(1.63)	(1.61)	(1.48)
	Mother's age 21-30	0.82	0.823	0.838
		(2.05)*	(2.03)*	(1.82)
	Mother's age 31-40	1.02	1.022	1.042
		(0.12)	(0.14)	(0.26)
	Mother's age 41 and over	1.60	1.638	1.621
		(1.18)	(1.22)	(1.16)
	Birth order			
	Birth order 2 or more (ref)			
	First birth	1.41	1.415	1.410
		(2.89)**	(2.91)**	(2.86)**
	Preceding irth interval			
	24-35 months (ref)			
	less than 18 months	2.04	2.043	2.018
		(5.10)**	(5.12)**	(4.99)**
	18-23 months	1.25	1.251	1.234
		(1.61)	(1.61)	(1.49)
	36 months or over	0.75	0.759	0.761
		(2.39)*	(2.31)*	(2.25)*
Matern-al health and nutrition	**Antenatal complications**			
	No antenatal complications reported (ref)			
	Mother reported antenatal complication	1.20 (2.23)*	1.199 (2.23)*	1.144 (1.64)
	Maternal height			
	Maternal height 145cm or over			
	Maternal height less than 145cm	1.11 (0.95)	1.115 (0.98)	1.129 (1.08)
Use of health care services	**TT immunisations**			
	Less than 2 TT (ref)			
	2 or more TT	0.67	0.664	0.671
		(3.79)**	(3.89)**	(3.74)**
	ANC			
	No ANC (ref)			
	Received recommended ANC	0.46 (3.83)**	0.460 (3.79)**	0.488 (3.51)**
	Received some (but not recommended) ANC	0.66 (3.77)**	0.654 (3.82)**	0.665 (3.64)**
	Place of delivery			
	Home delivery – no trained attendant			
	Home delivery with trained attendant	1.01 (0.09)	1.018 (0.12)	1.005 (0.03)
	Delivery in Government institution	1.36 (2.48)*	1.360 (2.47)*	1.354 (2.42)*
	Delivery in private/NGO	1.13	1.130	1.114

	Model	(7)	(8)	(9)
		All health care variables added	*Maternal autonomy added*	*Weight added : full model for neonatal*
	institution	(0.82)	(0.80)	(0.71)
	Data missing	2.20	2.139	2.323
		(1.25)	(1.20)	(1.33)
	Delivery by Caesarean section	1.03	1.046	1.018
		(0.18)	(0.24)	(0.10)
Maternal autonomy	**Involvement in decision making on healthcare**			
	Mother not involved			
	Mother involved in decision on seeking healthcare		0.827	0.825
			(2.34)*	(2.36)*
	Whether allowed to put money aside			
	Allowed to put money aside			
	Not allowed to put money aside		1.174	1.198
			(2.01)*	(2.22)*
	Visits to natal kin			
	Not allowed to visit family (ref)			
	Needs permission		1.149	1.162
			(1.21)	(1.31)
	No permission needed		0.792	0.776
			(0.70)	(0.76)
Biological	**Sex of child**			
	Female child (ref)			
	Male child	1.08	1.080	1.099
		(1.05)	(1.01)	(1.22)
	Child is a twin	6.05	6.057	4.855
		(8.62)**	(8.54)**	(6.84)**
	Mother's estimate of birth size			
	Average (ref)			
	Larger than average			1.252
				(1.89)
	Smaller than average			1.541
				(4.54)**
	Very small			3.446
				(9.45)**
	Constant (logit)			-3.33

Robust z statistics in parentheses * significant at 5%; ** significant at 1%

Appendix 15: Results of logistic regression with sample disaggregated by tertile and highest level of maternal education with neonatal mortality as dependent variable

	Model:	(1) neonatal deaths: Wealth tertile 1 only	(2) neonatal deaths: Wealth tertile 3 only	(3) neonatal deaths: No education only	4) neonatal deaths: Secondary/further education only
Socio-political environment	**State grouping**				
	Southern (ref)				
	BIMARUO	0.897	0.567	1.018	0.605
		(0.42)	(2.08)*	(0.09)	(1.80)
	Other Northern States	0.36	0.703	0.887	0.601
		(1.51)	(1.29)	(0.49)	(1.67)
	Other Eastern States	0.793	0.249	0.817	0.286
		(0.67)	(2.08)*	(0.61)	(2.03)*
	Northeast	1.046	1.249	1.004	1.244
		(0.13)	(0.59)	(0.01)	(0.65)
	West	0.892	0.756	0.917	0.964
		(0.35)	(1.06)	(0.37)	(0.14)
Socio-economic	**Urban/rural**				
	Rural residence (ref)				
	Urban residence	0.888	0.698	1.010	1.106
		(0.39)	(1.65)	(0.06)	(0.43)
	Scheduled or	0.925	1.011	1.001	1.163
	backward caste/tribe	(0.49)	(0.06)	(0.01)	(0.81)
	Religion				
	Hindu (ref)				
	Religion: Muslim	0.559	0.741	0.743	0.834
		(2.57)*	(1.16)	(1.80)	(0.60)
	Religion: other	0.650	0.763	0.304	1.017
		(0.83)	(0.95)	(3.20)**	(0.05)
	Wealth quintiles	0.948	0.948	1.012	1.119
		(0.43)	(0.28)	(0.21)	(1.13)
	Education				
	No education (ref)			N/A	N/A
	Primary education	0.710	0.548	N/A	N/A
		(1.46)	(2.12)*		
	Secondary education	0.657	0.686	N/A	N/A
		(1.46)	(1.68)		
	Further education	XX	0.568	N/A	N/A
			(1.87)		
Environmental factors	**Sanitation**				
	No sanitation (ref)				
	Flush toilet	0.554	0.922	0.849	0.746
		(0.80)	(0.36)	(0.71)	(1.15)
	Latrine	1.534	0.687	1.322	0.776
		(1.26)	(1.35)	(1.30)	(0.90)
	Water				
	Well (ref)				
	Piped	0.893	3.126	1.084	1.865
		(0.47)	(3.58)**	(0.51)	(2.62)**

	Pump	1.139	2.781	1.074	1.867
		(0.93)	(3.09)**	(0.61)	(2.26)*
	Open	0.933	0.117	0.750	0.762
		(0.22)	(2.63)**	(1.00)	(0.53)
Bio-demographic Factors	**Mother's age**				
	16-20 (ref)				
	Mother's age 10-15	0.762	2.882	1.144	2.798
		(0.94)	(1.94)	(0.54)	(1.97)*
	Mother's age 21-30	0.874	1.021	0.881	0.927
		(0.84)	(0.10)	(1.02)	(0.39)
	Mother's age 31-40	1.055	1.074	1.057	1.041
		(0.24)	(0.19)	(0.30)	(0.10)
	Mother's age 41 and over	1.732	xx	1.649	xx
		(0.98)		(1.08)	
	Birth order				
	Birth order 2 or more (ref)				
	First birth	1.573	1.260	1.565	1.429
		(2.39)*	(1.01)	(2.90)**	(1.49)
	Preceding birth interval				
	24-35 months (ref)				
	Less than 18 months	1.975	1.912	2.454	1.162
		(2.99)**	(2.27)*	(5.37)**	(0.41)
	18-23 months	1.319	1.226	1.447	1.306
		(1.26)	(0.66)	(2.20)*	(0.84)
	36 months or over	0.758	0.819	0.768	0.841
		(1.56)	(0.73)	(1.80)	(0.61)
Maternal health and nutrition	**Antenatal complications**				
	None reported (ref)				
	Mother reported complication	0.961	1.224	1.095	1.198
		(0.32)	(1.17)	(0.90)	(1.05)
	Maternal height				
	145cm or over				
	Less than 145cm	0.965	1.068	1.122	1.255
		(0.21)	(0.25)	(0.87)	(0.82)
Use of health care services	**TT immunisations**				
	Less than 2 TT (ref)				
	2 or more TT	0.626	0.543	0.718	0.399
		(3.13)**	(1.61)	(2.90)**	(2.60)**
	ANC				
	No ANC (ref)	1.0	1.0	1.0	1.0
	Recommended ANC	0.891	0.431	0.704	0.410
		(0.27)	(2.32)*	(1.14)	(2.39)*
	Some ANC	0.689	0.641	0.663	0.672
		(2.10)*	(1.47)	(3.20)**	(1.27)
	Place of delivery				
	Home delivery – no professional attendant (ref)				
	Home delivery with professional attendant	0.789	0.932	0.836	1.026
		(0.74)	(0.22)	(0.80)	(0.08)
	Government institution	1.317	1.634	1.691	1.145
		(1.17)	(2.09)*	(3.24)**	(0.56)
	Private/NGO institution	1.161	1.279	1.497	0.897

		(0.51)	(0.92)	(2.04)*	(0.39)
	Data missing	1.806	18.576	1.907	8.618
		(0.52)	(2.50)*	(0.77)	(2.00)*
	Delivery by Caesarean section	1.026	1.225	0.547	1.429
		(0.07)	(0.80)	(1.78)	(1.42)
Socio-economic: Maternal autonomy	**Involvement in decision making on healthcare**				
	Mother not involved (ref)				
	Mother involved	0.809	0.687	0.869	0.759
		(1.64)	(2.30)*	(1.38)	(1.65)
	Whether allowed to put money aside				
	Allowed to put money aside				
	Not allowed to put money aside	1.247	1.483	1.199	1.064
		(1.80)	(2.06)*	(1.85)	(0.33)
	Visits to natal kin				
	Not allowed to visit (ref)				
	Needs permission to visit family	1.341	0.843	1.110	1.118
		(1.51)	(0.79)	(0.71)	(0.51)
	Does not need permission to visit family	1.173	1.163	0.778	0.604
		(0.36)	(0.21)	(0.65)	(0.55)
Biological	**Sex of child**				
	Female child (ref)				
	Male child	1.094	0.980	0.994	1.282
		(0.75)	(0.12)	(0.06)	(1.47)
	Child is a twin	6.012	3.052	4.879	6.334
		(5.52)**	(2.16)*	(5.57)**	(3.95)**
	Mother's estimate of birth size				
	Average (ref)			1.0	1.0
	Larger than average	1.265	1.197	1.260	1.087
		(1.26)	(0.72)	(1.53)	(0.34)
	Smaller than average	1.480	1.842	1.564	1.636
		(2.72)**	(2.99)**	(3.95)**	(2.26)*
	Very small	2.275	4.886	2.652	4.985
		(3.78)**	(5.66)**	(5.80)**	(5.93)**
	Constant (logit)	-3.02	-3.10	-3.30	-3.69

Robust z statistics in parentheses
* significant at 5%; ** significant at 1%

Appendix 16: Results of logistic regression with sample disaggregated by state level of trained attendance and urban/rural residence with neonatal mortality as dependent variable

		Model (1) **% state trained attendance over 60%**	Model (2) **% state trained attendance below 35%%**	Model (3) **Urban only**	Model (4) **Rural only**
Socio-political environment	**State grouping**				
	Southern (ref)				
	BIMARUO			0.695	0.947
				(1.36)	(0.31)
	Other Eastern States			0.213	0.776
				(2.45)*	(0.91)
	Other Northern States			0.658	0.875
				(1.35)	(0.63)
	North East			0.908	1.204
				(0.24)	(0.81)
	West			0.771	1.018
				(0.92)	(0.09)
Socio-economic	**Urban/rural**				
	Rural residence (ref)				
	urban residence	1.238	1.018		
		(0.75)	(0.09)		
	Scheduled or backward	0.947	0.991	1.087	0.998
	caste or tribe	(0.25)	(0.06)	(0.40)	(0.02)
	Religion				
	Hindu (ref)				
	Religion: Muslim	0.493	0.754	0.710	0.751
		(1.89)	(1.46)	(1.48)	(1.79)
	Religion: other	0.773	0.694	0.703	0.758
		(0.86)	(1.26)	(0.82)	(1.15)
	Wealth quintiles	1.213	1.025	1.077	1.042
		(1.70)	(0.35)	(0.68)	(0.83)
	Education				
	No education (ref)				
	primary education	0.649	0.644	0.469	0.814
		(1.57)	(2.13)*	(2.39)*	(1.51)
	secondary education	0.859	0.721	0.818	0.732
		(0.62)	(1.55)	(0.84)	(2.07)*
	further education	0.939	0.181	0.612	0.553
		(0.17)	(3.29)**	(1.52)	(1.74)
Environmental factors	**Sanitation**				
	No sanitation (ref)				
	flush toilet	0.722	0.865	0.723	0.846
		(1.01)	(0.55)	(1.25)	(0.76)
	latrine	0.868	1.230	1.015	0.993
		(0.40)	(0.86)	(0.05)	(0.04)
	Water				
	Well (ref)				
	piped	2.074	1.249	1.314	1.167
		(2.40)*	(1.04)	(0.82)	(1.15)
	pump	2.724	1.198	0.899	1.237
		(3.02)**	(1.29)	(0.29)	(2.01)*

		Model (1) **% state trained attendance over 60%**	Model (2) **% state trained attendance below 35%%**	Model (3) **Urban only**	Model (4) **Rural only**
	open	0.763 (0.29)	0.754 (0.75)	0.165 (3.22)**	0.856 (0.65)
Bio-demographic Factors	**Mother's age**				
	16-20 (ref)				
	Mother's age 10-15	2.246 (1.98)*	1.049 (0.17)	1.840 (0.80)	1.317 (1.27)
	Mother's age 21-30	0.927 (0.33)	0.838 (1.19)	0.820 (0.88)	0.849 (1.52)
	Mother's age 31-40	1.944 (1.80)	0.925 (0.37)	1.158 (0.44)	1.022 (0.13)
	Mother's age 41 and over	XX	2.359 (1.78)	7.938 (3.31)**	1.090 (0.16)
	Birth order				
	Birth order 2 or more (ref)				
	First birth	1.325 (1.07)	1.648 (2.78)**	1.663 (1.92)	1.372 (2.33)*
	Preceding birth interval				
	24-35 months (ref)				
	< 18 months	2.031 (2.26)*	1.605 (2.16)*	2.001 (2.07)*	2.056 (4.62)**
	18-23 months	1.245 (0.64)	1.320 (1.38)	1.217 (0.52)	1.235 (1.37)
	36 months or over	0.819 (0.65)	0.713 (2.03)*	0.985 (0.06)	0.723 (2.39)*
Maternal health and nutrition	**Antenatal complications**				
	No antenatal complications reported (ref)				
	Mother reported antenatal complication	1.151 (0.75)	1.058 (0.47)	1.364 (1.58)	1.098 (1.04)
	Maternal height				
	145cm or over				
	less than 145cm	0.984 (0.05)	1.049 (0.32)	1.356 (1.24)	1.086 (0.66)
Use of health care services	**TT immunisations**				
	Less than 2 TT (ref)	1.0	1.0	1.0	1.0
	2 or more TT	0.671 (1.04)	0.663 (3.05)**	0.958 (0.12)	0.640 (3.96)**
	ANC				
	No ANC (ref)	1.0	1.0	1.0	1.0
	Received recommended ANC	0.433 (1.80)	0.467 (1.87)	0.524 (1.63)	0.422 (3.10)**
	Received some ANC	0.591 (1.33)	0.556 (3.83)**	0.590 (1.59)	0.680 (3.20)**
	Place of delivery				
	Home delivery – no professional attendant	1.0	1.0	1.0	1.0
	home delivery with professional attendant	1.416 (1.14)	0.825 (0.67)	0.947 (0.14)	1.012 (0.07)
	Government institution	0.919 (0.32)	1.758 (2.70)**	1.022 (0.08)	1.504 (2.82)**

		Model (1) **% state trained attendance over 60%**	Model (2) **% state trained attendance below 35%%**	Model (3) **Urban only**	Model (4) **Rural only**
	Private/NGO institution	0.718	1.403	0.839	1.239
		(1.17)	(1.40)	(0.54)	(1.26)
	Data missing	0.824	4.638	8.138	1.395
		(0.17)	(1.73)	(1.95)	(0.40)
	Delivery by Caesarean section	1.027	1.263	1.353	0.790
		(0.08)	(0.71)	(1.04)	(0.93)
Socio-economic: Maternal autonomy	**Involvement in decision making on healthcare**				
	Mother not involved (ref)				
	Mother involved	0.756	0.912	0.769	0.844
		(1.53)	(0.78)	(1.46)	(1.86)
	Whether allowed to put money aside				
	Allowed to put money aside				
	Not allowed to put money aside	1.122	1.324	0.924	1.269
		(0.57)	(2.43)*	(0.40)	(2.69)**
	Visits to natal kin				
	Not allowed (ref)				
	Needs permission	1.077	1.458	1.110	1.161
		(0.32)	(1.85)	(0.50)	(1.10)
	Does not need permission	0.553	0.841	0.683	0.786
		(0.53)	(0.36)	(0.35)	(0.68)
Biological	**Sex of child**				
	Female child (ref)				
	Male child	0.821	1.235	1.174	1.076
		(1.10)	(1.88)	(0.90)	(0.86)
	Child is a twin	5.874	5.578	9.578	3.973
	Mother's estimate of birth size				
	Average (ref)				
	Larger than average	0.944	1.567	1.550	1.178
		(0.20)	(2.52)*	(1.75)	(1.21)
	Smaller than average	1.268	1.962	1.984	1.477
		(0.94)	(4.96)**	(3.01)**	(3.70)**
	Very small	9.203	2.652	3.623	3.452
		(8.59)**	(5.18)**	(4.13)**	(8.55)**
Constant		-3.69	-3.70	-3.52	-3.33

Robust z statistics in parentheses
* significant at 5%; ** significant at 1%

Appendix 17: Results of two-stage least square regression for neonatal mortality with delivery variables instrumented using distance from government hospital, distance from private hospital and distance from all weather road.

N.B Model (1) not instrumented (ordinary least squares regression) for comparison purposes.

Distance variables treated as dummies

	Model (1) Delivery variables **not instrum-ented**	Model (2) Delivery variables **instrum-ented**	Model (3) Wealth tertile 1 only: Delivery variables **instrum-ented**	Model (4) Wealth tertile 3 only: Delivery variables **instrum-ented**	Model(5) No education only: Delivery variables **instrum-ented**	Model(6) Secondary/ further education only: Delivery variables **instrum-ented**	Model(7) State attend-ance over 60% only **instrum-ented**	Model(8) State attendance below 35% only **instrum-ented**
State grouping								
Southern (ref)								
BIMARUO		-0.016	-0.047	-0.029	-0.021	-0.000		
	(0.43)	(1.09)	(1.73)	(1.14)	(1.06)	(0.00)		
Other Northern	-0.005	-0.017	-0.053	-0.030	-0.026	0.001		
	(0.82)	(0.89)	(2.01)*	(0.95)	(1.13)	(0.02)		
Other Eastern	-0.01	-0.016	-0.028	-0.051	-0.027	-0.024		
	(0.95)	(0.71)	(0.79)	(1.41)	(0.98)	(0.74)		
North East	0.00	-0.015	-0.053	-0.028	-0.020	0.014		
	(0.63)	(0.68)	(1.51)	(0.78)	(0.81)	(0.34)		
West	0.00	-0.012	-0.055	-0.018	-0.015	0.006		
	(0.01)	(1.21)	(1.79)	(1.08)	(0.91)	(0.27)		
Scheduled or backward caste or tribe	0.00	-0.001	-0.011	-0.008	-0.002	0.003	0.008	0.000
	(0.02)	(0.15)	(1.21)	(1.07)	(0.29)	(0.39)	(0.81)	(0.01)
Religion								
Hindu (ref)								
Muslim	-0.01	-0.016	-0.051	0.003	-0.016	0.007	-0.005	-0.018
	(1.92)	(2.07)*	(2.13)*	(0.26)	(1.77)	(0.40)	(0.29)	(1.60)
Other	-0.01	-0.001	-0.019	0.004	-0.024	0.000	0.002	-0.006
	(1.11)	(0.09)	(1.01)	(0.19)	(2.24)*	(0.02)	(0.15)	(0.31)
Wealth quintiles	0.00	0.007			0.006	-0.006	-0.002	0.010
	(0.87)	(1.66)			(1.03)	(0.54)	(0.23)	(1.50)
Education								
No education (ref)								
Primary	-0.01	-0.001	0.005	-0.008			0.003	-0.009
	(1.58)	(0.17)	(0.28)	(0.48)			(0.17)	(0.97)
Secondary	-0.01	-0.000	0.021	-0.014			0.003	0.009
	(2.22)*	(0.03)	(0.80)	(0.87)			(0.16)	(0.52)
Further	-0.02	-0.008	0.076	-0.017			-0.004	-0.007
	(2.11)*	(0.56)	(0.90)	(0.92)			(0.17)	(0.29)
Sanitation								
No sanitation (ref)								
Flush toilet	-0.00	-0.004	-0.028	-0.001	-0.001	-0.001	0.003	-0.006
	(0.81)	(0.45)	(0.72)	(0.06)	(0.05)	(0.06)	(0.19)	(0.26)
Latrine	-0.00	-0.001	0.036	-0.017	0.011	-0.008	-0.007	0.009
	(0.01)	(0.16)	(1.27)	(1.67)	(0.77)	(0.86)	(0.49)	(0.64)
Water								
Well (ref)								
Piped	0.00	0.007	-0.002	0.025	0.004	0.010	0.018	0.024
	(1.07)	(0.99)	(0.17)	(2.74)**	(0.35)	(1.43)	(1.84)	(1.70)
Pump	0.01	0.008	0.011	0.016	0.008	0.016	0.037	0.012
	(1.95)	(1.69)	(1.33)	(1.67)	(1.06)	(1.45)	(2.73)**	(1.96)
Open	-0.01	-0.012	-0.004	-0.028	-0.014	-0.010	-0.005	-0.018
	(0.82)	(1.35)	(0.24)	(1.58)	(1.21)	(0.87)	(0.24)	(1.32)

	Model (1) Delivery variables **not instrum-ented**	Model (2) Delivery variables **instrum-ented**	Model (3) Wealth tertile 1 only: Delivery variables **instrum-ented**	Model (4) Wealth tertile 3 only: Delivery variables **instrum-ented**	Model(5) No education only: Delivery variables **instrum-ented**	Model(6) Secondary/ further education only: Delivery variables **instrum-ented**	Model(7) State attend-ance over 60% only **instrum-ented**	Model(8) State attendance below 35% only **instrum-ented**
Mother's age								
16-20 (ref)								
10-15	0.02 (1.31)	0.011 (0.71)	-0.038 (1.37)	0.064 (1.07)	0.009 (0.48)	0.061 (1.24)	0.043 (1.14)	-0.004 (0.19)
21-30	-0.01 (1.58)	-0.005 (0.95)	-0.001 (0.13)	0.007 (0.82)	-0.002 (0.34)	0.005 (0.51)	-0.011 (1.01)	-0.009 (1.01)
31-40	-0.00 (0.10)	0.004 (0.40)	0.008 (0.61)	0.020 (1.06)	0.004 (0.37)	0.011 (0.61)	0.022 (0.69)	-0.009 (0.90)
41 and over	0.00 (0.00)	0.001 (0.04)	0.034 (0.96)	-0.064 (1.54)	-0.002 (0.08)	0.007 (0.20)	0.022 (0.40)	0.031 (0.88)
Birth order								
Birth order 2 or more (ref)								
First birth	0.01 (2.19)*	0.024 (2.27)*	0.057 (2.16)*	0.010 (0.46)	0.030 (2.01)*	0.009 (0.42)	0.003 (0.17)	0.039 (2.62)**
Preceding birth interval								
24-35 months (ref)								
< 18 months	0.03 (3.95)**	0.040 (3.93)**	0.041 (2.41)*	0.021 (1.27)	0.060 (4.35)**	0.005 (0.31)	0.024 (1.09)	0.035 (1.72)
18-23 months	0.01 (1.35)	0.005 (0.61)	0.021 (1.53)	-0.000 (0.03)	0.015 (1.28)	0.001 (0.06)	0.014 (0.80)	0.008 (0.84)
36 months or over	-0.01 (2.17)*	-0.007 (1.39)	-0.003 (0.38)	0.002 (0.11)	-0.008 (1.20)	-0.003 (0.23)	0.007 (0.39)	-0.008 (1.24)
Antenatal complications								
No antenatal complications reported (ref)								
Mother reported antenatal complication	0.00 (0.92)	0.006 (1.30)	0.003 (0.45)	-0.003 (0.38)	0.005 (0.69)	0.002 (0.28)	0.004 (0.51)	0.011 (1.05)
Maternal height								
145cm or over (ref)								
Less than 145cm	0.00 (0.56)	0.005 (0.94)	0.001 (0.13)	0.001 (0.09)	0.005 (0.70)	0.003 (0.21)	-0.005 (0.37)	0.007 (0.82)
TT immunisat-ions								
Less than 2 TT (ref)								
2 or more TT	-0.02 (4.06)**	-0.012 (1.89)	-0.003 (0.22)	-0.019 (0.74)	-0.014 (1.71)	-0.035 (1.39)	0.001 (0.06)	-0.011 (1.06)
ANC								
No ANC (ref)								
Recommended ANC	-0.02 (3.53)**	-0.007 (0.36)	0.040 (0.94)	-0.012 (0.29)	0.018 (0.54)	-0.032 (0.64)	-0.056 (1.36)	0.021 (0.61)
Some ANC	-0.01 (3.11)**	-0.006 (0.61)	0.009 (0.46)	-0.004 (0.16)	-0.013 (1.34)	-0.017 (0.42)	-0.027 (1.13)	0.001 (0.04)
Place of delivery								
Home delivery – no prof. attendant (ref)								
Home delivery professional attendant	0.00 (0.00)	-0.128 (1.11)	-0.545 (1.64)	-0.016 (0.10)	-0.016 (0.09)	0.024 (0.10)	-0.171 (1.27)	-0.281 (1.11)
Government institution	0.01 (2.46)*	-0.072 (0.83)	-0.217 (0.89)	0.032 (0.24)	0.006 (0.04)	0.032 (0.17)	-0.064 (0.84)	-0.141 (0.53)

	Model (1) Delivery variables **not instrum-ented**	Model (2) Delivery variables **instrum-ented**	Model (3) Wealth tertile 1 only: Delivery variables **instrum-ented**	Model (4) Wealth tertile 3 only: Delivery variables **instrum-ented**	Model(5) No education only: Delivery variables **instrum-ented**	Model(6) Secondary/ further education only: Delivery variables **instrum-ented**	Model(7) State attend-ance over 60% only **instrum-ented**	Model(8) State attendance below 35% only **instrum-ented**
Delivery in private/NGO institution	0.01 (1.38)	-0.053 (0.56)	-0.014 (0.05)	-0.047 (0.40)	-0.195 (1.09)	0.022 (0.17)	0.068 (0.58)	-0.071 (0.47)
Data missing	0.01 (0.38)	-0.964 (0.58)	-0.330 (0.21)	-0.427 (0.20)	0.210 (0.12)	-1.884 (0.99)	0.958 (0.74)	-0.853 (0.46)
Delivery by Caesarean section	-0.01 (1.21)	0.011 (0.36)	0.074 (0.97)	0.000 (0.01)	0.056 (0.89)	-0.007 (0.23)	-0.035 (0.93)	0.055 (0.72)
Involvement in decision making on healthcare								
Mother not involved (ref)								
Mother involved in decision on seeking healthcare	-0.01 (1.99)*	-0.006 (1.56)	-0.010 (1.40)	-0.005 (0.64)	-0.003 (0.49)	-0.006 (0.85)	-0.001 (0.09)	-0.003 (0.42)
Whether allowed to put money aside								
Allowed to put money aside (ref)								
Not allowed to put money aside	0.01 (2.67)**	0.008 (2.17)*	0.009 (1.40)	0.015 (1.81)	0.010 (2.00)*	0.003 (0.33)	0.016 (1.47)	0.013 (2.04)*
Visits to natal kin								
Not allowed to visit family (ref)								
Needs permission	0.01 (1.32)	0.006 (1.16)	0.016 (1.40)	-0.011 (0.91)	0.006 (0.89)	0.003 (0.25)	-0.002 (0.26)	0.019 (1.98)*
No permission needed	-0.01 (0.69)	-0.004 (0.35)	0.039 (1.29)	-0.004 (0.11)	0.000 (0.01)	-0.028 (1.57)	-0.016 (0.43)	0.006 (0.32)
Sex of child								
Female child (ref)								
Male child	0.00 (0.89)	0.005 (1.35)	0.005 (0.90)	-0.007 (1.06)	0.001 (0.21)	0.008 (1.08)	-0.008 (0.95)	0.008 (1.52)
Child is a twin	0.10 (3.20)**	0.110 (3.37)**	0.155 (2.79)**	0.052 (1.15)	0.121 (2.70)**	0.157 (2.17)*	0.069 (0.82)	0.126 (2.74)**
Mother's estimate of birth size								
Average (ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Larger than average	0.01 (1.29)	0.009 (1.53)	0.021 (1.60)	0.005 (0.50)	0.005 (0.66)	-0.002 (0.18)	-0.010 (0.96)	0.021 (1.50)
Smaller than average	0.01 (3.33)**	0.012 (2.68)**	0.017 (2.06)*	0.007 (0.71)	0.019 (3.18)**	-0.004 (0.53)	-0.001 (0.15)	0.027 (3.22)**
Very small	0.07 (6.05)**	0.075 (5.72)**	0.052 (2.78)**	0.078 (2.35)*	0.065 (3.92)**	0.074 (2.80)**	0.157 (3.99)**	0.054 (3.26)**
Constant	0.04 (4.08)**	0.048 (3.64)**	0.088 (2.78)**	0.078 (2.10)*	0.043 (2.01)*	0.057 (1.54)	0.041 (1.14)	0.040 (0.16)
Observations	20800	20318	8458	4216	11659	5253	3671	8659

Robust statistics in parentheses
* significant at 5%; ** significant at 1%

GLOSSARY OF MATERNAL AND CHILD HEALTH TERMINOLOGY

Anaemia: A qualitative or quantitative deficiency of haemoglobin or red blood cells in circulation resulting in a reduced capacity of the blood to carry oxygen to organs and tissues.

Anganwadi worker (AWW): An Indian cadre who receive basic training in aspects of child health and are paid a monthly honorarium by the Government.

Antepartum/antenatal: The time period from conception until the onset of labour, about 40 weeks.

Antepartum haemorrhage: Bleeding from the genital tract occurring after the 20th week of gestation but before delivery of the baby.

Apgar score: A summary measure of the condition of the newborn infant based on heart rate, respiratory effort, muscle tone, reflex irritability and colour. Each factor is given a score of 0, 1, or 2; the sum of these five values is the Apgar score, ranging from 0 to 10.

Auxiliary Nurse midwife (ANM): An Indian semi-skilled cadre of health worker who receives an 18 month training including the skills to perform normal deliveries and identify and refer complications.

Birth asphyxia: The failure to initiate and sustain breathing at birth.

Body mass index (BMI): Calculated as weight in kilograms divided by height in metres squared.

Breech presentation/delivery: Presentation of the buttocks or feet of the foetus during labour.

Caesarean section (Caesarean delivery): A surgical intervention including abdominal and uterine incision for delivery of a baby carried out when birth via the cervix and vagina is impossible or dangerous.

DHS II: DHS surveys carried out between 1988 and 1993

DHS Plus: DHS surveys commencing in 1997 with expanded content for maternal and child health

Fertility Rate: The number of births in a given population per year or other unit of time.

Early childhood mortality rate (ECMR): The number of deaths in children over 12 months of age but less than five years of age per 1000 children reaching 12 months.

Eclampsia: Convulsions, sometimes followed by coma, occurring in a pregnant or puerperal woman and associated with hypertension, oedema and/or proteinurea.

Infant mortality rate (IMR): The number of deaths in children before the age of one year per 1000 live births.

Intrauterine growth restriction: The growth of the foetus is abnormally slow. When born, the baby appears too small, considering its dates. Intrauterine growth restriction (IUGR) is associated with increased risk of medical illness and death in the newborn. It is also known as intrauterine growth retardation.

Live birth: The complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy, which, after such separation, breathes or shows any other evidence of life, such as beating of heart, pulsation of the umbilical cord, or definite movement of voluntary muscles, whether or not the umbilical cord has been cut or the placenta is attached.

Low birth weight: A birth weight of less than 2500g. Very low birth weight is defined as a birth weight of less than 1500g.

Maternal death: The death of a woman while pregnant or within 42 days of termination of the pregnancy, irrespective of the duration and the site of pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.

Maternal mortality ratio: The number of maternal deaths per 100 000 live births.

Neonatal death: Death of a live-born infant during the first 28 completed days of life. It can be subdivided into early neonatal death, occurring during the first seven days of life, and late neonatal death, occurring after the seventh day but before 28 completed days of life.

Neonatal mortality rate (NMR): The number of neonatal deaths per 1000 live births during a fixed period.

Neonatal tetanus: Neonatal tetanus is acquired when the spores of the bacterium *Clostridium Tetani* infect the umbilical stump. It is normally fatal, and is particularly common in rural areas where deliveries are at home without sterile procedures. WHO estimated that neonatal tetanus killed about 180,000 babies in 2002. It can be prevented by administering a course of tetanus toxoid immunisation to the mother either prior to conception or during pregnancy.

Obstructed labour: A labour in which progress is arrested by mechanical factors, necessitating operative delivery.

Perinatal death: Death of a foetus or a newborn in the perinatal period that commences at 22 completed weeks (154 days) of gestation (the time when birth weight is normally 500g) and ends seven completed days after birth.

Perinatal mortality rate: The number of perinatal deaths per 1000 total births during a fixed period.

Primagravidae: Women who are in their first pregnancy.

Pre-eclampsia: A condition in pregnancy manifested by hypertension (high blood pressure), oedema (swelling) and/or proteinuria (protein in the urine).

Postpartum / postnatal care: Care provided to a woman during the postpartum period by skilled health personnel for reasons related to the birth.

Postpartum haemorrhage: The loss of 500ml or more of blood from the genital tract after delivery of the baby. In anaemic mothers, a lower level of blood loss should be the cut-off point for starting therapeutic action.

Skilled birth attendant: An accredited health professional such as a midwife, doctor or nurse who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth and the immediate postnatal period and in the identification, management and referral of complications in women and newborns.

Stillbirth: The birth of a dead child weighing at least 500g (or when birth weight is unavailable, after 22 completed weeks of gestation or with a crown-heel length of 25cm or more), death occurring before the complete expulsion or extraction from its mother. A fresh stillbirth refers to the birth of a dead child where intrauterine (foetal) death has occurred during labour/delivery whereas a macerated stillbirth refers to the birth of a dead child where death has occurred sometime before the onset of labour/delivery, and the foetus shows degenerative changes.

Stillbirth rate: The stillbirth rate is the number of stillbirths per 1000 total births during a fixed period.

Stunting: Shortness that is a deficit, or linear growth that has failed to reach genetic potential as a result of the interaction between poor diet and disease.

Traditional birth attendant (TBA): A person who assists mothers during childbirth and initially acquired her skills by delivering babies herself or through apprenticeship to other TBAs. Includes family member designated by an extended family to attend births in that family.

Trained traditional birth attendant (TBA): A TBA who has successfully completed a recognised short period of instruction in the management of childbirth.

Under five mortality rate (U5MR): The number of deaths in children before the age of five years per 1000 live births.

Xeropthalmia: An inflammation of the cornea that is associated with a nutritional deficiency, especially of vitamin A. The cornea becomes dry and infected, and night blindness may occur.

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