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Reducing Infant Mortality to Reach Millennium Development Goal 4

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ABSTRACT

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The World Health Organization (WHO) found that 6.6 million children under five died in 2012 (WHO 2013). Almost half of all of these child deaths take place in the first month of life, and 75% of all under five deaths occur within the child's first year of life (WHO 2013). The aim of this study is to compare the most influential factors that decrease infant and neonatal mortality in order to find where policy makers, governments, and international organizations need to focus their efforts in order to get all countries on track for Millennium Development Goal 4 to reduce child mortality.

Mosley and Chen (1984) suggest that infant mortality should be studied more as a process with multifactorial origins opposed to an acute, single phenomenon. To study the multifaceted nature of infant mortality they suggest grouping select variables into broad categories. This paper uses this model to test the contribution of the following four types of factors: 1) healthcare system 2) social determinants 3) reproductive behavior and 4) national context in order to understand which category impacts infant mortality most significantly. This study utilizes the Demographic and Health Surveys and was estimated using a discrete time hazard model. Results suggest that social determinants reduce infant mortality most significantly over the other three factors and that maternal education is the key to reaching Millennium Development Goal 4. This research suggests that healthcare interventions, although important, are not a substitute for mother's education. The combination of prenatal care and maternal education will ensure the safest first year for a child.

Keywords: infant mortality, Millennium Development Goals, maternal education

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INTRODUCTION

The World Health Organization (WHO) found that 6.6 million children under five died in 2012 (WHO 2013). Globally, under-five mortality has decreased 47% from 1990 to 2012, with an annual rate reduction between 1.2 and 3.9 deaths per 1,000 births (WHO 2013); at the regional level, the progress towards improving child mortality has been slow, and varies greatly (Bhutta et al. 2010). The highest rates of child mortality remain in sub-Saharan Africa with only a 28% decrease from 1990 to 2008, from 90 deaths per 1,000 live births, to 65. In comparison, Latin America and the Caribbean have successfully decreased their child mortality by 56% (You et al. 2009).

The Millennium Development Goals (MDGs) were established by the United Nations in 2000 to commit governments and international organizations to improve child mortality and a broad range of other health and development indicators by 2015. Each goal is designed with an achievable target and timetable to be met by 2015, and goals range from eradicating extreme poverty and hunger to combating HIV/AIDS, malaria, and other diseases. Many of these goals have been reached ahead of the established timetable, while the progress of other goals has been uneven across different regions (Bhutta et al. 2010, You et al. 2009). MDG 4 aims to reduce mortality in children younger than 5 years by two-thirds from the 1990 level. Since the MDG's implementation in 2000, the resulting child mortality reduction efforts have varied among regions. Yet success in many countries such as in Latin America provides proof that MDG 4 is attainable, even in the poorest surroundings. The question then arises, why are some countries succeeding in regards to achieving MDG 4, while others are far from the target?

There is much discussion of possible avenues to reach MDG 4, in particular to decrease neonatal and infant mortality. Almost half of all child deaths under age five take

place in the first month of life, and 75% of all under five deaths occur within the child's first year (WHO 2013). The risk of a child dying before completing the first year of age is highest in the WHO African region (63 per 1000 live births), about six times higher than that in the WHO European region (10 per 1000 live births). Similar to child mortality, globally the infant mortality rate has decreased from an estimated rate of 63 deaths per 1,000 live births in 1990 to 35 deaths per 1,000 live births in 2012 (WHO 2013).

Much of the discussion of neonatal and infant mortality reduction has focused on one specific avenue and has failed to include other possibilities to determine which would be most effective. The aim of this study is to compare the most influential factors that decrease neonatal and infant mortality in order to find where policy makers, governments, and international organizations need to focus their efforts in order to get all countries on track for MDG 4. Mosley and Chen (1984) suggest that infant mortality should be studied more as a process with multifactorial origins opposed to an acute, single phenomenon. To study the multifaceted nature of infant mortality they suggest grouping select variables into broad categories. I use their model as a framework and test the contribution of the following four types of factors: 1) the healthcare system 2) social determinants 3) reproductive behaviors, and 4) the national context in order to understand which category impacts neonatal and infant mortality most and to understand change in mortality over time.

MILLENIUM DEVELOPMENT GOALS

Each year an annual report is gathered to assess how the world is doing in implementing the policies and actions needed to achieve the MDG's and related outcomes. The 2013 annual report notes that there has been success in regards to some of the MDG's. For example, the goal of eliminating gender disparity in primary education was accomplished in 2010. In addition,

there has been global progress in eliminating gender disparity in secondary education. Similarly, clear progress has been made toward the goals of achieving universal primary education (IMF 2013). However, in contrast to the success of increased education, overall global progress on health-related targets has been less than impressive. The Global Monitoring Report explains that many countries are likely to miss the MDG on child mortality, hence working to accelerate progress towards the attainment of this goal is not only desirable, but crucial.

UNEQUAL PROGRESS TOWARDS MDG 4

In regards to MDG 4 specifically, data do show progress in the reduction of child mortality, although it is distributed unevenly between countries (Rajaratnam 2000). At one end, Latin America and Eastern Europe are on target to meet, or surpass MDG 4. These regions have achieved a greater than 55% reduction in under-5 mortality between 1990 and 2008 (You et al. 2009). While at the other end, South-East Asia and Sub-Saharan Africa have made some progress, but not sufficient to meet the goal. South-East Asia alone still counts for 32% of deaths in neonates and children, with one out of every 13 children dying before age five. Although this number has decreased from 39% since 1990, this rate of decline is not adequate to meet MDG 4 (Nair et al. 2012; You et al. 2009).

Bhutta and associates (2010) reviewed progress toward the child mortality goal from 1990 to 2010. They looked at 68 countries accounting for more than 90% of maternal and child deaths worldwide. They found that 19 countries were on track to meet MDG 4, in 47 they noted acceleration in the yearly rate of reduction in mortality of children younger than 5 years, and in 12 countries progress had decelerated since 2000. They concluded that progress towards the reduction of child mortality has been minimal in some countdown countries, while others have

reduced longstanding inequalities. The success represented by some countries supports the MDG goal, providing proof that it is attainable, even in poor environments.

One concern of not meeting the goal is that in these poor environments where disease and deaths are far too high, development of the area is stifled. Deaths and disease impede development by lowering rates of economic growth, lowering population growth, inhibiting savings and investment, lowering worker productivity, and influencing family dynamics through fertility (Sachs and Malaney, 2002). Given the vision of success achieved by some countries, addressing the devastating effects of high child mortality and saving thousands of children's lives should motivate spreading success to all participating countries.

REDUCING INFANT MORTALITY

There are many overlapping and influential factors that play a role in neonatal and infant mortality. It is important to understand which actions will have the most influence on mortality reduction in order to focus efforts in areas with the most potential for change. In a similar study conducted by Pridmore and Carr-Hill (2010), they presented a synthesis of available evidence to highlight interventions that can effectively address child under-nutrition in developing countries. My analysis, like the one by Pridmore and Carr-Hill recognizes that the causes of infant mortality and child under nutrition, respectively, are complex, multiple, and interactive. As a result, in both studies, it is not possible to deal with all possible interventions extensively. Instead, focusing on interventions that are implementable on a large scale is the primary focus.

Addressing neonatal and infant mortality is critical because deaths in these periods are increasing, and the MDG for child survival cannot be met without substantial reductions in neonatal and infant mortality. About 99% of neonatal deaths worldwide are in low-income and middle-income countries; about half of the infant deaths occur at home. Global estimates of

neonatal deaths in 2000 indicate that preterm birth (28%), severe infection (36%), and complications of asphyxia (23%) are the main causes of reported death in infancy (Lawn, Cousens and Zupan. 2005).

Mosley and Chen (1984), in proposing a comparative analysis, grouped the proximate determinants of child mortality into broad categories, allowing a more feasible and integrated analysis of the biological and social determinants of mortality. The following four categories are extensively studied in the literature, have been determined influential in reducing neonatal and infant mortality rates, and are potentially implementable on a large scale. If extensive time and resources were available to devote to reducing all stages of child mortality, all four of these categories could be addressed. But with little time and resources to spread effectively among all four categories, and with the ever pressing risk of child death, this research seeks to find the most influential avenues to decrease neonatal and infant mortality so that efforts can be focused on the most beneficial areas to create the most change. These categories reflect types of activities that matter in regards to infant mortality reduction found in the literature. These include improving the healthcare system, enhancing social determinants, modifying reproductive behavior, and enhancing the macro context.

1. Healthcare System

The first category, improving the healthcare system, includes the location of child delivery and the use of prenatal care. Adequate healthcare is essential to improving child-health outcomes (Fay et al. 2005). Research has shown that achievement of MDG 4 is only possible through maternal, newborn, and child health interventions (Black et al. 2010), which has caused a large shift of funding from other interventions toward healthcare strategies. One strategy successfully implemented in some environments to decrease child mortality has been placing

greater emphasis on maternal health, in particular, skilled care during childbirth at a designated health facility. About 70% of neonatal deaths and thousands of maternal and child deaths occur because effective yet simple interventions do not reach those that need them most in countries not utilizing maternal healthcare (Knippenberg et al. 2005).

Child delivery at a health center is a key healthcare intervention that can help prevent maternal and infant deaths, but access to trained deliveries is limited in developing countries (Say and Raine, 2007; Gage 2007). By giving birth at a health center, mothers and children can receive critical care by trained staff. Indirectly, mothers who deliver at a health center also develop a relationship with the healthcare system that may increase the likelihood they will return to the center for other services such as immunizations, regular well-baby care, oral rehydration, medication for malaria, and so forth. The immunization of children indicates parental awareness and use of modern medical care (Gupta 1990).

In 2008, 68% of the estimated 8.795 million deaths in children younger than 5 years worldwide were due primarily to pneumonia, diarrhea, and malaria (Black et al. 2010). The Gates Foundation (2013) notes that every 20 seconds worldwide, a child dies from a vaccine-preventable condition, such as pneumonia, and that vaccines save about 2.5 million lives each year which. In addition to vaccinations, centers routinely monitor growth of children and give assistance with under-nourished children. Visits to the health center can also establish a relationship of trust with healthcare providers, facilitating the exchange of information and health services (Gage 2007).

Just like a safe delivery, prenatal care is also critical for both newborn and maternal health (Guliani, Sepehri, and Serieux 2012). In regards to prenatal care specifically, non-utilization may result in missed opportunities to recognize and manage complications that may

threaten the life of the baby or mother. The inclusion of prenatal interventions in child health programs in primary healthcare could prevent 29-40% of all postnatal deaths in children under 5 (Bhutta et al. 2008). In addition to infant delivery at a health center, prenatal care is another important entry point into the health system that can facilitate women's access to medical care for future needs and increase the mother's confidence and familiarity with the health system (Pallikadavath, Foss and Stones 2004). Strengthening maternal and infant health at the primary healthcare level should be a priority for countries to reach their MDG targets to reduce child mortality.

2. Social Determinants

The second category includes social determinants such as mother's age at childbirth, education, and residence. In regards to mother's age, pregnancy in adolescence is associated with a greater risk of infant and maternal mortality. Young mothers (13 to 17) and older teenagers (18-19) are at higher risk of delivering an infant with low birth weight, a premature infant, or one small for gestational age compared to births to older women. This finding is significant even in studies controlling for marital status, education, and use of prenatal care (Fraser, Brockert and Ward 1995).

In addition to a mother's age, maternal education is strongly correlated with three different markers of child health: reduced infant mortality, increased height-for-age, and increased immunizations. This effect can be attenuated once controls for socioeconomic characteristics are introduced, but that is only when the socioeconomic characteristics compensate for low maternal education (Desai and Alva 1998). Maternal education is repeatedly shown to influence infant mortality. Desai and Alva (1998) demonstrate persuasively that a mother's education has an independent, influential, and positive impact on the survival of her

children. This impact may exist because education affects access to health facilities at the community level thereby improving the health of children in communities with high levels of education. They suggest that this may be because educated mothers are more likely to engage in health promoting behaviors such as antenatal care, hospital delivery, and immunizations for the baby. Widening access to education has been a goal for many developing countries in the last few decades, but the EFA Global Monitoring Report for 2013/2014 notes that education has been slipping down the global agenda as donors move their funding elsewhere. This funding is often reallocated to healthcare interventions because it is assumed that healthcare would have the greatest effect on infant mortality. The other side of the debate suggests that education magnifies the potential impact of healthcare interventions, increasing the need of understanding the relationship between maternal education, healthcare interventions, and infant survival.

In addition to education, urban women are more likely to deliver with the help of a skilled health worker than are rural women, possibly due to proximity of health centers and ease of access. Similarly, urban resident women are more likely to use medical settings for delivery than are rural women, and more likely to receive early antenatal care (Say and Raine 2007). It is the inadequate utilization of appropriate healthcare that accounts for the low survival of many women and children during pregnancy and childbirth (Chambers and Booth 2012).

Gender discrimination through low levels of female education and lack of empowerment reduces a woman's autonomy to make decisions and access the best choices for her children's health. This results in critical delays and unnecessary deaths (Kinney et al. 2010). Women with greater freedom and control over finances, decision-making power, and mobility, are more likely to obtain higher levels of antenatal care and use safe child delivery methods (Bloom, Wypij, and

Das Gupta 2001). The influence of women's autonomy on the proper use of healthcare is as important as other known determinants such as education (Bloom et al. 2001).

3. Reproductive Behavior

The third category focuses on reproductive behaviors, specifically details about numbers of births and their spacing, as well as child sex. Several studies find short intervals between pregnancies are connected to an increased risk of low birth weight, maternal death, and/or preterm delivery. Short birth intervals, both before and after, increase the child's risk of death during the first two years of life (Conde-Agudelo, 2006; Forste 1994). Studies find that the risk of mortality increases if infants had a sibling born within the preceding two years. Similarly, the risk of dying during the second year of life is higher if the mother has an additional birth within a short period (Hobcraft, McDonald, and Rutstein. 2000). Birth intervals affect infant mortality because rapid succession of births wear down the nutritional and reproductive resources of the mother leading to a higher incidence of premature and lower weight births (Pebley and Stupp 1987).

Likewise the birth order of the child can impact the resources available in the family. There is a connection between infant survival and parental investment in children based on resource allocation (Rosenzweig and Shultz 1982). Children close in age compete for scarce resources such as clothing and food, and have increased susceptibility for disease transmission among siblings. This struggle for resources and increased susceptibility to disease increases the risk of mortality. Children expected to be economically productive adults are likely to receive a larger share of the already limited family resources which gives them a greater propensity to survive (Rosenzweig and Shultz 1982). Many of these issues can be addressed by successful family planning; thus, an increase in the practice of family planning can reduce infant mortality

rates (Hobcraft 1987). If contraceptive understanding and use leads to a reduced proportion of high risk births (short birth-spacing and high parity), infant mortality should decrease (Bongaarts 1987).

In addition to birth order and birth spacing, the sex of the child can influence survival. In regards to sex, a comparison of childhood mortality rates completed by Hill and Upchurch (1995) noted that female disadvantage was present in almost 90 percent of observations. This girl disadvantage is most prevalent for children 1-4 years, when childcare is more important than genetic factors in determining mortality risks. However, they also note that girls in most countries have a disadvantage in infancy. In more biological terms, male babies are biologically weaker than females, being more susceptible to disease and premature death which may over-shadow the improper treatment many female babies encounter (Gupta 1995). The circumstances of a child's birth and their sex impact the child from the second they are born and beyond. Addressing these issues, whether by family planning or other means can influence infant survival.

4. National Context

Research on national involvement in child health has received limited attention in developing countries due to the lack of data on public expenditures (Filmer and Pritchett 1999). Even though the research is limited, understanding the national context for reducing infant mortality cannot be overlooked. These national characteristics include the human development index (HDI), national health expenditures and literacy by sex. The HDI is a composite score created by combining indicators of life expectancy, educational attainment, and income. These national characteristics represent two possible avenues to improve reaching MDG 4: increasing the inputs themselves (i.e. increasing HDI and national health expenditure), or increasing the

efficiency with which the existing inputs are being used. The human development index, health expenditures, and the adult literacy rate are often used to estimate life expectancy which is correlated with infant mortality (Jayasuriya and Wodon 2003).

Many national level factors such as the HDI per capita are strong determinants of both neonatal and infant mortality. The human development index is a way to measure social and economic development by combining indicators of educational attainment, income, and life expectancy into one index. At the national level, higher GDP per capita, lower inequality, and higher female literacy all reduce infant mortality (Fay et al. 2005), which are all indicators of the HDI. Affordable, available, and adequate healthcare is essential to improving child-health outcomes, and is generally related to national health expenditures or factors comprising the HDI. The HDI is a successful alternative to using gross domestic product (GDP) because measuring the socio-economic progress at national and sub-national levels is possible. National life expectancy and literacy by sex represent a level of equality within a country. It is possible that as gender equality in a country rises, couples have fewer children and the importance of human capital increases which in turn decreases the mortality rate (Lagerlof 2003). Regarding literacy, child survival is higher among the children of literate women, compared to those of illiterate women (Anand 2004). These infrastructure interventions have an important role in reducing child mortality and failure to recognize this, according to Fay and colleagues (2005), can risk undermining success.

There is much discussion in the literature of possible avenues to reach MDG 4. Many of these discussions focus on one avenue to reduce infant mortality and fail to compare various possible avenues to determine which is most critical. Bhutta et al. (2008) suggest that the key to achieving MDG 4 is to implement what we know works through all possible channels. They note

that almost 75% of the 68 countries with the greatest number of maternal, newborn, and child deaths are off target to achieve MDG 4 goals. Increasing care on the basis of what we know will work, is a moral imperative. With that, I aim to find which of the following factors has the largest influence on neonatal and infant mortality and if they account for change over time: 1) the healthcare system 2) social determinants 3) reproductive behaviors, or 4) the national context. This information will inform policy makers, governments, and international organizations that seek to help countries reach MDG 4.

METHODS

Data

This analysis utilizes data from the *Demographic and Health* surveys (DHS) which have been administered in over 90 countries, advancing global understanding of health and population trends in developing countries. The DHS are nationally-representative household surveys of women of childbearing age (15-49). They include information regarding health, nutrition, family planning, and maternal well-being. This analysis utilizes the Children's Recode data which has one record for every child born to women respondents in the five years preceding the survey.

This specific dataset contains information about pregnancy, postnatal care, health, and immunizations in addition to demographic information about the mother. Although nutritional status of the child is influential for their survival (Anderson et al. 2002; Pelletier 1995), the data utilized in this study do not report nutritional information for infants who have died. The unit of analysis is a child born to the mother in the last five years (0-59 months). Data for this study come from 39 countries (APPENDIX 1) that have been surveyed at least twice, and have at least one survey since 2000. This sample is selected because the Millennium Development Goals were implemented in 2000; selected countries were surveyed at least once before and after the

implementation of the goals. The sample includes countries from Africa, Asia, and Latin America and the data have been merged together for a total sample size of 1,196,775 children. Utilizing these data, I examine change over time and across region. In addition to the DHS, select national level indicators have been compiled from The World Bank.

Measures

The outcome variable is infant mortality, determined by death or survival before one year of age, accounting only for live births. This is based on whether the child was still living at the date of survey and the duration from birth to either the date of the survey or the date of the child's death. In addition, 44% of all child deaths occur in the first month of life (WHO 2013). Comparing this WHO statistic to the DHS infant mortality data used in this study indicated no statistical difference.

Age heaping can be a significant source of bias in regards to reported age. Accuracy in the data is affected by respondents' precise knowledge of vital events. Some respondents may be unable to give their exact age, or the exact age of their child, which produces evidence of age heaping on ages ending with 0 and 5. Rutstein and Bicego (1990) report that most demographic parameters are relatively insensitive to age heaping; however, month heaping can produce inaccuracies in regards to the month a child died. Because this analysis is looking at mortality in the first month, and mortality in the first year, this could produce bias. The impact of heaping at one month and 12 months of age on mortality rates has been assessed previously regarding DHS data. Marckwardt and Rutstein (1995) report that data quality of the DHS has improved in all regions since its emphasis on full birth histories and larger sample sizes. They conclude that heaping of child age at 12 months has been reduced by 75% in recent DHS models, suggesting that age heaping in child death reporting has been reduced as well.

Other scholars have assessed the quality of the DHS data in regards to infant mortality. They conclude that errors are minimal in most cases and that these data still provide one of the most accurate measures of infant mortality available (Sullivan et al. 1990; Curtis 1995). The ratios of neonatal to infant mortality from the WHO statistics for each country have been compared with a random selection of countries from this data. No major differences were found, indicating that the relative magnitude of neonatal and infant mortality in the DHS is similar to other reported vital statistics, underscoring confidence in conclusions drawn from the DHS.

To examine neonatal mortality, I include interactions between each variable and the first month of life in order to determine which of the factors are more or less important during the neonatal period. The interaction between time and the first month, if above or below one, suggests that the trend in neonatal mortality is different in the first month of life than the following 11 months.

The primary independent variable categories include: 1. Healthcare system 2. Social determinants 3. Reproductive behaviors and 4. National context. The four categories are comprised of the following specific measures:

1. Healthcare system

Healthcare system measures include the location of delivery and the use of prenatal care. The location of delivery is a dichotomous variable comparing those who delivered at home and those who delivered in a private or public health center or hospital (coded 1= health center, 0= at home). Similarly, the use of prenatal care is a dichotomous variable that compares mothers who reported some prenatal care and those who reported no care (coded 1= some prenatal care, 0= no prenatal care).

2. Social determinants

Social determinants include the following maternal measures: mother's age at birth, education, and residence. Mother's age at birth is measured on a continuous scale of reported age in years. Maternal educational attainment is measured as one variable with ordered categories labeled 0= "no education," 1= "incomplete primary," 2="complete primary," 3= "incomplete secondary," 4="complete secondary and higher." Finally, residence is a dichotomous variable based on the woman's place of usual residence, either rural or urban (coded 1= urban, 0= rural).

As noted in the review of literature, wealth and autonomy are also social determinants that may influence child health outcomes. Initial analyses, however, indicated that these factors were not predictive of infant or neonatal mortality. They were not included in further analyses to reduce the number of missing cases and for reasons of parsimony.

3. Reproductive behaviors

Reproductive behaviors include the preceding birth interval, first births, and sex of the child. Preceding birth interval measures in months the period from the target child's birth to the previous termination of pregnancy or birth. A healthy interval is a dichotomous variable coded (0 = not healthy interval, 1 = healthy interval) with a healthy interval being between 24 and 48 months following the proceeding birth or pregnancy termination. First births are a dichotomous variable coded (0= not first birth, 1= first birth). Sex is a dichotomous variable (coded male=1, female=0).

4. National context

National measures include the human development index (HDI) and national health expenditures. Due to limitations in the *Demographic and Health Survey*, these data are compiled from The World Bank. The HDI is a composite score created by combining indicators of life expectancy, educational attainment, and income. The HDI sets a minimum and maximum (called

goalposts), and shows where individual countries stand in relation to these goalposts. Values are between 0 and 1. Health expenditure is expressed as percent of GDP. All of these numbers from The World Bank were matched to the DHS countries based on survey year (APPENDIX 1). In cases where specific years were not available from The World Bank, the next closest year (within 5 years) was used.

Literacy rates, as noted in the literature review, are also national level indicators that may influence infant survival. Initial analysis included the literacy rate measured as the percentage of people ages 15-24 who can with understanding read and write a short, simple statement on their everyday life. This factor was calculated separately for men and women by dividing the number of male and female literates aged 15 years and over by the corresponding age group population and multiplying the end result by 100. Taking the numbers for males and females, the number of literate females was divided by the number of literate males to get the percent or ratio of literate females to males. However, this measure was not predictive of infant survival. As a result, literacy was not included in further analysis.

Analysis

To estimate infant survival to 1 year of age I use a discrete time hazard model. An aggregate impact of each individual factor on infant mortality is then determined. The unit of time is month and all models control for geographic region. The regression requires transforming the data into a person period dataset which allows each child to have multiple records--one for each measurment occasion which "most naturally supports meaningful analyses of change over time" (Singer and Willett 2003).

To measure change I include the year mothers were interviewed as a covariate. The coefficient for year shows the overall trend in the outcome. I then introduce the four domains in

four individual models. If the coefficient for year is reduced when other variables are added, it can be concluded that the added variables account for changes over time in infant survival status. The effects of each individual variable comprising the four factors are analyzed in more detail within each model. This allows identification not only of the most influential factor as a whole, but also the most influential variables on their own.

A fifth analysis considers whether healthcare practices and maternal education have separate effects; that is if one can serve as a substitute for the other. One argument is that as new healthcare technologies are introduced, educated people are best able to benefit from those technologies, suggesting an important relationship between the two interventions (UNESCO 2014). An alternative argument supports sole funding of healthcare technologies or sole funding of education, seeing them as two separate effects on infant survival. This fifth model combines the most influential variables from each of the previous four models, including an interaction between prenatal care and maternal education to underscore which factors are most influential in meeting MDG 4.

The analytical plan begins with an outline of descriptive statistics in order to describe the sample of mothers and children used in this analysis (Table 1). Next, the influence of the variables within each of the four models on neonatal and infant mortality (Table 2) is presented based on multivariate analyses. These categories follow the outline proposed by Mosely and Chen (1984) for analysis of infant and neonatal mortality. The fifth model in Table 2 includes the single most influential variable from each of the four models, including an interaction between maternal education and prenatal care. Last a model summarizing key factors influencing neonatal and infant mortality (Table 3) is presented to underscore the contributions of the healthcare system, social determinants, reproductive behaviors, and the national context.

RESULTS

Descriptive Statistics

The descriptive statistics presented in Table 1 indicate that mothers on average were about 29 years old at the birth of their child, and mean maternal education levels are between incomplete primary and complete primary. Only about 34% of children are living in urban areas. In terms of healthcare utilization, 47% were born in a health center and 79% had mothers that received some prenatal care. About 66% of the children were born following a healthy birth interval while, another 25% were first births. The distribution between male and female births is about equal at 50%. Finally, the average development level of the countries analyzed, indicated by HDI, is about .5, exactly half way between the goal posts set at 0 and 1. The average health expenditures as a percent of GDP is about 5%.

(Table 1 about here)

The correlations in Table 1 indicate which variables are changing over time, and which have potential to change. Over the time of these surveys, the health expenditures in the countries appear to have changed the most (0.394). Similarly, health center deliveries increased, as well as prenatal care (all around 0.11). Although the correlations suggest there have been changes, these as well as the other variables included still have potential as interventions. Maternal education and healthy birth intervals have remained relatively stable over the time periods surveyed, indicating potential for improvement.

Influence of Categories on Infant Mortality

Multivariate models are presented in Table 2. Overall, the most influential category to reduce infant mortality is social determinants surrounding the birth, based on log likelihood comparisons of each model to the baseline (Table 2). The log likelihood is best if it is the lowest,

indicating that the social determinants have the largest effect on infant mortality. This includes the mother's age at birth, urban residence, and maternal education. The order of impact on infant mortality from most to least, based on the log likelihood is social determinants, healthcare system, reproductive behavior, and then national context. Although each of the categories has an independent influence on infant mortality, it does not account for changing infant mortality over time (*Baseline*, Table 2). Year is consistent across all models at 0.94, regardless of which variables are included, indicating that these variables do not account for mortality changes between the years surveyed.

(Table 2 about here)

In addition to the multivariate models presented in Table 2, all factors within each of the four categories influencing neonatal and infant mortality are summarized in Table 3. This table facilitates the identification of factors most influential to neonatal or infant mortality. In Table 3, the neonatal effects are calculated by multiplying the coefficient for each variable by its interaction with month 1 as reported in Table 2.

(Table 3 about here)

In the baseline model in Table 2, the infant mortality rate is .007 per month in the post-neonatal period (constant), and is 6.87 (Month 1) times more likely in the neonatal period. As indicated previously, of the categories outlined by Mosley and Chen (1984), social determinants were the factors most predictive of infant mortality, followed by healthcare systems, reproductive behavior, and national context. I examine the factors within each of these categories in greater detail, starting with social determinants.

Social determinants

Among the measures of social determinants, maternal education had the largest influence on infant mortality. For every step increase in maternal education, an infant was 22% less likely to die. The impact of maternal education was not as great in the neonatal period, as each unit increase reduced neonatal mortality by only about 10% (Table 3). In addition to education, the residence of the mother was predictive of infant survival. Post-neonatal mortality was 20% lower in urban relative to rural areas but again the impact was less in the neonatal period (Table 3). Additionally, mother's age at birth reduced mortality by 1% for each year increase in age and had a similar effect in the first month of life.

Healthcare system

As reported in Table 3, if an infant's mother received at least some prenatal care, the risk of dying in the first year was decreased by over 30%. The effect of prenatal care was even greater for infant survival in the neonatal period, reducing mortality by about 40% (Table 3). The effect of delivery at a health center on infant mortaltiy was similar to that of prenatal care. Delivery at a health center reduced the risk of dying in the first year by 28%. However, unlike the influence of prenatal care during the neonatal period, delivery at a health center was associated with no change in mortality during the neonatal period.

It may be that complications at birth or high risk births are more likely to occur at a health center, thus increasing the risk of mortality at birth in a center. However, for infants that survive the first month, having been born in a health center may represent maternal acceptance or utilization of modern healthcare associated with reduced infant mortality overall. Overall, involvement with the healthcare system through prenatal care and delivery has an important influence on infant survival, second only to the social characteristics of the mother.

Reproductive behavior

Reproductive behavior measures include the preceding birth interval, birth order, and sex of the child. The coefficients in Table 3 show that infants born following a healthy interval were 13% less likely to die (post-neonatal). In that neonatal period, an infant was almost 30% less likely to die following a healthy birth interval (Table 3). First born children had a 2% decreased risk of mortality in the post-neonatal period, however, they were 49% more likely to die as neonates relative to higher parity children. Males were more likely to die as infants relative to females, especially during the neonatal period where males were about 30% more likely to die than females (Table 3).

National context

The HDI composite score of life expectancy, educational attainment, and income indicates that an increase from a score of zero (no development) to a score of one (complete development) is associated with a 90% reduction in post-neonatal mortality (Table 3). This impact is reduced (0.095*4.824=0.458) in the neonatal period (Table 3). And finally, health expenditure is expressed as percent of GDP appears to have minimal influence on infant and neonatal mortality.

Combined model of social determinants, healthcare, reproductive behavior, and national context

Each of the four categories has one variable that reduces infant or neonatal mortality the most. For the category of social determinants that is maternal education, healthcare system it is prenatal care, reproductive behavior is a healthy birth interval, and for the national context it is the HDI. The fifth model looks at these all together, and adds an interaction between maternal education and prenatal care in order to see if they have separate effects on infant survival.

Looking at maternal education, for every step increase in maternal education, an infant was almost 7% less likely to die with no impact in the neonatal period (Table 3). As reported in Table 3, if an infant's mother received at least some prenatal care, the risk of dying in the first year was decreased by over 20%. The effect of prenatal care was even greater for infant survival in the neonatal period, reducing mortality by about 31% (Table 3). The interaction between maternal education and an infant's mother receiving prenatal care suggests that the effect of prenatal care on infant survival is greater for educated women. If a mother received prenatal care, and as her education level goes up one step, a child is 14% less likely to die in the first year and 9% less likely in the first month.

The coefficients in Table 3 show that infants born following a healthy interval were almost 24% less likely to die (post-neonatal) and 25% less likely to die in the neonatal period. And finally, if a country's HDI score were to go from 0 to 1 (which is hypothetical), a child is 70% less likely to die in the post-neonatal period, with little or no effect in the neonatal period.

CONCLUSION

Globally, under-five mortality has decreased 47% from 1990 to 2012, with an annual rate reduction between 1.2 and 3.9 (WHO 2013); regionally the progress towards improving child mortality has been slow, and varies greatly (Bhutta et al. 2010). Based on the model proposed by Mosley and Chen (1984), I examined the influence of four primary categories-- the healthcare system, social determinants, reproductive behaviors, and national context on neonatal and infant mortality across 39 countries. Of these categories, social determinants of the mother (education, residence, age at birth) had the most influence on mortality reductions. These are also the factors that have changed the least since the implementation of the MDG 4.

This research shows that a mother's education has the greatest chance to reduce infant mortality. Widening access to education has been a goal for many developing countries in the last few decades, but the EFA Global Monitoring Report for 2013/2014 notes that education has been slipping down the global agenda as donors move their funding elsewhere, just at the time that education is needed to get countries on track to reach other development goals. This implies a once world-wide recognition that education is essential for producing many positive outcomes such as economic, social, and health development needs to resurface. Whatever the focus that countries and donors have placed on increasing access to education in the past, this research suggests that years of maternal education have increased only slightly since the implementation of MDG 4.

Hill and King (1997) looked into the status of maternal education in developing countries right before the implementation of the MDG's. They noted that, multiple indicators- including literacy, enrollment, and years in school- reveal important trends in women's education in developing countries. Each of these indicators leads to the same conclusion: the level of female education is low in the poorest countries. The fact that maternal education was low in 1997 before the implementation of the MDG's and has not improved much in the years following should be worrisome. However, the fact that maternal education reduces infant mortality more than the other interventions looked at in this research and has room for growth should leave us with hope for the future. If increased time and investment is placed specifically on maternal education, this growth in maternal education over time should result in reduced infant mortality. The already strong impact of maternal education on infant survival has the potential to magnify as more mothers become educated.

The EFA Global Monitoring Report for 2013/2014 strongly advocates for a shift in focus that "[places] education at the heart of the global development agenda" (UNESCO 2014:i). No matter the outcome, whether it be increased quality of life, increased opportunities, or increased child survival, a focus on accessible, quality education is a critical response. The Report states that providing not just any education, but a quality education is key; that "poor quality is holding back learning even for those who make it to school" (UNESCO 2014:i). This is crucial to reaching MDG 4. UNESCO (2014) claims that if all women in these low and lower-middle income countries completed a secondary education, the under 5-mortality rate would fall by 49%. Governments and donors need to return the focus to education by ensuring that education is high quality and is reaching the girls and women who are bearing and raising the next generation.

A mother's education does not just work alone, past research shows that a mother's education works through many avenues to increase infant survival. The Center for Disease Control and Prevention claim that a woman's education level is the best predictor of how many children she will have and the age at which she will have these children (CDC 1997). An increase in education will also increase a women's age at childbirth which is important for infant survival. A policy focused on providing a proper primary and secondary education to young girls as well as older women in their reproductive years has implications for other interventions looked at in this research.

Although the social determinants provide the greatest reduction in infant mortality, variables in the other categories also have an independent impact on infant mortality. For healthcare, the major factor for survival in the neonatal period is prenatal care. The utilization of prenatal care is shown to increase the likelihood of delivering at a health center as a result of

complication recognition and increased medical understanding (Guliani et al. 2012). Schooling increases mother's understanding of specific diseases and complications, so they can take measures to prevent them. Mothers are able to recognize signs of illness early, seek advice, and act on it (UNESCO 2014). Educating a women young, not just in numbers and reading, but in proper hygiene, baby delivery and care will likely increase healthcare utilization through prenatal care and health center delivery. If a girl learns young that attending prenatal care will increase the chance her child will survive that crucial first month of life, a significant proportion of neonatal deaths would be avoided. This research shows that prenatal care cannot be a substitute for a mother's education. Funding and focus need to remain on education because the influence of healthcare interventions rely on it. They act together; as women are more educated they are able to utilize healthcare services more effectively and confidently (UNESCO 2014).

In terms of reproductive behavior, a healthy birth interval will increase an infant's chance of survival in that first month as well. Short intervals between pregnancies are connected to an increased risk of low birth weight, maternal death, and/or preterm delivery resulting in a safer first month, year, and beyond (Conde-Agudelo, 2006; Forste 1994). This intervention is not only effective, but the spread of information about healthy birth intervals is entirely free and is more likely to be followed properly when mothers are educated (UNESCO 2014). Understanding proper birth spacing should be a focus not only in prenatal care but in basic education. An education does not have to be limited to science, math and reading. A young boy and girl need to understand proper health practices that impact not only themselves but their posterity.

At the national level, HDI gives the governments, literally, the most bang for their buck. At their most basic form, HDI is related to maternal education. This suggests that not only government policy, but government spending should focus on investing in education (not just

health expenditures) to reduce infant mortality. If governments are able to redirect some of their spending to provide an education for women and children, to ensure that the teachers and curriculum work together to provide a quality education, and to teach proper healthcare practices, the MDG for child mortality may become more attainable for many countries.

The Director-General of UNESCO, in her letter for the EFA Global Monitoring Report 2013/2014 stated that, "we must ensure that all children and young people are learning the basics and that they have the opportunity to acquire the transferable skills needed to become global citizens" (UNESCO 2014:ii). This research suggests that those basic skills must include proper health, child delivery, and child care practices that will ensure infant survival. In order to reach MDG 4 it has to start with a commitment to educating girls. The Monitoring Report claims that "education's power to accelerate the achievement of wider goals needs to be much better recognized in the post-2015 framework" (UNESCO 2014:143). The reallocation of government and donor spending away from education and towards healthcare interventions is not the solution. The combination of prenatal care and maternal education will ensure the safest first year for a child.

As 2015 approaches and many countries are not on track to reach MDG 4, placing education at the heart of development policy agendas is the key to guaranteeing the survival of future generations. Education is a powerful way to improve people's health- and to make sure the benefits are passed on to future generations. This link has been replaced or overlooked in some countries by a primary focus on healthcare interventions. Although necessary, a sole focus on healthcare interventions is not sufficient to promote infant survival. Maternal education is also necessary to ensure that healthcare interventions are utilized, and that beyond 2015, reductions in infant mortality continue.

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APPENDIX

Country	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6	n
Bangladesh	1993-4	1996-7	1999-00	2004	2007	2011	38,706
Benin	1996	2001	2006				24,435
Bolivia	1994	1998	2003	2008			30,011
Burkina Faso	1993	1998	2003	2010			37,470
Cambodia	2000	2005	2010				25,356
Cameroon	1991	1998	2004	2011			25,524
Chad	1996-7	2004					13,043
Colombia	1990	1995	2000	2005	2010		45,939
Cote d'Ivoire	1994	1998-99	2011-12				13,766
Dominican Republic	1991	1996	1999	2002	2007		31,915
Egypt	1992	1995	2000	2005	2008		57,089
Ethiopia	2000	2005	2011				32,388
Ghana	1993	1998	2003	2008			12,338
Guinea	1999	2005					12,198
Haiti	1994-5	2000	2005-6	2012			23,511
India	1992-3	1998-9	2005-6				101,644
Indonesia	1991	1994	1997	2002-3	2007		86,199
Jordan	1990	1997	2002	2007			31,353
Kenya	1993	1998	2003	2008-9			21,674
Lesotho	2004	2009					7,696
Madagascar	1992	1997	2003-4	2008-9			26,817
Malawi	1992	2000	2004	2010			47,302
Mali	1995-6	2001	2006				33,366
Morocco	1992	2003-4					11,377
Mozambique	1997	2003	2011				25,550
Namibia	1992	2000	2006-7				13,073
Nepal	1996	2001	2006	2011			22,437
Nicaragua	1998	2001					15,440
Niger	1992	1998	2006				20,890
Nigeria	1990	1999	2003	2008			46,130
Pakistan	1990-1	2006-7					15,605
Peru	1991-2	1996	2000				40,608
Philippines	1993	1998	2003	2008			30,995
Rwanda	1992	2000	2005	2010			31,083
Senegal	1992-3	1997	2005	2010-11			36,287
Tanzania	1991-2	1996	1999	2004-5	2010		34,729
Uganda	1995	2000-1	2006	2011			29,116
Zambia	1992	1996	2001-2	2007			26,825
Zimbabwe	1994	1999	2005-6	2010-11			16,890
							N= 1,196,775

TABLES

Table 1
Descriptive statistics for factors measuring categories predictive of infant survival

Variables	Minimum	Maximum	Mean	S.D.	Correlation with time
Healthcare system					
Health center delivery	0	1	0.473	0.499	0.110
Prenatal Care	0	1	0.793	0.405	0.115
Social determinants					
Mom age at birth	10.33	49.833	29.559	6.620	-0.004
Urban	0	1	0.337	0.473	-0.033
Maternal education	0	4	1.422	1.423	0.031
Reproductive behavior					
Healthy birth interval	0	1	0.659	0.474	0.008
First birth	0	1	0.245	0.430	0.021
Male child	0	1	0.507	0.450	0.000
National context					
HDI	0	0.840	0.479	0.131	0.053
Health expenditures	0.1	10.5	5.169	1.775	0.394

Source: Demographic and Health Surveys

Table 2

Effects of categories predictive of infant survival on infant mortality with neonatal interactions (odds ratio)

Variables	Baseline	Healthcare system	Social determinants	Reproductive behavior	National context	Combined model
Base Line						
Period	0.974*	0.974*	0.974*	0.974*	0.974*	0.975*
Month 1	6.870*	6.731*	5.240*	6.270*	4.133*	4.068*
Year	0.946*	0.950*	0.949*	0.946*	0.951*	0.953*
Interaction	1.016*	1.016*	1.015*	1.016*	1.017*	1.014*
Healthcare system						
Health center delivery		0.719*				
Interaction		1.390*				
Prenatal care		0.687*				
Interaction		0.862*				
Social determinants						
Mom age at birth			0.994**			
Interaction			1.004*			
Urban			0.797*			
Interaction			1.131*			
Maternal education			0.785*			
Interaction			1.151*			
Reproductive behavior						
Healthy birth interval				0.866*		
Interaction				0.820*		
First birth				0.987		
Interaction				1.509*		
Male child				1.029**		
Interaction				1.256*		
National context						
HDI					0.095*	
Interaction					4.854*	
Health expenditures					1.016**	
Interaction					0.964*	
Combined model						
Prenatal care						0.796*
Interaction						0.866*
Maternal education						0.933*
Interaction						1.060**
Interaction prenatal care and maternal education						0.858*
Interaction						0.764**
Healthy birth interval						0.853*
Interaction						0.983
HDI						0.301*
Interaction						3.468*
Constant	0.007	0.011	0.011	0.008	0.016	0.017
Log likelihood(df)	-251625.48(7)	-250256.52(11)	-250125.32(13)	-251081.10(13)	-250918.57(11)	-249373.23(16)

Source: Demographic and Health Surveys

Note= Interactions are for neonatal period (1st month)

Note=All models control for region

Note= The combined model controls for first birth

N=9,562,883

*P=.000 **P<.05

Table 3
Variables within the four models and combined model influencing neonatal and infant (post-neonatal) mortality

Variables	Neonatal	Post-neonatal
Social determinants		
Mom age at birth	0.998	0.994
Urban	0.901	0.797
Maternal education	0.904	0.785
Healthcare system		
Health center delivery	0.999	0.719
Prenatal care	0.592	0.687
Reproductive behavior		
Healthy birth interval	0.710	0.866
First birth	1.489	0.987
Male child	1.292	1.029
National context		
HDI	0.458	0.095
Health expenditures	0.979	1.016
Combined model		
Prenatal care	0.689	0.796
Maternal education	0.989	0.933
Interaction prenatal care and maternal education	0.907	0.858
Healthy birth interval	0.751	0.764
HDI	1.043	0.301

Source: Demographic and Health Surveys
Note= All models control for region
Note= The combined model controls for first birth