THE HEALTH OF NATIONS:
THREE ESSAYS IN HEALTH ECONOMICS

A thesis presented by

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Abstract

Three essays form this thesis which addresses the effectiveness of interventions aimed at attaining two health Millennium Development Goals (MDG) set by the United Nations: a $2/3^{rds}$ reduction by 2015 of 1990 child mortality rates (MDG4) and $3/4^{th}$ reduction of 1990 maternal mortality rates by the same date (MDG5). The first chapter assesses the relative efficiency of 85 countries at using these interventions for the reduction of child and maternal mortality. It teases out the extent to which mortality reduction is a result of the interventions themselves as opposed to the context in which they are implemented. A three step procedure which includes Data Envelopment Analysis indicates that efficiency is mainly driven by context.

Chapter 2 addresses the association between the 2000-2008 rates of change of interventions and the rate of change of mortality. It uses finite mixture modeling to take account of the possibility that there may be underlying heterogeneity in the mortality reduction functions of the 32 sub-Saharan African countries studied. Results support this hypothesis and show that an intervention may exhibit increasing returns to scale in some countries and decreasing returns to scale in others.

Chapter 3 assesses the link between interventions and mortality rates and examines cost-minimizing scenarios for attaining MDG4 and MDG5 in 27 sub-Saharan African countries. Lagged data on interventions predicts mortality rates (by OLS) to take into account the potential reverse causality between the two. Results indicate that achieving MDG mortality targets at the least possible cost invariably requires very substantive increases in medical human resources, yet training physicians has not been the main objective of public health organizations. Furthermore, improving the context in which interventions are implemented - increasing female literacy or effectiveness of political stability- allows countries to reach mortality targets with substantially lower levels of interventions (including, much lower levels of physician density).

Sommaire

Trois essais forment la présente thèse qui porte sur l'efficacité des interventions liées aux deux objectifs du Millénaire pour le développement (OMD) établis par les Nations Unies et touchant à la santé: l'OMD4 (réduire de deux tiers, entre 1990 et 2015, la mortalité infantile) et l'OMD5 (réduire de trois quarts la mortalité maternelle).

Le premier chapitre traite de l'efficience de 85 pays dans leur utilisation des interventions pour fin de réduction de mortalité. Le travail identifie dans quelle mesure la réduction de mortalité est attribuable aux interventions elles-mêmes et non au contexte qui les entoure. Une approche en trois étapes, qui inclut l'analyse d'enveloppement des données, indique que la source principale de l'efficience est le contexte dans lequel les interventions sont exécutées.

Le deuxième chapitre porte sur le lien entre le taux de variation des interventions entre 2000 et 2008 et le taux de variation de mortalité observée durant la même période. La possibilité d'hétérogénéité dans la fonction de réduction de mortalité de 32 pays de l'Afrique sub-saharienne est prise en considération à l'aide d'un modèle de mélanges finis. Les résultats supportent cette hypothèse et indiquent qu'une intervention peut avoir des rendements d'échelle croissants dans un pays et des rendements d'échelle décroissants dans un autre.

Le troisième chapitre s'attarde sur le lien entre les interventions et le taux de mortalité, et examine plusieurs stratégies qui permettraient d'atteindre les OMD4 et OMD5 dans 27 pays d'Afrique sub-saharienne à moindres coûts. Des données sur les interventions, décalées de quelques années par rapport au taux de mortalité afin de prendre en considération la possibilité de causalité inverse, prédisent ce dernier à l'aide du principe des moindres carrés ordinaires. Une augmentation massive de ressources humaines médicales serait nécessaire afin d'atteindre

les OMD à moindres coûts bien que la formation de médecins n'est pas l'objectif principal des organismes œvrant en santé publique. De plus, l'amélioration du contexte qui entoure les interventions - taux d'alphabétisation des femmes ou stabilité politique - permettrait aux pays d'atteindre les OMD en utilisant moins de ressources, y compris moins de médecins.

Contents

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Introduction

In light of the poverty levels and mortality rates in the developing world, the United Nations launched a fifteen year international initiative in 2000- the Millennium Development Goals- aimed at addressing development related issues. Eight broad objectives characterize this international undertaking: 1) eradication of extreme poverty and hunger 2) ensuring universal primary education 3) promoting gender equality and empowering women 4) the reduction of child mortality 5) improvement of maternal health 6) combating HIV/AIDS, malaria and other diseases 7) ensuring environmental sustainability and 8) creating a global partnership for development. These goals are part of the Millennium Declaration adopted in 2000 after series of global conferences and summits on extreme poverty held in the 90's.

This thesis focuses explicitly on the two health Millennium Development Goals (MDGs) which relate to child and maternal health: MDG4 which targets a $2/3^{rds}$ reduction in the under-five mortality rate between 1990 and 2015 and MDG5 which established as its objective a 75% reduction in maternal mortality rate during that same period. International organizations such as UNICEF, the United Nations and the World Bank have promoted specific health interventions in order to achieve MDG mortality targets. For example, given the main causes of child mortality in developing countries, health interventions which address diarrheal related conditions (e.g. oral rehydration therapy; zinc supplementation) and pneumonia prevention and treatment are strongly encouraged. Similarly, since sepsis and postpartum hemorrhaging contribute greatly to maternal mortality, actions which address these issues (e.g. clean deliveries, oxytocin injections) are actively promoted by the public health international community.

When analysing the effect of interventions one cannot of course abstract from the context in which they are implemented. Broad environmental and institutional factors can either impede or enhance the effectiveness of interventions. For example, a country with weak political stability could have higher mortality rates due to indirect causes such as the inability to systematically sustain the provision of appropriate healthcare services during pregnancy. Other factors, such as education and literacy, are also known catalysts of health interventions. It is therefore important to include such factors when one is analysing the effectiveness of health MDG interventions.

It is surprising that, to date, the evaluation of the success of the interventions used to achieve the MDGs has largely been carried out by public health specialists and not by health economists. After all, the topic is highly pertinent to health economics as it requires an assessment of the efficiency and effectiveness of specific allocations of scarce health resources at generating desired health outcomes. Moreover, economists show strong interest in health status of populations since health affects labour market participation and productivity. Health and development are widely seen to be intricately linked, and so the health MDG topic should be particularly of interest to health economists whose work focuses on developing regions of the world. The three chapters of this thesis bring an economist's perspective to the examination of the impact of interventions on the attainment of the health MDG goals. The findings, which are grounded in econometric analysis, should provide useful guidance to policy makers.

The first chapter assesses the relative efficiency of health-MDG interventions designed to reduce under-5 and maternal mortality in 85 developing countries while taking into account the broad environmental and institutional factors which characterise the country-specific context in which the interventions are undertaken. The chapter distinguishes between two potential ways by which countries may differ in efficiency: 1) efficiency is driven by the interventions 2) efficiency is driven by the context in which interventions are implemented. If efficiency is driven by context then improvements - and deteriorations - in health outcomes are explained largely by the more favourable broad environmental and institutional factors rather than by the resources allocated to the health sector. Equally saliently, improvements in the overall context will lead to better health care outcomes, without requiring increased expenditure on interventions.

Following De Sousa da Conceiçao Sampaio et al. (2012) and Latruffe et al. (2008), a three stage process is used to identify the extent to which efficiency is due to interventions as opposed to context. In the first stage, a non-parametric technique- Data Envelopment Analysis (DEA) - uses health MDG interventions as inputs and mortality outcomes as outputs and estimates relative efficiency scores for each country. Since the method generates relative measures of efficiency, one has to first parse the data into similar subgroups in order to obtain results that can be meaningfully compared. To this effect, the data is first separated by World Bank income classification of countries: low-income countries (GNI per capita of $975 or less), lower-middle income countries (GNI per capita between $976 and $3,855) and upper-middle income countries (GNI per capita between $3,856 and $11,905).

For each mortality group and each income category, efficiency scores are subsequently regressed (Tobit regression) on a set of contextual factors (e.g. GNI, Private expenditure on health, political stability, share of income spent on food, literacy, child labor) to decompose the impact of both interventions and the contextual variables. The Tobit regression residuals represent the 'unexplained' portion of the efficiency score that is not dependent on country context. Therefore, the residuals represent the contribution of the actual interventions (net of country context) on the DEA score. The third step involves calculation of the share of DEA efficiency score attributable to the actual MDG interventions. This is calculated as the ratio of the Tobit regression residuals to the total DEA efficiency score.

Results indicate that the driving force behind relative efficiencies is indeed the national context in which interventions are implemented. Factors such as control of corruption, promotion of civil liberties and decreased private expenditures on health are some of the contextual elements that lead to higher efficiency of health interventions at reducing child and maternal mortality rates in developing countries.

The second chapter of the thesis examines the factors which are associated with neonatal, child and maternal mortality in 32 sub-Saharan African countries over the period 2000 to 2008. The chapter examines the extent to which changing levels of the 12 main UN interventions have influenced the rate of reduction of child and maternal mortality rates. Although the United Nations has not set a neonatal mortality target, that subgroup accounts for 40% of deaths of children under-five, and so is included in the analysis.

The literature review reveals a striking lack of consensus regarding the role played by interventions in the observed reduction in child and maternal mortality between 2000 and 2008. One potential explanation for the contradictory findings in both single-country and cross-country studies is that there may be underlying heterogeneity in the health production technology in sub-Saharan Africa. After all, Africa is the most genetically diverse region in the world, it has an extremely diverse pharmaceutical imprint and is subject to diseases caused by strains of varying virulence. For these three reasons the same mix of interventions could possibly have a different impact on mortality. To acknowledge that countries may have different health production functions (or different mortality reduction functions), a finite mixture model is used to endogenously group countries based on their unobserved heterogeneity. As a key objective of the analysis is to study how changes in interventions have resulted in changes in mortality rates, the chapter uses average annual rates of change (compound rates of change) of interventions and mortality rather than levels of interventions and mortality rates. This approach has the added benefit of drawing attention to the time dimension of the MDGs, i.e., to the fact that these objectives are to be attained by 2015.

Findings suggest that there may be underlying heterogeneity (at least locally) in the nature of the relationship between mortality and interventions across the region, regardless of whether one is interested in child or maternal mortality. Countries are consistently sorted into two groups. Although the methodology employed does not discriminate between alternative theories of the underlying reason for the heterogeneity, e.g., whether there are different health production functions in sub-Saharan Africa, or whether merely some countries are currently operating in different sections of the same health production function, from a practical point of view this does not lead to different policy guidance: in both cases, what is important is that the results suggest that a 'one size fits all' approach to implementing interventions is inappropriate. A given intervention or contextual factor may exhibit increasing returns to scale in some countries and decreasing returns in others. For example, for one group of countries female literacy shows increasing returns to scale in relation to neonatal mortality while government effectiveness shows decreasing returns. The inverse is true for the second group of countries. Similarly, factors associated with child mortality also differ across country groupings. Countries from one component are mainly characterized by high initial coverage of interventions and low initial mortality values, and in these countries there are strong diminishing returns to interventions: rapid expansion in coverage of interventions is not necessarily associated with significant changes in mortality rates, at the margin. In contrast, the second group of countries exhibits increasing returns to scale for most interventions (pneumonia treatment, malaria prevention immunization, and HIV). A similar pattern is found for interventions that reduce maternal mortality. Although most interventions show increasing returns to scale in both groups, female literacy and government effectiveness have different effects across the two country groupings. Additionally, family planning (captured here by avoided teen pregnancies) has a very strong impact on mortality reduction. For both groups of countries the economic significance of family planning overwhelms that of all the other variables, but is three times stronger in one group than in the other. It is important to keep in mind, however, that the results presented in this chapter are merely correlations, and that causal linkages are not established. The results nonetheless suggest that policies should tailor the interventions to the specific conditions in given countries or group of countries.

Strikingly, relatively little attention in the literature has been directed to identifying cost-minimizing strategies for determining which health interventions should be most actively promoted to attain the health MDGs. This issue is the concern of Chapter 3, which presents a series of cost-minimizing scenarios for attaining child and maternal Millennium Development Goals mortality targets through effective interventions. A second concern of this chapter is to take account of potential reverse causality with respect to the levels of interventions and the prevalence of particular causes of mortality. To this end, an OLS regression of mortality rates on lagged values of interventions is performed. The regression results suggest that several of the interventions do have significant effects on child and maternal mortality rates.

The results of the OLS regression are then used as the basis for analysis of a series of scenarios which identify cost minimizing combinations of interventions under a series of different hypotheses. A Kuhn-Tucker programming approach is used to estimate the coverage of interventions that are required to attain MDG4 and MDG5 at the least possible cost. Six distinct scenarios are presented in this simulation exercise: 1) effectiveness of variables is measured by the point estimate 2) scenario 1 is coupled with a 25% increase in female literacy 3) effectiveness is measured at the upper bound values of coefficients calculated with the OLS regression standard errors 4) effectiveness is measured at the lower bound values of coefficients calculated with the OLS regression standard errors 5) effectiveness is measured at the point estimate for all variables but political stability for which effectiveness is measured at its upper bound value 6) effectiveness is measured at the point estimate for all variables but political stability for which effectiveness is measured at its lower bound value.

A clear message emerges: child and maternal mortality targets will not be attained without dramatically increasing the supply of physicians. Increasing interventions such as immunization or family planning is simply not enough. This is important given that international organizations have been mainly focused on direct health interventions rather than long-terms investments in training physicians. Although training physicians is a timely and costly endeavour, it is by far the most cost-effective approach for reaching MDG mortality targets in sub-Saharan Africa. Additionally, results indicate that improving the broader social context in which interventions are implemented, for example by increasing female literacy or by increasing the effectiveness of political stability, that countries can reach the desired mortality targets with substantially lower levels of interventions, including much lower levels of physician density.

This thesis suggests actions that can be taken into consideration when addressing how to improve mortality rates in developing countries. Although worldwide child mortality has decreased by close to 50% between 1990 and 2010, more disaggregated data shows that some countries, especially those in sub-Saharan Africa , are far behind in their mortality targets (Suzuki (2013)). Similarly, worldwide there was a relatively slow reduction in maternal mortality, 34% between 1990 and 2008 WHO, UNICEF, UNFPA and The World Bank (2010). Although not all countries will reach the MDG targets, the fifteen year initiative can guide the post-2015 international development agenda and actions to be taken by UN member states to keep combatting child and maternal mortality in developing countries.

Chapter 1

The Relative Efficiency of Millennium Development Goal Health Interventions.

1.1 Introduction

In 2000, the 189 member states of the United Nations and dozens of international organizations agreed on eight Millennium Development Goals (MDG) which committed the signatories to concerted actions intended to decrease mortality rates and improve living standards in developing nations by 2015 (see Appendix A for detailed list). This chapter uses Data Envelopment Analysis to assess the relative efficiency of health-MDG interventions designed to reduce under-5 and maternal mortality in developing countries. It also seeks to tease out the extent to which the differences in mortality rates are a result of the interventions themselves as opposed to the context in which interventions are implemented (e.g. the level of political stability of the country or its control of corruption). It is important to emphasize that relative efficiency[1] represents a measure of relative performance and depicts the relatively optimal usage of inputs required for attaining specified outputs. The inputs used are health-MDG interventions and not monetary investments, consequently the term efficiency does not relate to financial efficiency. Relative performance is measured by a score obtained from cross-section data on developing countries so that a country with high mortality levels can be more efficient than one with low mortality. From a development perspective it is interesting to examine relative efficiency and survival rates because the two may not necessarily be aligned. A less efficient country with low mortality rate could actually benefit from high levels of inputs and a favorable context but could have achieved lower than realised mortality or the same mortality but with fewer resources.

[1]The term efficiency is used in the text to represent relative efficiency.

Evidence indicates that several developed countries have inefficient healthcare expenditures which generate low social returns. For example, in 2012 the United States spent 2.5 times more dollars per capita than the average amount spent by OECD countries. Its expenditure on healthcare as a share of GDP was one of the highest as was its absolute heath spending across any categories of care (e.g. ambulatory, hospitals, nursing homes, pharmaceuticals) (OECD (2013)). In the context of this study, these large investments in health are seen as inefficient because other countries, for example Norway, make much smaller expenditures on health and have lower mortality rates and rank higher on the development index (UNDP (2013)).

This chapter considers two sources for the observed efficiency of interventions: variation in the interventions themselves and variation in the context in which they are implemented. If efficiency is driven by context then improvement in health outcomes could be obtained by altering the broad environmental and institutional factors rather than by adding resources. This is particularly important in resource constrained settings where for the same coverage of interventions a country could generate better health outcomes. Adapted from De Sousa da Conceiçao Sampaio et al. (2012) and Latruffe et al. (2008), a three-stage process is performed to quantify the extent to which efficiency is attributable to interventions versus context. In the first stage, a non-parametric approach generates relative efficiency scores for each country. In the second stage, a linear regression nets out the effect of contextual variables on the efficiency score. In the third step, the extent to which intervention and context contribute to overall efficiency is calculated.

This paper differs from much of the existing literature on the efficiency of the healthcare sector in developing countries as it focuses on the contribution of the interventions undertaken in pursuit of the health MDGs. It does not evaluate the performance of healthcare systems as an entity, an approach that has been heavily criticized by public health specialists (details provided in Section 1.2).

This paper makes two contributions. Foremost, it is the first to use sets of internationally agreed coverage indicators as inputs to identify the relative efficiency of interventions aimed at reducing child and maternal mortality. These indicators represent the actual utilisation of health services which translate more directly into health outcomes than availability and accessibility of health resources (Tanahashi (1978)).

Secondly, this paper quantifies the extent to which broad environmental and institutional factors affect the difference in mortality rates observed across countries. In this way, we gain insight into the mechanisms which link survival rates and health interventions. The study tests whether elements that are outside of the control of the Ministry of Health, such as literacy rates or political stability, are crucial factors for lowering child and maternal mortality rates. Our findings indicate that the driving force behind relative efficiencies is indeed the national context in which interventions are implemented. Factors such as control of corruption, promotion of civil liberties and decreased private expenditures on health are some of the contextual elements that may lead to higher efficiency of health interventions to reduce child and maternal mortality rates in developing countries.

This work is organized as follows. Section 1.2 reviews papers which address efficiency of the health sector. Section 1.3 describes the methodology used. Section 1.4 describes the data. Section 1.5 presents and interprets the results. Section 1.6 contains a discussion of results, policy recommendations and concluding remarks.

1.2 Literature Review

The literature on healthcare efficiency is large and can be divided into two areas: 1) papers which focus on efficiency gains generated with respect to specific health conditions; and 2) papers which focus on efficiency gains generated by improvements of a health system as an entity. While efficiency in both cases refers to the ratio of outcomes to inputs, the focus of the efficiency measurement is either: 1) condition-specific; 2) systemic. The current study differs from these papers by measuring efficiency with respect to an outcome target.

Efficiency gains in healthcare attributable to the attention given to specific health conditions have been especially studied for conditions that have had increasing incidence and prevalence over the years (Dans et al. (2011); Miranda et al. (2008); Narayan et al. (2006)). For example, the burden on healthcare caused by the rise of chronic non-communicable diseases such as diabetes and cardiovascular disease, led to performance measurement studies of healthcare actions linked those clinical conditions (Kahn et al. (2008); Testi et al. (2013)). Efficiency studies indicate that, in favoring preventative measures today, health systems save money and lives in the future (Woolf (2009)). In these papers efficiency is viewed as the impact that a shift in the health agenda (towards preventative measures) has on health and healthcare.

Alternatively, efficiency is described as gains in health and/or alleviation of financial burden on healthcare obtained from a general set of healthcare inputs . This definition is mainly used in studies on efficiencies of health care systems. Efficiency defined in this manner is increasingly of interest for both developing and developed countries. With rising prices of commodities (including pharmaceuticals), it has become vital to be able to generate more outcomes with less inputs or at least more outcomes with the current set of inputs (OECD (2010)).

Several methods are used to evaluate the efficiency of a health system. For example, The World Health Report (2000) compares the efficiency of healthcare systems worldwide by creating a composite index of five key outcomes (health, child survival, responsiveness, responsiveness inequality and financial fairness)[2] that reflect the effectiveness of the system. This approach was heavily criticised by health economists and public health specialists as it presumes the same elements characterize healthcare systems in all the 191 countries studied (Coyne and Hilsenrath (2002); Nord (2002); Ollila and Koivusalo (2002); Pedersen (2002); Richardson et al. (2003); Williams (2001)). It is more reasonable to assume that countries have different health objectives, priorities and inputs. Furthermore, the use of identical exogenous weights assigned to components of the index of performance across all countries can be criticized (Navarro (2002)). Moreover, given the linearity of the index, countries which assign a very low value (or even zero score) to some of the components can have the same efficiency score as countries with average values for all components. The World Health Report (2000) uses these efficiency scores merely to rank countries, which by itself has little added value for policymakers.

A modification of the methodology used in The World Health Report (2000) is proposed by Lauer et al. (2004). Using the index components of the report as output variables, Lauer et al. undertake a data envelopment analysis[3] (DEA) to generate efficiency scores for the 191 countries of the study. The DEA algorithm assigns weights to each component for each country and generates relative efficiency scores for each country. The objective of their paper is to provide a ranking method of countries which takes into account their differences. This approach is an improvement on the one used by The World Health Report (2000) but it provides no indication to policymakers as to which factors should be promoted for greater efficiency. In other studies, DEA

[2]The five key outcomes of the composite index presented in The World Health Report 2000 are 1) health: disability-adjusted life year (DALY); 2) health inequality: child survival distribution by wealth index; 3) responsiveness: surveyed key informants; 4) responsiveness inequality: distribution of responsiveness across wealth quintiles; 5) financial fairness: household spending on health.

[3]DEA is explained in details in the Methodology section.

is occasionally used to rank various items (e.g. countries, hospitals, firms) based on their relative performance (Benneyan et al. (2007); Despotis (2005); Jacobs (2001)).

In order to provide information on sources of efficiency a two-stage analysis combining DEA and linear regression is often used in performance measurement of health and other sectors (Banker and Natarajan (2008); Cooper et al. (2006); Kao and Hwang (2008); Marschall and Flessa (2011); Sebastian and Hailemariam (2010); Yang (2006)). For example, Alexander et al. (2003) use data envelopment analysis of disability-adjusted life year outcomes (DALY) relative to health expenditure per capita to generate efficiency scores for 51 developing countries. This approach leads to endogenously determined weights on health expenditures for each country. Secondly, the estimated DEA scores are regressed on variables such as education level, nutrition indicators, health system accessibility measures and the burden of HIV. The second stage allows for the identification of factors that lead to better performance, rendering the procedure useful to policymakers.

An alternative methodology used for measurement efficiency in the health sector is stochastic frontier analysis (SFA) (Hollingsworth (2008); Rosko (2001)). SFA is a parametric measure of efficiency based on the assumption that the production frontier is influenced by technical inefficiency and random shocks (Aigner and Schmidt (1977)). It takes into account statistical noise and in this respect is advantageous over DEA. However, SFA, being a parametric model, requires prior knowledge of the functional form for health production. Additionally, it does not create a true upper bound limit on which efficiency scores can be compared as it uses conditional means to generate the frontier. Overall, the literature seems to indicate that choosing between DEA and SFA is more based on personal preferences than on actual advantages of one method over another (Hollingsworth and Street (2006)). This chapter uses the DEA approach because the health production function studied is not known.

Regardless of the methodology used, all the papers which evaluate the relative efficiencies of the health sector explicitly impose the researcher's notion of what should be valued as health objectives. In contrast, the inputs used in the analysis in this paper are the interventions that were implemented by the United Nations in all the countries analyzed, and the output measures are the agreed health MDGs.

1.3 Methodology

This chapter determines the relative ability of health interventions to attain observed child and maternal mortality rates observed in developing countries and seeks to ascertain whether improved health outcomes are attributable to either the best possible usage of health interventions or to the national context in which such interventions are implemented. In order to answer these questions a three-step procedure is used. Firstly, measures of health care performance (i.e. outcomes related to the specific MDGs under review) are required for each country. As mentioned in the literature review, one way of measuring health care performance is by creating a performance index based on exogenous weights to be assigned to each component of the index. As noted above, this is problematic on two bases: a) there is no theory that justifies separate countries using an identical set of exogenous weights for the various components; and b) there is no evidence on which to calibrate country-specific exogenous weights for each component. Consequently, this study proposes a method which assigns endogenously-determined weights to the performance index components which affect child or maternal mortality rates in 2008. The proposed methodology is data envelopment analysis (DEA).

DEA is a non-parametric linear programming technique which identifies relative (i.e. country specific) optimal efficiency scores for each observation (also called a decision making units, DMU). DEA scores represent a measure of technical efficiency since they are obtained from a output-input ratio and do not touch on the topic of allocation of inputs. It is important to reiterate that relative optimal scores are presented for each country as DEA represents each DMU in the 'best possible light' in terms of an optimization in relation to all other DMUs (Charnes et al. (1978)). There are several types of DEA models, not all of which are suited for studies in the health sector. For instance, an "input orientated" DEA seeks to minimize inputs for a given level of output but fails to address the objective of health outcome maximization. For this reason, an "output oriented" DEA is the norm in the health sector which maximizes health outcomes given a set of inputs (Hollingsworth (2003); Hollingsworth et al. (1999))). The output oriented DEA (hereafter referred to as "DEA" without a qualifier) determines efficiency scores for each DMU by maximizing the ratio of the sum of endogenously weighted outputs to the sum of endogenously weighted inputs. Endogenously determined weights for inputs and outputs for an observation are selected to give the highest efficiency score possible to that observation relative to any other set of weights that are applied equally to all other DMUs. Additionally, because there is no reason to assume that changes in inputs cause proportional changes in outputs (any given intervention can decrease the *probability* of mortality and does so at a different rate), the DEA method uses variable returns to scale in the measurement of relative efficiency.

For example, for any country (k) the maximization problem assigns weights across countries for each output and set of inputs such that the selected weights maximize the country (k)'s DEA score (θ_k) relative to any other set of weights used equally across all other countries *ceteris paribus*. Weights are selected such that they show a country in the best possible light (highest efficiency score).

$$\theta_k = \max_{\mu,\nu} \quad \frac{\mu * output_k}{\sum_{i=1}^{I} \nu_i * inputs_{ik}}$$

$subject\,to_{\mu,\nu}$

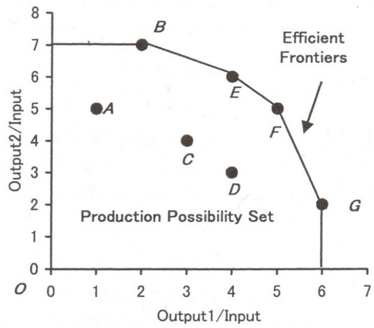
$$\frac{\mu * output_j}{\sum_{i=1}^{I} \nu_i * inputs_{ij}} \leq 1 \qquad \forall\, M countries \tag{1.1}$$

$$\mu > 0 \tag{1.2}$$

$$\nu_1, \nu_2, ..., \nu_I > 0 \tag{1.3}$$

where θ_k is the DEA efficiency score of country k; country indices are j, k ϵ M; and input indices (i) are ϵ {1,...,I}; μ and ν are output and input weights respectively. In the context of this study, the output measure is either the child or maternal survival rate (per 1,000 and 100,000 respectively) and the inputs are health interventions which target these sub-population (e.g. basic child immunization; malarial preventative measures such as mosquito nets, antenatal care, antiretroviral drugs for combating HIV/AIDS).

As noted above, the efficiency maximization problem generates relative efficiency scores θ_k. The score takes values on the unit interval [0, 1] where a score of zero represents a completely inefficient (relative) DMU and a score of one represents a fully efficient (relative) DMU. As DEA scores are relative measures, the set of efficient DMUs form an efficiency frontier against which all other DMUs can be assessed in terms of the degree of their (relative) efficiency. As illustrated below, the efficiency frontier (i.e. production possibility set) is empirically constructed and represents the possible frontier given endogenously weighted inputs and outputs for each DMU.



Source: Cooper et al. (2006)

The DEA efficiency scores are influenced by "outlier" observations so it is important to ensure that the data does not contain 'unreasonable' observations which drive the efficiency frontier outward and identify otherwise reasonably efficient DMUs as inefficient. Wilson (1993) proposed a technique which identifies outliers in nonparametric settings. A modified Andrews and Pregibon statistic determines the extent to which the log-ratio of output to input affects the variation of relative efficiency scores. This test sequentially identifies which DMU inflates the variation of efficiency scores such that it expands the efficiency frontier. The exercise is repeated until there are no DMUs which drag out the efficiency frontier.

Once efficiency scores are obtained for each country, the second step consists of decomposing the impact of both interventions and country context and 'netting out' the effect of the context in which interventions were implemented. For this purpose, the efficiency scores are regressed on a set of contextual variables (e.g. gross national income per capita, private expenditure on health per capita, worldwide governance indicators, poverty and nutrition indicators). The methodology commonly used in DEA second stage analysis involves Tobit regression of efficiency scores on environmental and institutional factors (Marschall and Flessa (2011); Milliken et al. (2011); Yang (2006)). The regression used here is:

$$\theta_k = \beta_0 + \beta_1\, context_{1,k} + \beta_2 context_{2,k} + ... + \beta_n context_{n,k} + \varepsilon_k \tag{1.4}$$

The Tobit regression is used because the DEA score (dependent variable) lies on the unit interval and is censored at one (Cooper et al. (2011)).[4] If only the first two steps are performed, namely the estimation of the efficiency scores and subsequent Tobit regression, then one is unable to answer the main question raised by this paper regarding the portion of the relative efficiency score that is attributable to interventions. The third stage uses the Tobit regression residuals which represent the 'unexplained' portion of the efficiency score that is not dependent on country context. Therefore, the residuals represent the contribution of the actual interventions (net of country context) on the DEA score. This is calculated as the ratio of the Tobit regression residuals to the total DEA efficiency score (Ray (2004)).

In order to obtain reliable results relevant to policy makers, it is important to group countries based on some common dimension (Charnes et al. (1981)). A vast literature groups countries by income level so this approach is implemented using income groupings as defined by the World Bank.[5] Consequently, three separate DEA are performed to assess the efficiency of interventions aimed at each of: a) child survival and b) maternal survival for country groupings involving:
1) low income countries; 2) lower-middle income countries; and 3) upper-middle income countries. These separate DEA analysis ensure that countries are more homogeneous (in terms of income)

[4]The Tobit regression is preferred to other methods such as OLS because of the large number of DMUs with a score of one (Cooper et al. (2011)).

[5]The three World Bank income groupings used in this chapter are: 1) low income countries: GNI per capita of \$975 or less 2) lower-middle income countries: GNI per capita between \$976 and \$3,855 3) upper-middle income countries: GNI per capita between \$3,856 and \$11,905.

than if all countries were pooled together. This allows greater likelihood for country context to be differentiated in a manner that does not confound differences in country context (e.g. political/social environment) with differences in country income level.[6] If all countries are grouped together, certain very well performing countries may act as outliers compared to the less efficient ones in the group. It is more meaningful, to policy makers, to compare differential efficiency of MDG health interventions among relatively income-homogeneous countries. Outliers may pull the efficiency frontier outwards and indicate that some countries are not fully efficient when they actually are highly efficient at their income level. Consequently, efficiency scores can lose their policy relevance (Charnes et al. (1981)).

1.4 Variables and Data Sources

In 2000, the United Nations created a list of eight Millennium Development Goals to be attained by 2015. Two of these focussed specifically on the problem of child mortality (MDG4) and maternal mortality (MDG 5) in the developing world. In order to meet these objectives, specific health interventions were promoted through the MDG initiative. These interventions dictate the choice of inputs used in this study's DEA. Since interventions are implemented in a given context, broad environmental and institutional factors form the variables used in the second stage of this study. There is, however, no single database that has all of the variables required for this study, and so it is necessary to piece together a dataset from various international sources. To ensure comparability of data, any variable used in this study has to be collected by the same agency or organization across all countries included in the project. The following sections describe the selection of countries for the study as well as the selection of outputs, inputs and independent variables necessary for this research.

[6]Classification by income grouping was preferred to other grouping methods such as the human development index (HDI) classes because of the ubiquitous usage of income grouping in performance measurement and because HDI is a composite index formed of several of the variables used in the second stage.

1.4.1 Selection of Countries

Data required for this study is not readily available or collected on an annual basis. The dataset is for 2008 and includes 108 developing and developed countries. Countries were assigned by income groupings defined by the World Bank. After elimination of countries which fall outside of the range of income studied in this chapter as well as the deletion of outliers the analysis of child survival includes 29 low-income countries, 36 lower-middle income countries and 20 upper-middle income countries (see Table 1.1). Similarly, the study of maternal survival examines 26 low-income countries, 29 lower-middle countries and 27 upper-middle income countries.

1.4.2 DEA Outputs

The child mortality rate is defined as the number of children who die before reaching five years of age per 1,000 children. The child survival rate is the inverse transform of the child mortality rate. Similarly, the maternal mortality rate is defined as the number of women who die during pregnancy, per 100,000 live births, and the maternal survival rate is, again, its simple inverse transform. Following the method of Afonso and St. Aubyn (2006), mortality rates are transformed into child and maternal survival rates defined as:

$$CSR = (1,000 - U5MR) \div U5MR \tag{1.5}$$

$$MSR = (100,000 - MMR) \div MMR \tag{1.6}$$

where CSR is the child survival rate, $U5MR$ is the under-5 mortality rate, MSR is the maternal survival rate and MMR is the maternal mortality rate. This approach takes into account the scaling issues that arise when survival rates are expressed in terms of survival per 1,000 or 100,000 (for child and maternal survival respectively).

1.4.3 DEA Inputs

The selected health interventions to achieve MDG 4 and MDG5 were identified by analysis of the main clinical causes of child and maternal mortality. The DEA uses these health MDG interventions as inputs in the production of health outcomes (i.e. survival rates). As shown in Tables 1.2 and 1.3 , the main policies for the reduction of child and maternal mortality can be grouped into two categories: a) density of utilization and effective utilization of (skilled) medical personnel; and b) preventative, antenatal and perinatal care measures. Child survival (MDG4) interventions include: passive and active immunization[7]; antiretroviral drugs to prevent mother-to-child transmission of HIV/AIDS during pregnancy; mosquito nets for prevention of malaria; vitamin A supplementation for healthy child development; antenatal care; exclusive breastfeeding; and density and utilization of medical personnel (e.g. skilled birth attendants, nurses, physicians). It is important to note that the data presented are not provider specific. The data do not just address the coverage of interventions attributed to UN agencies and their counterparts but rather to usage of an intervention regardless of the provider (e.g UN and its counterparts, government, non-governmental organizations).

Correlation scores of MDG4 interventions shown in Table 1.4 indicate that BCG, DPT3, Polio, MCV vaccines are strongly correlated between them with correlation values that range from 0.705 to 0.972 for low income countries. High correlation between vaccination variables is a characteristic of all three income groups studies. This is not surprising given that these vaccinations are often given concurrently or are part of the same vaccination campaign. Table 1.5 indicates that MCV vaccination and DPT3 have very similar descriptive statistics and that mean values of DPT3, polio and MCV vaccination coverage increase with income category: 78.87%, 78.07% and 78.33% for low-income countries, 85.53%, 85.28% and 84.08% for lower-middle income countries and 87.70% 88.43% and 88.27% for upper-middle income countries. Similarly,

[7]The term immunization includes vaccination for BCG, DPT3, Polio, MCV, Hib3 and tetanus.

the percentage of institutional deliveries is more highly correlated with the percentage of births assisted by a skilled birth attendant (SBA) than the density of nurses and midwives. The correlation is decreasing with country income grouping while the mean values are increasing with income grouping (45.57%, 50.93% and 11.85%; 67.48%, 72.30% and 18.40% and 94.37%, 95.93% and 31.87% for low income, lower-middle income and upper-middle income countries respectively).

The DEA efficiency score for child survival is generated by an algorithm from this equation:

$$\begin{aligned} CSR = f(&Immunization,\ antiretroviral\,therapy\,for\,infants,\ preventative\,measure\,for\\ &malaria,\ vitamin\,A\,supplementation,\ antenatal\,care,\ exclusive\,breastfeeding,\\ &usage\,of\ skilled\,medical\,personnel,\ usage\,of\,medical\,institutions,\\ &density\,of\,medical\,personnel\,(nurses\,\&\,midwives)) \end{aligned} \tag{1.7}$$

Maternal survival (MDG5) interventions include: family planning; antenatal care; antiretroviral drugs for HIV/AIDS; prevention of malaria; coverage of institutional deliveries; and availability and utilization of medical personnel. Table 1.6 indicates a negative correlation between physician density and skilled birth attendants in low income countries only. This implies a possible substitution effect between these two health resources in low income settings. Additionally, correlations between met family planning and skilled birth attendants or institutional deliveries is increasing with income category.

Descriptive statistics shown in Table 1.7 indicate that the mean values of all interventions with the exception of malaria prevention are increasing with country income groupings. It is not surprising that coverage of bednets for malaria prevention is decreasing with income, since malaria is much less of a concern in the richer countries analysed in this chapter.

The DEA efficiency score for maternal survival is generated by an algorithm from this equation:

$$\begin{aligned} MSR = f(\,&antiretroviral\,therapy,\ preventative\,measure\,for\,malaria^{8},\ antenatal\,care,\\ &usage\,of\ skilled\,medical\,personnel,\ usage\,of\,medical\,institutions,\\ &density\,of\,medical\,personnel\,(nurses\,\&\,midwives;\ physicians),\,family\,planning) \end{aligned} \tag{1.8}$$

1.4.4 Tobit Regression: Independent Variables

It is reasonable to assume that the country context in which interventions are implemented can promote or impede their efficiency. Seminal frameworks for the study of child and maternal mortality were proposed by Mosley and Chen (1984) and McCarthy and Maine (1992). Both of these frameworks show that broad environmental and institutional factors have an impact on health outcomes. Additionally, a large body of literature acknowledges the validity of a social determinants of health model proposed by Dahlgren and Whitehead (1993) that includes factors such as: education and literacy; gender; the built environment; and unemployment (Raphael (2004); Dunn and Dyck (2000); Kunitz (2007); PHAC (2008); Günther and Günther (2011)).

Moreover, according to the Grossman model, health is as a capital stock that depreciates with time and that is, in part, *produced* by investing time and consuming health services. Health is also influenced by factors that are outside of the control of health systems and is conditional on education (Grossman (1972); Nocera and Zweifel (1998)). As per Mullahy (2010), the Grossman model of health of individuals is extended here to studies on population health.

All the aforementioned factors shape the country context in which health interventions are implemented and are therefore likely to affect their efficiency. This study includes country

[8] Data on preventative measures for malaria used by pregnant women is not available. As per the methodology used in several papers, data on children sleeping under a bed net is used as a proxy.

contextual variables on: economic situation (e.g. GNI); expenditures on health (e.g. private expenditures on health); governance indicators (e.g. political stability and absence of violence, rule of law and presence of elections); poverty indicators (e.g. share of income spent on food[9]); inequality indicator (e.g. percentage of urban population); gender related indicators (e.g. female literacy); measures of child protection (e.g. failed child protection can be measured by child labor indicators); and ethnic diversity. Additionally, I acknowledge the regional differences in efficiency (and effectiveness) noted in the literature and control for them with dummy variables for sub-Saharan Africa and the Americas and the Caribbeans. All these contextual variables are used in the second stage Tobit regression of efficiency scores. Table 1.8 lists these independent variables and their sources.

The Tobit regression for child mortality is :

$$\begin{aligned}\theta = f(&SSA,\ GNI,\ Private\ expenditure\ on\ health,\ political\ stability,\ elections,\ rule\ of\ law,\\ &share\ of\ income\ spent\ on\ food,\ literacy,\ MMR,\ child\ labor^{10},\ ethnic\ diversity)\end{aligned} \tag{1.9}$$

The Tobit regression for maternal mortality is:

$$\begin{aligned}\theta = f(&SSA^{11},\ GNI,\ Private\ expenditure\ on\ health,\ political\ stability,\ elections,\\ &control\ of\ corruption,\ share\ of\ income\ spent\ on\ food,\ literacy,\ ethnic\ diversity)\end{aligned} \tag{1.10}$$

There is a lack of consensus in the public health literature regarding the expected (a priori) signs of several of these contextual variables. For example, in countries where even basic care is subject to private payments (to either public or private healthcare providers), poor households may incur catastrophic expenditures when paying for medical care or may decide not to seek

[9] Share of income spent on food is preferred to a measure of poverty such as headcount poverty ratio as it captures simultaneously the effect of poverty and nutrition and therefore allows one to use a smaller number of independent variables in the Tobit regression.

[10] Child labor is a factor that is only relevant in low income countries.

[11] For upper-middle income countries, the SSA variable in the Tobit regression is replaced by the Americas and the Caribbeans region.

medical attention. In the latter situation, private expenditures on health decrease the efficiency of steps taken by public healthcare systems to decrease child or maternal mortality (Ke Xu et al. (2005)). Conversely, it has been argued that out-of-pocket expenditures on health care can alleviate pressures on the public sector, especially in middle income countries where the private provision of health may generate gains in efficiency, responsiveness and quality (Preker et al. (2000); Bhattacharyya et al. (2010)). The sign of the poverty indicator (i.e. share of consumption expenditures allocated to food) can also be positive or negative. In countries where a large proportion of the population has an average daily income of less than \$1.25, food constitutes a large share of consumption expenditure. This could indicate that a person's minimum nutrition needs are met due to the money allocated to food consumption. However, the recommended daily caloric intake or nutrition quality may still be subpar despite the (relatively large) financial investment; one can spend more on empty calories to suppress hunger. Stability, rule of law and tenure of elections can also increase or decrease efficiency. On the one hand, clarity, transparency and enforceability of tax effectiveness and legislation may increase the effectiveness of all public programs (including health care) and therefore increase efficiency of the MDG intervention. However, the bureaucratic red tape behind these processes may slow down the implementation of policies. Elections may generate spending to increase the probability of being reelected; which can be either efficient or inefficient. Similarity, ethnic diversity can be a signal of the influx of foreigners from adjacent fragile states so that MDG interventions may not be able to cope with such unplanned population growth and ethnic diversity. The variable can also represent the multiple tribal or ethnic divisions that affect efficiency through their impact on communications. Conversely, knowledge sharing through the influx of foreigners and melding of cultures may lead to an increase in health care efficiency. Another variable for which the estimated sign is uncertain is geographic location. Certain regions have proven to be a challenge for development programs proposed by various international organizations (e.g. sub-Saharan Africa (SSA)). Conversely, in the Americas and the Caribbeans (TAC) some countries have become leaders in health care system innovations (e.g.

Cuba) while other have stagnated. Based on the information provided above several contextual variables were included in the Tobit regression.

1.5 Results

Results are displayed in the Tables 1.9 to 1.24 in section 1.7. Table 1.9 shows information on child survival rates and DEA efficiency scores for low-income countries. Data are ordered by descending order of efficiency. Whenever efficiency scores are equal between two countries the data are sorted by descending survival rate and alphabetical order. Table 1.10 shows the results of the regression of efficiency scores on a set of contextual factors. Table 1.11 shows the decomposition of the results in terms of the contribution of child-health interventions and contextual factors. Tables 1.12, 1.13 and 1.14 present comparable results for in lower-middle income countries while Table 1.15 shows DEA results for the upper-middle income countries.[12] Tables 1.16, 1.17 and 1.18 show efficiency scores, Tobit regression results and sources of efficiency for maternal mortality studies in low income countries. Tables 1.19, 1.20 and 1.21 present comparable results for lower-middle income countries while Tables 1.22, 1.23 and 1.24 do the same for upper-middle countries.

1.5.1 MDG4 Low-Income Countries

The DEA efficiency scores shown in Table 1.9 show that twelve out of 29 countries (Bangladesh, Comoros, Eritrea, Ethiopia, Iraq, Kyrgyzstan, Madagascar, Nepal, Niger, Tajikistan, Uzbekistan, Zimbabwe) lie on the efficiency frontier.[13] It is not surprising to see that a large

[12]High homogeneity of efficiency scores prevented performing Tobit regressions for child survival for the upper income group.

[13]For both mortality groups and all income groups, after the deletion of outliers, the results remain robust to the omission of DMUs (e.g. Burkina Faso, Burundi, Kyrgyzstan and Tajikistan) or the choice of DEA inputs (e.g. instead of employing all immunizations, I use only one to represent all vaccines).

number of countries form the efficiency frontier. After all, the DEA score does not represent absolute efficiency but rather a relative one. Given the inputs used by other countries and their observed survival rates, twelve countries are relatively efficient in the context of this study. Additionally, of the twelve fully efficient low-income countries more than half also have the highest survival rates. It is interesting to observe, however, that some inefficient countries have lower mortality rates than those that are part of the efficiency frontier. Therefore, being highly efficient (slightly less than fully efficient) in terms of interventions does not translate directly into low mortality rates (e.g. Madagascar: survival rank 15, DEA rank 1; Ethiopia: survival rank 17, DEA rank 1; Niger: survival rank 23, DEA rank 1). Conversely, having a poor efficiency rank does not necessarily mean a poor mortality ranking (Ghana: survival rank 8, DEA rank 24, Malawi: survival rank 12, DEA rank: 25, Cambodia survival rank: 9, DEA rank 26). This implies that one can be efficient in terms of interventions even though there are outside factors which cause mortality to remain high.

A Tobit regression of efficiency scores on contextual factors is the next step towards identifying the source of efficiency. Regression results shown in Table 1.10 indicate that, all else being equal, being part of sub- Saharan Africa decreases the efficiency scores relative to other countries in the low income group. Similarly, ethnic diversity, represented by immigrant languages spoken as a first language, also decreases efficiency in a statistically significant manner. *Ceteris paribus* an increase in GNI per capita increases the efficiency score while an increase in private expenditure on health decreases efficiency scores in the low income group. An increase in the value of governance indicators (stability and absence of violence, presence of elections or the rule of law) decreases efficiency. As mentioned earlier, the bureaucratic red tape behind these processes or lack of individual freedoms may be the cause of these reductions in efficiency. An increase in the share of income spent on food, which captures information on poverty and nutrition, leads to a decrease in efficiency score. Gender related concerns, captured here by female literacy and maternal mortality, are jointly significant whereas female literacy is not individually significant. As expected maternal mortality reduces efficiency scores.[14]

DEA efficiency scores and residuals generated by the Tobit regression are used in the third stage to determine the driving force behind efficiency. The last column of table 1.11 shows that, for countries that are fully efficient or very close to being fully efficient, efficiency is driven by factors that are outside of the control of the healthcare system. Only a few countries, all part of sub-Saharan Africa, exhibited efficiency scores where health interventions accounted for a portion (but always less than 50%) of the efficiency score (Togo, Guinea-Bissau, Mali, Uganda, Mozambique, C.A.R., Tanzania and Ghana). The importance of broad environmental and institutional factors is further supported by efficiency results of four specific countries (Cambodia, Malawi, Gambia and Rwanda). Indeed, the Tobit regression results (contextual variables) indicate that the efficiency of these countries is much higher than suggested by the DEA scores (interventions).

1.5.2 MDG4 Lower-Middle Income Countries

Efficiency scores and survival rates values and ranking are presented in Table 1.12. More than 65% of the countries in this group are found to be on the efficiency frontier (Viet Nam, Sri Lanka, Syrian Arab Republic, Republic of Moldova, El Salvador, Jordan, China, Tunisia, Armenia, Egypt, Ecuador, Cape Verde, Georgia, Morocco, Solomon Islands, Indonesia, Mongolia, India, Yemen, Lesotho, Bhutan, Pakistan, Djibouti, Sudan and Mauritania). On the one hand, we see that the top 10 countries with the highest survival rates are part of the fully efficient group, while on the other the bottom 30 percent of countries with highest mortality are also fully efficient. Half of the inefficient countries have also the highest mortality rates. A few countries (Nicaragua, Paraguay and Honduras) are within the top 30 to 45 percent of lower mortality countries. As in the previous

[14] Appendix B indicates that Tobit regression results are robust to various specifications (e.g using the natural log of GNI, including the percentage of urban population as an independent variable to measure inequality).

section, DEA scores indicate that being highly efficient in terms of health interventions does not translate directly into lower mortality rates. Table 1.13 shows the results of the Tobit regression of efficiency scores for lower-middle income.[15] All things being equal, an increase in GNI increases the efficiency score in a statistically significant manner. Rule of law and share of income spent on food also have a positive significant effect. Conversely, stability, maternal mortality and linguistic diversity all decrease efficiency in a statistically significant manner. The remaining variables are not individually significant but are jointly significant at a 1 percent confidence level. The residuals of the Tobit regression and efficiency scores are used to quantify the extent to which efficiency is driven by interventions as opposed to context.

As shown in Table 1.14, efficiency is again driven by contextual factors which account for 100% of the efficiency scores for all countries. Only in four countries (Mauritania, Congo, Paraguay and Cameroon) do interventions play a part in the observed efficiency. Moreover, the importance of netting out the influence of contextual variables on efficiency scores is highlighted by the fact that the DEA underestimates the actual efficiency in five countries (Honduras, Zambia, Nicaragua, Guyana and Swaziland).

1.5.3 MDG4 Upper-Middle Income Countries

The upper-middle income group consists of only 20 countries. The sample is small and very homogeneous. DEA scores indicate that 18 of out the 20 countries are fully efficient or borderline efficient (Table 1.15). The lack of variability in the efficiency score renders the Tobit regression impossible. An alternative parsing of the data by income was attempted to capture the efficiency of interventions in "higher" income countries. When the dataset is divided by income tier (instead

[15]The parsimonious Tobit regression does not contain the percentage of urban population as a regressor because the latter is not statistically significant. Appendix C shows that results are robust to various specifications (e.g. natural log of GNI, percentage of urban population).

of by World Bank income grouping) the same problem arises for the upper income group. Hence, for child survival, the driving force of efficiency could not be identified for the richest countries of this dataset.

1.5.4 MDG5 Low-Income Countries

Efficiency scores shown in Table 1.16 indicate that half of the countries form the efficiency frontier (Eritrea, Cambodia, Bangladesh, Comoros, Togo, Nepal, Uganda, Madagascar, Ethiopia, Burkina Faso, Zimbabwe, Niger and Burundi). Of these 13 countries, seven also are in the top ten rank on survival while four are in the lowest survival rate quartile. The efficient group contains countries that are in the lowest survival rate quartile. This inconsistency between survival and efficiency ranking is also observed for inefficient countries. For example, Paraguay and Bolivia are in the lowest efficiency quartile but are in the highest survival rate quartiles, reinforcing the earlier observation that efficiency rankings and survival rate rankings are not necessarily aligned. A country can use the inputs it has in an efficient way, however the quality and quantity of inputs as well external factors may cause it to have high mortality rates.

Table 1.17 presents the Tobit regressions of the efficiency scores for the low-income group. All things being equal, an increase in GNI is associated with a higher efficiency score. The results indicate that being part of sub-Saharan Africa creates lower efficiency scores. Similarly, ethnic diversity also leads to lower efficiency. Conversely, control of corruption increases efficiency.[16]

The decomposition of sources of efficiency (interventions and context) is shown in Table 1.18. Results indicate that for fully efficient countries are mainly determined by contextual variables.

[16]As shown in Appendix D, Tobit regression results are robust to usage of GNI or natural log of GNI. Furthermore, the inclusion or omission of percentage of urban population as an independent variable does not alter the relative magnitude or the statistical significance status of other variables.

Broad environmental and institutional factors account for 70% to 100% of the efficiency value. Interventions account for efficiency scores of only six countries (Philippines , Viet Nam, Indonesia, Côte d'Ivoire, Honduras and Paraguay) but even then they account for less than 50% of the score. Moreover, the importance of contextual factors is further proven by the fact that DEA underestimates the efficiency of several countries.

1.5.5 MDG5 Lower-Middle Income Countries

Efficiency scores reported in Table 1.19 show that the set of efficient countries is formed of two types of countries: 1). countries which have the highest survival ranking 2). countries which are in the lowest survival rate quartile. This is consistent with the fact that efficiency in interventions is not directly linked to levels of survival.

A regression of efficiency scores on contextual variables shows that efficiency increases with GNI per capita, control of corruption and the share of income spent on food (Table 1.20). Conversely, the presence of elections, private expenditure on health and being part of SSA all decrease efficiency.[17] The decomposition of sources of efficiency shown in Table 1.21 indicates that, for twelve countries, efficiency is solely driven by contextual variables. Additionally, interventions affect efficiency in only six of the 29 countries (Philippines, Viet Nam, Indonesia, Côte d'Ivoire, Honduras and Paraguay) and only account for 1% to 30%.

1.5.6 MDG5 Upper-Middle Income Countries

The efficiency scores shown in Table 1.22 indicate that twelve countries form the efficiency frontier (Serbia, Bosnia and Herzegovina, Macedonia, Chile, Lebanon, Uruguay, Malaysia, Costa

[17] Appendix E indicates that results are robust to various specifications (e.g. inclusion of natural log of GNI, percentage of urban population).

Rica, Thailand, Argentina, Colombia and Namibia). This group of efficient countries include those that are in the top ten ranking on survival rates as well as those that are part of the second quartile of survival rates. This reflects the idea that a country with high mortality rates can use inputs efficiently when one compares its inputs to the inputs usage of countries with better health outcomes. The same conclusion can be drawn from inefficient countries. For example, Gabon is in the first survival quartile (and has the lowest survival rate of the sample) and ranks 13^{th} on the efficiency ranking while Belarus is in the 4^{th} survival quartile yet it ranks 23^{rd} on the efficiency score.

Unlike in the study of child survival in upper-middle income countries, there is sufficient variability in contextual and dependent variables to successfully run a Tobit regression. Table 1.23 shows that efficiency is lowered when a country is part the Americas and the Caribbean group. Additionally, private expenditure on health, political stability and ethnic diversity lower efficiency. The only factors that lead to higher efficiency are GNI per capita and control of corruption.[18]

From the Tobit regression one finds that efficiency is driven by contextual factors. From Table 1.24 one sees that for the majority of countries which form the efficiency frontier, contextual factors account for the entire efficiency score. Moreover for countries for which interventions affect efficiency, context is responsible for more than 50% of the score; interventions account for 1% to 33% of the efficiency value. One element that distinguishes these results from those of other income groups is the fact that interventions affect efficiency only in countries that are efficient or almost fully efficient (DEA scores between 0.9992 and 1).

[18]Appendix F shows that Tobit regression results are robust to usage of the natural log of GNI and inclusion of percentage of urban population as regressors.

1.6 Discussion, Policy Recommendations and Concluding Remarks

This chapter assesses the *relative* efficiency of health-MDG interventions designed to reduce mortality in developing countries. The main objective is to determine the extent to which efficiency is driven by intervention as opposed to the context in which they are implemented. Although, there exist a large body of literature on the efficiency of healthcare, papers usually study efficiency of actions taken to combat a specific health conditions (e.g. efficiency of interventions for reducing the incidence of diabetes) or efficiency of health care systems. This chapter builds on the strengths of these studies of efficiency and performs an efficiency analysis of Millennium Development Goals health *interventions* aimed at reducing child and maternal mortality.

The first finding of this chapter is that efficiency rankings do not follow survival rate rankings, irrespective of the income level of the countries under study. A country can have higher mortality rates, given its contextual environment, and use the little inputs it has very efficiently. Conversely, a country with low mortality rates can be inefficient which would indicate that it either could generate better health outcomes with the same levels of inputs or use less inputs to generate the observed outcomes.

Another important finding is that for all country groupings, for child and maternal survival, contextual factors are the driving force behind the estimated efficiencies. The effect of health interventions should therefore not be assessed outside of the environmental context in which they are implemented. Indeed, for several countries context is the only source of efficiency. For others, where efficiency is also affected by interventions, the effect of the latter is always less than the effect of contextual factors. This finding suggests that policy prescriptions based on studies that focus solely on interventions are potentially missing information that could generate better outcomes.

Results also indicate that although most countries that are fully or almost fully efficient at addressing child survival are as efficient at addressing maternal survival, there are some exceptions. For example, in low income countries, Cambodia, is efficient at dealing with maternal mortality but fails to achieve that status for child mortality. Conversely, Benin and Sierra Leone, are efficient at dealing with child mortality but not at dealing with maternal mortality. A similar pattern emerges in lower-middle income countries where a small number of countries are efficient at addressing only one of mortality challenges (e.g. Congo, El Salvador and Zambia).[19] It is thus important to consider both child and maternal mortality when evaluating the efficacy of MDG interventions.

Several policy implications arise form the work of this chapter. First, some countries with relatively high survival rates could do better with the current level of inputs. This is reflected by the high efficiency scores of countries that have relatively low survival rates and, less favorable context and/or health inputs. This could be attained by focusing on contextual factors, since they are the driving force of efficiency of actions taken to address mortality in developing countries. For example, whenever private expenditure on health is significant, it decreases efficiency. Universal health coverage offered through social health insurance schemes, community based financing or through government based medical savings accounts that exist in certain countries could decrease the need for large private expenditures on health (especially in financially constrained settings) and therefore increase efficiency of actions taken to reduce mortality. Moreover, whenever political stability is significant it has a negative sign. The variable captures information on civil unrest as defined by demonstrations. This seems to indicate, that policies which advocate freedom of speech, and therefore general freedoms for its population, are likely to create an environment that promotes efficiency. Another policy that should be considered relates to the control of corruption

[19]No comparison is possible for upper-middle income groups because of lack of convergence of the Tobit regression in the child mortality study.

or rule of law. It often has a very strong, positive impact on efficiency. These policies are recommended for the entire set of countries analyzed.

For the small number of countries which are only efficient in one of the two survival groups studied here, a more equitable approach would generate better health outcomes. After all, results indicate that maternal mortality decreases the efficiency of actions taken to increase child survival. Since child and maternal survival are linked, if policies were not polarized on these issues, better general health outcomes could be attained.

The policies aforementioned are likely to create a context in which efficiency of health actions is improved. Consequently, better health outcomes can be attained with the same inputs or more inputs could generate far greater improvements in survival rates.

This paper, through a three-stage approach, quantifies the efficiency of health-MDG interventions and contextual variables at affecting child and maternal survival rates. It also allows formulating policy recommendations for improvement of efficiency and therefore, increases in survival rates. It is important to note that these recommendations are based on *relative* efficiency results irrespective of costs. Although this paper provides information could guide policymakers, it stands to be improved by using larger samples per income groupings if data were to become available for more countries. This paper analyses the extent to which interventions are well used for generating survival rates. The chapter that follows questions just how effective are the interventions in question at reducing mortality.

1.7 Tables

Table 1.1: List of countries considered for MDG4 and MDG5 relative efficiency analysis

MDG4

Low-income countries:
Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, CAR, Comoros, Eritrea, Ethiopia, Gambia, Ghana, Guinea-Bissau, Iraq, Kyrgyzstan, Liberia, Madagascar, Malawi, Mali, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Tajikistan, Tanzania, Togo, Uganda, Uzbekistan and Zimbabwe

Outlier: Lao People's Democratic Republic

Lower-middle income countries:
Armenia, Bhutan, Bolivia, Cameroon, Cape Verde, China, Congo, Djibouti, Ecuador, Egypt, El Salvador, Georgia, Guyana, Honduras, India, Indonesia, Jordan, Lesotho, Mauritania, Mongolia, Morocco, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Moldova, Senegal, Solomon Islands, Sri Lanka, Sudan, Swaziland, Syrian Arab Republic, Tunisia, Viet Nam, Yemen and Zambia

Outliers: Angola, Côte d'Ivoire, Papua New Guinea and Philippines

Upper-middle income countries:
Albania, Algeria, Argentina, Belarus, Botswana, Brazil, Chile, Colombia, Costa Rica, Jamaica, Kazakhstan, Malaysia, Mexico, Montenegro, Panama, Serbia, Thailand, The FYR of Macedonia, Ukraine and Uruguay

Outliers: Belize, Bosnia, Dominican Republic, Gabon, Lebanon, Namibia, South Africa, Suriname, Turkey and Venezuela

List of countries considered for MDG4 and MDG5 relative efficiency analysis

MDG5

Low-income countries:
Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, CAR, Comoros, Eritrea, Ethiopia, Gambia, Ghana, Guinea-Bissau, Lao PDR, Liberia, Madagascar, Malawi, Mali, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Tanzania, Togo, Uganda and Zimbabwe

Outliers: Iraq, Kyrgyzstan, Tajikistan, Uzbekistan

Lower-middle income countries:
Bolivia, Cameroon, Cape Verde, Congo, Côte d'Ivoire, Djibouti, Ecuador, El Salvador, Georgia, Guyana, Honduras, India, Indonesia, Jordan, Lesotho, Mauritania, Mongolia, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Senegal, Sudan, Swaziland, Tunisia, Viet Nam, Yemen and Zambia

Outliers: Angola, Armenia, Bhutan, China, Egypt, Morocco, Papua New Guinea, Republic of Moldova, Solomon Islands, Sri Lanka and Syrian Arab Republic

Upper-middle income countries:
Albania, Argentina, Belarus, Belize, Bosnia and Herzegovina, Botswana, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Gabon, Jamaica, Kazakhstan, Lebanon, Malaysia, Mexico, Montenegro, Namibia, Panama, Serbia, South Africa, Suriname, Thailand, The FYR of Macedonia, Ukraine and Uruguay

Outliers:
Algeria, Turkey, Venezuela

Table 1.2: Interventions used to achieve MDG4 (reduction of child mortality)

Variable	Description	Source
OUTPUT		
U5MR	number of deaths between birth and exactly five years of age expressed per 1,000 (Under-5 mortality rate)	The State of the World's Children 2010
INPUTS		
Preventative, antenatal, and perinatal care		
BCG	percentage of one-year-olds immunized against tuberculosis (Bacille Calmette-Guérin)	The State of the World's Children 2010
DPT3	percentage of one-year-olds who have received three doses of the combined diphtheria, pertussis and tetanus toxoid vaccine	The State of the World's Children 2010
Pol3	percentage of one-year-olds who have received three doses of the polio vaccine	The State of the World's Children 2010
MCV	percentage of one-year-olds who have received at least one dose of measles-containing vaccine	The State of the World's Children 2010
Hib3	percentage of one-year-olds who have received three doses of Haemophilus influenzae type B vaccine	The State of the World's Children 2010
Neonatal Tetanus	proportion of live births protected (PAB) through maternal immunization with at least two doses of tetanus toxoid	The State of the World's Children 2010; Child Health Epidemiology Reference Group
i-ART	infants born to women living with HIV receiving antiretrovirals for preventing mother-to-child transmission estimated coverage	"Towards universal access: scaling up priority HIV/AIDS interventions in the health sector" (WHO, UNICEF and UNAIDS)
Net	proportion of children aged 0-59 months sleeping under a net of any type	UNICEF Global Database

Interventions used to achieve MDG4 (reduction of child mortality)

Variable	Description	Source
Vitamin A	vitamin A supplementation coverage rate for children aged between 6 and 59 months	The State of the World's Children 2010
Antenatal care	percentage of women aged 15-49 years attended at least once during pregnancy by skilled health personnel (ANC)	The State of the World's Children 2010
EBF	percentage of children less than six months old who are fed breast milk alone (exclusive breastfeeding)	The State of the World's Children 2010
Density and effective utilization of medical personnel		
SBA	percentage of births with skilled birth attendant	The State of the World's Children 2010
Nurses & Midwives	nursing and midwifery personnel density (per 10 000 population)	Global Health Observatory
iDelivery	percentage of deliveries held in an institution	The State of the World's Children 2010

Table 1.3: Interventions used to achieve MDG5 (reduction of maternal mortality)

Variable	Description	Source
OUTPUT		
MMR	number of women who die during pregnancy and childbirth, per 100,000 live births (Maternal mortality ratio)	The World Bank (http://data.worldbank.org/)
INPUTS		
Density and effective utilization of medical personnel		
SBA	percentage of births with skilled birth attendant	The State of the World's Children 2010
iDelivery	percentage of deliveries held in an institution	The State of the World's Children 2010
Nurses and midwives	nursing and midwifery personnel density (per 10 000 population)	Global Health Observatory (WHO)
Physicians	physicians density (per 10 000 population)	Global Health Observatory (WHO)
Preventative, antenatal and perinatal care		
PMTCT	estimated percentage of pregnant women living with HIV who received antiretrovirals for preventing mother-to-child transmission	"Towards universal access: scaling up priority HIV/AIDS interventions in the health sector"
Net	proportion of children aged 0-59 months sleeping under a net of any type	UNICEF Global Database
Family planning	met family planning is the difference between maximum fertility rate of the sample and TFR of the country	World Health Statistics 2010
Antenatal care	percentage of women aged 15-49 years attended at least once during pregnancy by skilled health personnel (ANC)	The State of the World's Children 2010

Table 1.4: Correlation between MDG4 interventions by income group

Low income countries

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	vitA	EBF	ANC	iART	Nets
BCG	1													
DPT3	0.747	1												
Pol3	0.735	0.972	1											
MCV	0.705	0.898	0.894	1										
Hib3	0.232	0.206	0.156	0.044	1									
Tetanus	0.252	0.157	0.096	0.269	0.263	1								
IDel	0.284	0.136	0.184	0.221	-0.027	0.096	1							
SBA	0.248	0.111	0.161	0.217	-0.106	0.103	0.946	1						
NMIDW	0.246	0.327	0.327	0.414	-0.229	0.036	0.641	0.662	1					
vitA	-0.122	-0.125	-0.137	-0.094	0.190	0.165	-0.237	-0.252	-0.441	1				
EBF	0.528	0.516	0.475	0.377	0.343	0.041	-0.121	-0.184	-0.167	0.185	1			
ANC	0.525	0.228	0.261	0.306	0.316	0.280	0.744	0.739	0.329	-0.007	0.129	1		
iART	0.271	0.310	0.305	0.301	0.209	0.176	0.206	0.121	0.081	0.283	0.417	0.309	1	
Nets	-0.081	-0.072	-0.086	-0.181	-0.214	-0.155	-0.364	-0.360	-0.317	0.263	0.318	-0.297	0.320	1

Lower-middle income countries

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	vitA	EBF	ANC	iART	Nets
BCG	1													
DPT3	0.797	1												
Pol3	0.725	0.940	1											
MCV	0.748	0.877	0.890	1										
Hib3	-0.009	0.147	0.101	0.054	1									
Tetanus	-0.014	-0.054	-0.138	-0.102	0.123	1								

Note:
BCG, DPT3, Pol3, MCV, Hib3, tetanus: Immunization; IDel: institutional delivery; SBA: skilled birth attendants; NMIDW: nurses and midwives; vitA: vitamin A; EBF: exclusive breastfeeding; ANC: antenatal care; iART: antiretroviral therapy for infants; Nets: malaria bed nets

Correlation between MDG4 interventions by income group

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	vitA	EBF	ANC	I-ART	Nets
Tetanus	-0.014	-0.054	-0.138	-0.102	0.123	1								
IDel	0.526	0.600	0.613	0.488	0.066	-0.277	1							
SBA	0.557	0.601	0.609	0.549	-0.025	-0.296	0.860	1						
NMIDW	0.292	0.345	0.381	0.403	-0.205	-0.425	0.418	0.417	1					
vitA	-0.130	-0.296	-0.376	-0.340	-0.034	0.216	-0.476	-0.626	-0.321	1				
EBF	0.163	0.098	0.184	0.152	-0.081	-0.208	0.145	0.132	0.049	-0.283	1			
ANC	0.630	0.563	0.511	0.552	-0.021	-0.129	0.706	0.689	0.302	-0.268	0.132	1		
iART	0.314	0.299	0.291	0.373	-0.040	-0.005	0.233	0.227	0.275	-0.115	0.062	0.244	1	
Nets	-0.106	-0.061	-0.023	-0.104	-0.013	0.103	0.001	0.075	-0.286	-0.264	0.290	0.141	0.024	1

Upper-middle income countries

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	EBF	ANC	iART	Nets
BCG	1												
DPT3	0.217	1											
Pol3	0.218	0.951	1										
MCV	0.468	0.794	0.852	1									
Hib3	-0.105	0.207	0.218	0.140	1								
Tetanus	0.281	-0.155	-0.142	-0.097	-0.276	1							
IDel	-0.009	0.297	0.362	0.312	0.263	-0.431	1						
SBA	0.063	0.483	0.545	0.500	0.268	-0.413	0.848	1					
NMIDW	0.092	0.086	0.051	0.092	-0.357	-0.227	0.199	0.136	1				
EBF	0.214	0.380	0.338	0.302	0.287	-0.031	0.160	0.232	-0.328	1			
ANC	-0.024	0.164	0.195	0.102	-0.221	-0.063	0.232	0.298	0.291	0.074	1		
iART	0.057	0.186	0.216	0.200	-0.420	-0.164	0.169	0.156	0.425	-0.156	0.222	1	
Nets	-0.023	-0.199	-0.152	0.027	0.074	0.310	-0.302	-0.259	-0.415	-0.208	-0.385	-0.199	1

Note:
BCG, DPT3, Pol3, MCV, Hib3, tetanus: Immunization; IDel: institutional delivery; SBA: skilled birth attendants; NMIDW: nurses and midwives; vitA: vitamin A; EBF: exclusive breastfeeding; ANC: antenatal care; iART: antiretroviral therapy for infants; Nets: malaria bed nets

Table 1.5: Descriptive statistics of DEA inputs for MDG4

Low-income countries

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	vitA	EBF	ANC	iART	Nets
Mean	88.17	78.87	78.07	78.33	39.73	83.65	45.57	50.93	11.85	49.83	38.40	77.47	19.19	33.95
Min.	64	54	47	52	0	47	5	6	1	0	4	28	0	2
Max.	99	98	98	99	97	97	97	100	108	100	88	99	57	88
SD	9.52	13.91	15.07	12.19	39.80	9.13	23.32	22.50	22.13	39.31	19.38	19.23	16.07	21.73

Lower-middle income countries

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	vitA	EBF	ANC	iART	Nets
Mean	91.15	85.53	85.28	84.08	37.88	73.47	67.48	72.30	18.40	25.10	33.83	84.58	26.40	31.77
Min	60	52	58	54	0	0	19	36	2	0	1	47	0	0
Max	99	99	99	99	99	96	100	100	66.5	97	76	99	95	95
SD	9.39	11.91	11.58	13.04	43.51	26.41	22.21	20.05	16.78	37.92	19.02	12.30	31.37	26.29

Upper-middle income countries

	BCG	DPT3	Pol3	MCV	Hib3	Tetanus	IDel	SBA	NMIDW	EBF	ANC	iART	Nets
Mean	85.53	87.70	88.43	88.27	65.93	39.17	94.37	95.93	31.87	24.73	94.07	54.80	25.51
Min.	0	38	31	53	0	0	80	81	4.8	2	72	0	0
Max.	99	99	99	99	98	92	100	100	125.6	85	100	95	77
SD	29.36	14.59	13.91	12.57	37.62	40.67	6.01	4.58	27.02	19.32	5.97	36.07	26.90

Note:
BCG, DPT3, Pol3, MCV, Hib3, tetanus: Immunization; IDel: institutional delivery; SBA: skilled birth attendants; NMIDW: nurses and midwives; vitA: vitamin A; EBF: exclusive breastfeeding; ANC: antenatal care; iART: antiretroviral therapy for infants; Nets: malaria bed nets

Table 1.6: Correlation between MDG5 interventions by income group

Low income countries

	SBA	IDel	NMIDW	Physicians	PMTCT	Nets	FP	ANC
SBA	1							
IDel	0.912	1						
NMIDW	0.186	0.208	1					
Physicians	-0.356	-0.369	0.368	1				
PMTCT	0.296	0.370	0.145	-0.346	1			
Nets	-0.060	-0.129	0.250	0.350	0.087	1		
FP	-0.182	-0.195	0.157	0.730	-0.339	0.255	1	
ANC	0.780	0.752	0.183	-0.471	0.410	-0.195	-0.242	1

Lower-middle income countries

	SBA	IDel	NMIDW	Physicians	PMTCT	Nets	FP	ANC
SBA	1							
IDel	0.844	1						
NMIDW	0.341	0.325	1					
Physicians	0.611	0.545	0.474	1				
PMTCT	0.204	0.293	0.299	0.111	1			
Nets	0.172	-0.005	-0.105	-0.189	0.070	1		
FP	0.772	0.568	0.355	0.563	0.242	0.112	1	
ANC	0.709	0.751	0.259	0.320	0.215	0.177	0.539	1

Upper-middle income countries

	SBA	IDel	NMIDW	Physicians	PMTCT	Nets	FP	ANC
SBA	1							
IDel	0.849	1						
NMIDW	0.111	0.196	1					
Physicians	0.534	0.556	0.515	1				
PMTCT	0.182	0.185	0.424	0.260	1			
Nets	-0.309	-0.343	-0.439	-0.427	-0.419	1		
FP	0.751	0.774	0.385	0.539	0.169	-0.413	1	
ANC	0.288	0.231	0.279	0.349	0.458	-0.432	0.328	1

Note:
SBA: skilled birth attendants; IDel: institutional delivery; NMIDW: nurses and midwives;
PMTCT: prevention of mother to child transmission of HIV; Nets: malaria bed nets; FP: family planning;
ANC: antenatal care

Table 1.7: Descriptive statistics for DEA inputs for MDG5

Low-income countries

	SBA	iDel	NMIDW	Physicians	PMTCT	Nets	FP	ANC
Mean	44.69	39.81	5.00	1.02	19.24	37.81	2.31	75.19
Min.	6	5	1	1	0	7	0	28
Max.	74	78	13	4	53	88	5	98
SD	16.52	18.43	3.05	0.81	13.91	20.69	1.11	19.56

Lower-middle income countries

	SBA	iDel	NMIDW	Physicians	PMTCT	Nets	FP	ANC
Mean	69.62	64.45	17.41	8.07	22.48	31.50	3.68	84.66
Min.	36	19	4	1	0	0	1	47
Max.	99	99	63	45	87	95	6	99
SD	19.80	22.48	15.57	9.92	26.26	24.93	1.15	13.14

Upper-middle income countries

	SBA	iDel	NMIDW	Physicians	PMTCT	Nets	FP	ANC
Mean	96.19	94.48	33.57	17.76	43.00	25.98	4.93	94.33
Min.	81	80	4	2.9	1	0	4	72
Max.	100	100	126	49	95	77	6	100
SD	4.72	6.28	27.98	12.49	29.22	27.42	0.58	6.21

Note:
SBA: skilled birth attendants; IDel: institutional delivery; NMIDW: nurses and midwives;
PMTCT: prevention of mother to child transmission of HIV; Nets: malaria bed nets; FP: family planning;
ANC: antenatal care;

Table 1.8: Broad environmental and institutional factors (independent variables in Tobit regression)

Variable	Description	Source
Economic situation and expenditures on health		
GNI	gross national income per capita	The World Bank (http://data.worldbank.org/)
PEH	private expenditure on health per capita at PPP	National Health Accounts (WHO)
Regions and ethnic diversity		
SSA	sub-Saharan Africa 1 if SSA, 0 otherwise	N/A
TAC	the Americas and the Caribbeans	N/A
Ethnic diversity	number of immigrant languages used as a first language in that country	Ethnologue Statistical Summaries
Governance indicators		
Stability & absence of violence	index of commonality of political unrest and terrorist threat (continuous variable between 0 and 1; lower values indicate less stability)	Global Insight Business Risk and Conditions (info.worldbank.org/governance/wgi/pdf/WMO.xlsx)
Rule of law	judicial independence: An assessment of how far the state and other outside actors can influence and distort the legal system.	Global Insight Business Risk and Conditions

Broad environmental and institutional factors (independent variables in Tobit regression)

Variable	**Description**	**Source**
Rule of law (*continued*)	crime: How much of a threat businesses face from crime such as kidnapping, extortion, street violence... (continuous variable between 0 and 1; lower values indicate more distorted legal systems and/or higher criminality)	
Elections	legislative or presidential elections (2008 or 2009)	PSEPHOS Election Archive
Inequality, poverty & nutrition		
Urban	urban population as a percentage of total population	United Nations (http://data.un.org/)
Food share	share (%) of food consumption expenditure in total consumption expenditure	Food and Agriculture Organization
Gender related concerns		
Literacy	literacy rates of 15-24 years old women (%)	United Nations
MMR	maternal mortality rates	The World Bank
Child Protection		
Child labor	percentage of children aged 5 to 14 years of age involved in child labour activities	The State of the World's Children 2010

Table 1.9: Child Mortality and survival rates, DEA efficiency scores and ranking of low income countries (n=29)

Country	U5MR	Survival rate	Survival rate rank	Efficiency	Efficiency rank
Kyrgyzstan	38	25.32	1	1	1
Uzbekistan	38	25.32	1	1	1
Iraq	44	21.73	3	1	1
Nepal	51	18.61	4	1	1
Bangladesh	54	17.52	5	1	1
Eritrea	58	16.24	6	1	1
Tajikistan	64	14.63	7	1	1
Zimbabwe	96	9.42	10	1	1
Comoros	105	8.52	14	1	1
Madagascar	106	8.43	15	1	1
Ethiopia	109	8.17	17	1	1
Niger	167	4.99	23	1	1
Sierra Leone	194	4.15	27	0.9999	13
Burundi	168	4.95	24	0.9999	14
Togo	98	9.20	11	0.9999	15
United Republic of Tanzania	104	8.62	13	0.9999	16
Central African Republic	173	4.78	26	0.9998	17
Uganda	135	6.41	21	0.9998	18
Liberia	145	5.90	22	0.9998	19
Benin	121	7.26	19	0.9997	20
Burkina Faso	169	4.92	25	0.9995	21
Mozambique	130	6.69	20	0.9994	22
Guinea-Bissau	195	4.13	29	0.9984	23
Ghana	76	12.16	8	0.5064	24
Malawi	100	9.00	12	0.4965	25
Cambodia	90	10.11	9	0.4263	26
Gambia	106	8.43	15	0.3135	27
Rwanda	112	7.93	18	0.2922	28
Mali	194	4.15	27	0.2537	29

Table 1.10: Coefficients from the Tobit regression of DEA efficiency scores on contextual factors (MDG4; low income group)

Explanatory variable	Coefficient
SSA	-0.682+
	(0.392)
GNI	0.001+
	(0.000)
PEH	-0.017***
	(0.004)
Stability	-0.721*
	(0.318)
Elections	-0.173
	(0.108)
Rule of law	-1.403*
	(0.564)
Share of income spent on food	-0.021**
	(0.006)
Literacy	0.004
	(0.003)
MMR	-0.001***
	(0.000)
Child labor	-0.009**
	(0.003)
Ethnic diversity	-0.045***
	(0.010)
Constant	4.973***
	(0.952)

*n=29; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Table 1.11: Efficiency and role of contextual factors (low income countries, MDG4)

country	DEA efficiency	Predicted value of efficiency	Residuals	% Efficiency explained by interventions
Iraq	1.0000	3.8518	-2.8518	
Bangladesh	1.0000	2.2656	-1.2656	
Comoros	1.0000	2.1826	-1.1826	efficiency explained
Nepal	1.0000	2.0280	-1.0280	
Zimbabwe	1.0000	1.9171	-0.9171	solely by broad
Ethiopia	1.0000	1.5994	-0.5994	
Niger	1.0000	1.5791	-0.5791	
Uzbekistan	1.0000	1.5250	-0.5250	environmental and
Eritrea	1.0000	1.4437	-0.4437	
Kyrgyzstan	1.0000	1.2012	-0.2012	institutional factors
Tajikistan	1.0000	1.2001	-0.2001	
Madagascar	1.0000	1.0867	-0.0867	
Sierra Leone	0.9999	1.0183	-0.0184	
Burundi	0.9999	1.0041	-0.0042	
Liberia	0.9998	1.1483	-0.1485	
Benin	0.9997	1.1380	-0.1383	
Burkina Faso	0.9995	1.0125	-0.0130	
Togo	0.9999	0.6527	0.3472	34.72
Guinea-Bissau	0.9984	0.8640	0.1344	13.46
Mali	0.2537	0.1479	0.1058	41.72
Uganda	0.9998	0.9137	0.0861	8.61
Mozambique	0.9994	0.9364	0.0630	6.30
C.A.R.	0.9998	0.9596	0.0402	4.02
United Rep. of Tanzania	0.9999	0.9639	0.0360	3.60
Ghana	0.5064	0.5064	0.0000	0
Cambodia	0.4263	0.4628	-0.0365	DEA
Malawi	0.4965	0.6138	-0.1173	underestimates
Gambia	0.3135	0.5273	-0.2138	efficiency of
Rwanda	0.2922	0.5094	-0.2172	these countries

n=29

Table 1.12: Child Mortality and survival rates, DEA efficiency scores and ranking of lower-middle income countries (n=36)

Country	U5MR	Survival rate	Survival rate rank	Efficiency	Efficiency rank
Viet Nam	14	70.43	1	1	1
Sri Lanka	15	65.67	2	1	1
Syrian Arab Republic	16	61.50	3	1	1
Republic of Moldova	17	57.82	4	1	1
El Salvador	18	54.56	5	1	1
Jordan	20	49.00	6	1	1
China	21	46.62	7	1	1
Tunisia	21	46.62	7	1	1
Armenia	23	42.48	9	1	1
Egypt	23	42.48	9	1	1
Ecuador	25	39.00	11	1	1
Cape Verde	29	33.48	14	1	1
Georgia	30	32.33	15	1	1
Morocco	36	26.78	17	1	1
Solomon Islands	36	26.78	17	1	1
Indonesia	41	23.39	19	1	1
Mongolia	41	23.39	19	1	1
India	69	13.49	23	1	1
Yemen	69	13.49	23	1	1
Lesotho	79	11.66	25	1	1
Bhutan	81	11.35	26	1	1
Pakistan	89	10.24	28	1	1
Djibouti	95	9.53	29	1	1
Sudan	109	8.17	31	1	1
Mauritania	118	7.47	32	1	1
Senegal	108	8.26	30	0.9997	26
Congo	127	6.87	33	0.9997	27
Nigeria	186	4.38	36	0.9995	28
Paraguay	28	34.71	13	0.9275	29
Nicaragua	27	36.04	12	0.6781	30
Honduras	31	31.26	16	0.6591	31
Bolivia (Plurinational State of)	54	17.52	21	0.3661	32
Swaziland	83	11.05	27	0.2647	33
Guyana	61	15.39	22	0.2194	34
Cameroon	131	6.63	34	0.1163	35
Zambia	148	5.76	35	0.1006	36

Table 1.13: Coefficients from the Tobit regression of DEA efficiency scores on contextual factors (MDG4; lower-middle income group)

Explanatory variables	Coefficients
SSA	-0.093
	(0.383)
GNI	0.0004*
	(0.000)
PEH	-0.002
	(0.002)
Stability	-3.155***
	(0.736)
Elections	-0.160
	(0.196)
Rule of law	6.955***
	(1.444)
Share of income spent on food	0.063***
	(0.013)
Literacy	0.003
	(0.003)
MMR	-0.001+
	(0.001)
Ethnic diversity	-0.072+
	(0.038)
Constant	-2.872*
	(1.091)

*n=36; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Table 1.14: Efficiency and role of contextual factors (lower-middle income countries; MDG4)

country	DEA efficiency	Predicted value of efficiency	Residuals	% Efficiency explained by interventions
Sri Lanka	1.0000	4.0858	-3.0858	
India	1.0000	3.5480	-2.5480	
Jordan	1.0000	3.1957	-2.1957	
Armenia	1.0000	3.1206	-2.1206	
Cape Verde	1.0000	2.8742	-1.8742	efficiency explained
China	1.0000	2.5888	-1.5888	
Tunisia	1.0000	2.5611	-1.5611	
Morocco	1.0000	2.5530	-1.5530	
Mongolia	1.0000	2.3476	-1.3476	
Egypt	1.0000	2.2943	-1.2943	
Pakistan	1.0000	2.1938	-1.1938	solely by broad
Syrian Arab Republic	1.0000	2.1568	-1.1568	
Georgia	1.0000	1.7831	-0.7831	
Yemen	1.0000	1.7617	-0.7617	
Sudan	1.0000	1.5839	-0.5839	
Indonesia	1.0000	1.5561	-0.5561	
Solomon Islands	1.0000	1.5137	-0.5137	environmental and
Djibouti	1.0000	1.3850	-0.3850	
Bhutan	1.0000	1.3587	-0.3587	
El Salvador	1.0000	1.3376	-0.3376	
Viet Nam	1.0000	1.2222	-0.2222	
Ecuador	1.0000	1.1629	-0.1629	
Lesotho	1.0000	1.0449	-0.0449	institutional factors
Republic of Moldova	1.0000	1.0231	-0.0231	
Mauritania	1.0000	0.6596	0.3404	34
Congo	0.9997	0.6610	0.3387	34
Paraguay	0.9275	0.8398	0.0877	9
Cameroon	0.1163	0.0780	0.0384	33
Senegal	0.9997	1.0717	-0.0720	DEA
Nigeria	0.9995	1.2295	-0.2300	underestimates
Honduras	0.6591	0.7081	-0.0490	efficiency of
Nicaragua	0.6781	0.7780	-0.0999	these
Bolivia	0.3661	1.0885	-0.7225	countries
Swaziland	0.2647	0.9952	-0.7305	
Guyana	0.2194	0.3846	-0.1652	
Zambia	0.1006	0.1967	-0.0961	

Table 1.15: Child Mortality and survival rates, DEA efficiency scores and ranking of upper-middle income countries (n=20)

Country	U5MR	Survival rate	Survival rate rank	Efficiency	Efficiency rank
Malaysia	6	165.67	1	1.0000	1
Serbia	7	141.86	2	1.0000	1
Montenegro	8	124.00	3	1.0000	1
Chile	9	110.11	4	1.0000	1
Costa Rica	11	89.91	5	1.0000	1
The FYR of Macedonia	11	89.91	5	1.0000	1
Belarus	13	75.92	7	1.0000	1
Albania	14	70.43	8	1.0000	1
Thailand	14	70.43	8	1.0000	1
Uruguay	14	70.43	8	1.0000	1
Argentina	16	61.50	11	1.0000	1
Mexico	17	57.82	13	1.0000	1
Colombia	20	49.00	14	1.0000	1
Panama	23	42.48	16	1.0000	1
Botswana	31	31.26	18	1.0000	1
Jamaica	31	31.26	18	1.0000	1
Algeria	41	23.39	20	1.0000	1
Ukraine	16	61.50	11	0.9998	18
Brazil	22	44.45	15	0.3134	19
Kazakhstan	30	32.33	17	0.2657	20

Table 1.16: Maternal Mortality and survival rates, DEA efficiency scores and ranking of low income countries (n=26)

country	MMR	Survival rate	Survival rank	Efficiency	Efficiency rank
Eritrea	280	356.14	1	1.0000	1
Cambodia	290	343.83	2	1.0000	1
Bangladesh	340	293.12	3	1.0000	1
Comoros	340	293.12	3	1.0000	1
Togo	350	284.71	5	1.0000	1
Nepal	380	262.16	7	1.0000	1
Uganda	430	231.56	10	1.0000	1
Madagascar	440	226.27	11	1.0000	1
Ethiopia	470	211.77	12	1.0000	1
Burkina Faso	560	177.57	16	1.0000	1
Zimbabwe	790	125.58	18	1.0000	1
Niger	820	120.95	20	1.0000	1
Burundi	970	102.09	23	1.0000	1
Malawi	510	195.08	13	0.8859	14
Benin	410	242.90	9	0.8510	15
Liberia	990	100.01	25	0.8094	16
Guinea-Bissau	1000	99.00	26	0.8063	17
Gambia	400	249.00	8	0.8056	18
Ghana	350	284.71	5	0.7994	19
Mozambique	550	180.82	15	0.7487	20
Lao PDR	580	171.41	17	0.7317	21
Sierra Leone	970	102.09	23	0.6889	22
Rwanda	540	184.19	14	0.6557	23
United Republic of Tanzania	790	125.58	18	0.6196	24
Mali	830	119.48	21	0.6079	25
Central African Republic	850	116.65	22	0.3903	26

Table 1.17: Coefficients from the Tobit regression of DEA efficiency scores on contextual factors (MDG5; low income group)

Explanatory variable	Coefficient
SSA	-0.559*
	(0.210)
GNI	-0.001
	(0.0005)
Private expenditure on health	-0.002
	(0.003)
Political stability	0.265
	(0.449)
Elections	-0.279
	(0.160)
Control of corruption	0.898*
	(0.390)
Share of income spent on food	-0.010
	(0.006)
Literacy	-0.002
	(0.003)
Ethnic diversity	-0.003+
	(0.002)
Constant	2.246***
	(0.427)

*n=26; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Table 1.18: Efficiency and role of contextual factors (low income countries; MDG5)

country	DEA efficiency	Predicted value of efficiency	Residuals	% Efficiency explained by interventions
Burundi	1	1.1249	-0.1249	efficiency explained
Burkina Faso	1	1.1675	-0.1675	
Zimbabwe	1	1.2218	-0.2218	solely by broad
Nepal	1	1.2523	-0.2523	
Eritrea	1	1.3511	-0.3511	environmental and
Niger	1	1.3628	-0.3628	
Bangladesh	1	1.4022	-0.4022	institutional factors
United Republic of Tanzania	0.6196	0.5581	0.0616	9.93
Benin	0.8510	0.8200	0.0310	3.65
Malawi	0.8859	0.7667	0.1192	13.46
Madagascar	1	0.9902	0.0098	0.98
Cambodia	1	0.9701	0.0299	2.99
Togo	1	0.9227	0.0773	7.73
Comoros	1	0.8805	0.1195	11.95
Uganda	1	0.8308	0.1692	16.92
Ethiopia	1	0.8123	0.1877	18.77
Mozambique	0.7487	0.7999	-0.0512	DEA
Guinea-Bissau	0.8063	0.8743	-0.0680	
Ghana	0.7994	0.8794	-0.0799	underestimates
Gambia	0.8056	1.0010	-0.1954	
Mali	0.6079	0.8111	-0.2031	efficiency of
Lao People’s Democratic Republic	0.7317	0.9865	-0.2548	
Rwanda	0.6557	0.9227	-0.2669	these
Sierra Leone	0.6889	0.9643	-0.2754	
Central African Republic	0.3903	0.6736	-0.2832	countries
Liberia	0.8094	1.1357	-0.3263	

Table 1.19: Maternal Mortality and survival rates, DEA efficiency scores and ranking of lower-middle income countries (n=29)

country	MMR	Survival rate	Survival rank	Efficiency	Efficiency rank
Georgia	48	2082	1	1.0000	1
Viet Nam	56	1785	2	1.0000	1
Jordan	59	1694	3	1.0000	1
Tunisia	60	1666	4	1.0000	1
Mongolia	65	1537	5	1.0000	1
Philippines	94	1063	6	1.0000	1
Yemen	210	475	14	1.0000	1
Indonesia	240	416	16	1.0000	1
Pakistan	260	384	17	1.0000	1
Djibouti	300	332	19	1.0000	1
Senegal	410	243	20	1.0000	1
Swaziland	420	237	21	1.0000	1
Côte d'Ivoire	470	212	22	1.0000	1
Zambia	470	212	22	1.0000	1
Lesotho	530	188	24	1.0000	1
Sudan	750	132	28	1.0000	1
Mauritania	550	181	25	0.9999	17
Nigeria	840	118	29	0.9996	18
Cape Verde	94	1063	6	0.9583	19
Nicaragua	100	999	9	0.9202	20
Honduras	110	908	10	0.7407	21
El Salvador	110	908	10	0.7382	22
Paraguay	95	1052	8	0.7004	23
India	230	434	15	0.5749	24
Congo	580	171	26	0.5531	25
Bolivia	180	555	13	0.4893	26
Ecuador	140	713	12	0.4597	27
Cameroon	600	166	27	0.3797	28
Guyana	270	369	18	0.3135	29

Table 1.20: Coefficients from the Tobit regression of DEA efficiency scores on contextual factors (MDG5; lower-middle income group)

Explanatory variable	Coefficient
SSA	-0.549**
	(0.190)
GNI	0.0002**
	(0.0001)
Private expenditure on health	-0.0003
	(0.0009)
Stability	0.064
	(0.348)
Elections	-0.201+
	(0.107)
Control of corruption	2.194**
	(0.598)
Share of income spent on food	0.056***
	(0.014)
Literacy	-0.008
	(0.006)
Ethnic diversity	-0.001
	(0.001)
Constant	-1.816
	(1.101)

*n=29; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Table 1.21: Efficiency and role of contextual factors (lower-middle income countries; MDG5)

country	DEA efficiency	Predicted value of efficiency	Residuals	% Efficiency explained by interventions
Zambia	1	1.6836	-0.6836	
Jordan	1	1.5648	-0.5648	
Senegal	1	1.3916	-0.3916	efficiency explained
Swaziland	1	1.3856	-0.3856	
Tunisia	1	1.3276	-0.3276	solely by broad
Mongolia	1	1.2741	-0.2741	
Georgia	1	1.2605	-0.2605	
Sudan	1	1.2564	-0.2564	environmental and
Yemen	1	1.2365	-0.2365	
Djibouti	1	1.1967	-0.1967	institutional factors
Pakistan	1	1.1742	-0.1742	
Lesotho	1	1.1157	-0.1157	
Philippines	1	0.9887	0.0113	1.13
Viet Nam	1	0.9628	0.0372	3.72
Indonesia	1	0.7066	0.2934	29.34
Côte d'Ivoire	1	0.6984	0.3016	30.16
Honduras	0.7407	0.6096	0.1310	17.69
Paraguay	0.7004	0.6177	0.0826	11.80
Guyana	0.3135	0.6989	-0.3854	DEA
Cameroon	0.3797	0.5754	-0.1956	
Ecuador	0.4597	0.5214	-0.0617	underestimates
Bolivia	0.4893	0.5477	-0.0585	
Congo	0.5531	0.7416	-0.1886	efficiency of
India	0.5749	1.1386	-0.5637	
El Salvador	0.7382	0.9313	-0.1931	these
Nicaragua	0.9202	1.0546	-0.1345	
Cape Verde	0.9583	1.0262	-0.0679	countries
Nigeria	0.9996	1.1656	-0.1660	
Mauritania	0.9999	1.1457	-0.1458	

Table 1.22: Maternal Mortality and survival rates, DEA efficiency scores and ranking of upper-middle income countries (n=27)

country	MMR	Survival rate	Survival rank	Efficiency	Efficiency rank
Serbia	8	12499	1	1.0000	1
Bosnia and Herzegovina	9	11110	2	1.0000	1
The FYR of Macedonia	9	11110	2	1.0000	1
Chile	26	3845	6	1.0000	1
Lebanon	26	3845	6	1.0000	1
Uruguay	27	3703	9	1.0000	1
Malaysia	31	3225	10	1.0000	1
Costa Rica	44	2272	12	1.0000	1
Thailand	48	2082	14	1.0000	1
Argentina	70	1428	16	1.0000	1
Colombia	85	1175	18	1.0000	1
Namibia	180	555	22	1.0000	1
Gabon	260	384	26	0.9999	13
Jamaica	89	1123	18	0.9999	14
Suriname	100	999	22	0.9998	15
Belize	94	1063	21	0.9998	16
Panama	71	1407	17	0.9998	17
Kazakhstan	45	2221	13	0.9997	18
Botswana	190	525	25	0.9996	19
Mexico	85	1175	18	0.9994	20
Albania	31	3225	10	0.9992	21
Montenegro	15	6666	3	0.5851	22
Belarus	15	6666	3	0.5333	23
Ukraine	26	3845	6	0.3076	24
Dominican Republic	100	999	22	0.2921	25
Brazil	58	1723	15	0.2143	26
South Africa	410	243	27	0.0636	27

Table 1.23: Coefficients from the Tobit regression of DEA efficiency scores on contextual factors (MDG5; upper-middle income group)

Explanatory variable	Coefficient
TAC	-0.251
	(0.169)
GNI	0.0002*
	(0.0001)
Private expenditure on health	-0.001*
	(0.001)
Stability	-1.554***
	(0.392)
Elections	0.035
	(0.267)
Control of corruption	1.285**
	(0.421)
Share of income spent on food	0.008
	(0.008)
Literacy	-0.0195
	(0.017)
Ethnic diversity	-0.003*
	(0.001)
Constant	2.472
	(1.718)

*n=27; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Table 1.24: Efficiency and role of contextual factors (upper-middle income countries; MDG5)

country	DEA efficiency	Predicted value of efficiency	Residuals	% Efficiency explained by interventions
Uruguay	1	1.7053	-0.7053	efficiency explained solely by broad environmental and institutional factors
Chile	1	1.5959	-0.5959	
Serbia	1	1.5086	-0.5086	
Lebanon	1	1.3877	-0.3877	
Colombia	1	1.2835	-0.2835	
Thailand	1	1.2716	-0.2716	
Bosnia and Herzegovina	1	1.0682	-0.0682	
Costa Rica	1	1.0647	-0.0647	
The FYR of Macedonia	1	0.9925	0.0075	0.75
Malaysia	1	0.9642	0.0358	3.58
Namibia	1	0.9328	0.0672	6.72
Argentina	1	0.6695	0.3305	33.05
Suriname	0.9998	0.7616	0.2382	23.83
Belize	0.9998	0.9090	0.0908	9.08
Kazakhstan	0.9997	0.7433	0.2564	25.65
Mexico	0.9994	0.9604	0.0390	3.90
Albania	0.9992	0.8318	0.1673	16.75
Gabon	0.9999	1.5157	-0.5158	DEA underestimates efficiency of these countries
Jamaica	0.9999	1.2377	-0.2378	
Panama	0.9998	1.3014	-0.3016	
Botswana	0.9996	1.0066	-0.0070	
Montenegro	0.5851	0.6460	-0.0609	
Belarus	0.5333	0.6164	-0.0831	
Ukraine	0.3076	0.6586	-0.3509	
Dominican Republic	0.2921	0.5983	-0.3062	
Brazil	0.2143	0.4675	-0.2531	
South Africa	0.0636	0.6273	-0.5637	

Chapter 2

Effectiveness of health policy instruments at reducing neonatal, child and maternal mortality.

2.1 Introduction

The first chapter of this thesis was concerned with the relative efficiencies of countries in trying to combat child and maternal mortality at one point in time (2008). In this chapter, we examine carefully the factors which are associated with child and maternal mortality in 32 countries of sub-Saharan Africa over the period 2000 to 2008. The analysis is restricted to sub-Saharan Africa (SSA) because most countries in that region are lagging behind on MDG mortality targets relative to those in a broader geographical region. It is also the case from the results of Chapter 1 that it is this region in which the relative efficiency of countries can be in part attributed to MDG health interventions.

In 2000, the United Nations (UN) announced its intention to pursue eight broad goals -the Millennium Development Goals (MDGs)- to deal with development and mortality in a large group of countries struggling with poverty. Two of these goals specifically address child (MDG4) and maternal (MDG5) mortality. A large number of interventions were introduced to support the attainment of these goals, such as increased access to antenatal care, skilled birth attendants, emergency obstetric care, clean deliveries, placental malaria control, HIV/AIDS transmission prevention, basic child immunization, and so on. While a large literature discusses many aspects of these MDGs, relatively little work has been done that focuses explicitly on the relative effectiveness of these interventions at reducing mortality rates.

The purpose of this chapter is to examine empirically the extent to which countries are moving towards child and maternal MDGs with the help of the 12 main UN interventions. Both of these MDGs are comprised of two parts. The first is a mortality target: each country is to achieve a $2/3^{rds}$ reduction in child mortality and a $3/4^{th}$ reduction in maternal mortality from 1990 levels. The second part is a time target: the reduction is to be achieved by 2015. Whereas a casual review of mortality data for sub-Saharan African countries shows that child and maternal mortality has been declining (see Tables 2.1 and 2.2), it is not clear what has driven the fall in mortality and, in particular, whether these interventions have played a critical role. The analysis contained in this chapter uses data from 2000 and 2008 to address this question and examine the relation between changes in the scope of MDG interventions and the decline in mortality in this region. A careful examination of the role played by interventions is essential if one wants to determine what set of interventions ought to be promoted to attain mortality targets. Although studying the association and causality between health interventions and mortality rates can help guide the public health agenda, these approaches form only a small part of impact assessment and program evaluation. Additional information on costs, expected and unintended externalities are just some of the aspects that when coupled with effectiveness analysis give a more complete picture of the situation. The cost aspect is studied in the third chapter. This chapter is concerned mostly with the first element of the MDGs, namely the reduction of child and maternal mortality but it will also examine how attainable are these goals by 2015.

When one is considering the impact of interventions on health outcomes, it is useful to think about the underlying health production (or, equivalently, mortality-reduction) technology. The UN interventions designed to achieve the MDGs (like vaccinations and mosquito nets) can be considered as inputs into a health production function. However, there is no reason to believe that these inputs will be equally effective in reducing mortality in all sub-Saharan African countries. Indeed, there are three main reasons to believe that this will not be the case. First, sub-Saharan

Africa is one of the most genetically diversified areas in the world (Campbell and Tishkoff (2010)). As a result, the effectiveness of certain health interventions, like vaccines for measles, may vary in efficacy across countries because of the different genetic predispositions of the diverse populations of this region. Moreover, many countries have had a different pharmaceutical imprint which dictates their current susceptibility or resistance to certain treatments. Additionally, a disease may be caused by strains of varying virulence - for example, it is well documented that malaria strains differ across countries in sub-Saharan Africa (Gupta et al. (1994)). This suggests that for two different countries, identical in all aspects but the three reasons mentioned above, the same mix of interventions could possibly have a different impact on mortality. It is therefore not appropriate to assume that the same production technology exists across sub-Saharan Africa. Nevertheless, the analyses to date that have considered the effectiveness of MDG interventions at reducing mortality in sub-Saharan Africa have used empirical methodologies that implicitly assume that this region shares one underlying technology for producing health from a given set of inputs. The first contribution of this chapter, therefore, is to take explicit account of the fact that these health production functions may differ across regions. To this end, a technique (the Finite Mixture Model) which endogenously separates groups of countries according to their production functions is employed. The results obtained suggest that there is indeed underlying heterogeneity across the region, and that better policy recommendations would be developed if this were properly taken into account.

The majority of papers in the literature focused on the determinants of neonatal, child and maternal mortality do not specifically look at the contribution of MDG interventions. Strikingly, of the relatively small number of papers which include interventions, they usually include only one or two at a time, rather than a broader package of the interventions targeting MDGs. While one cannot empirically determine the impact of all interventions at the same time because of potential collinearity between them - for example, the coverage of births attended by a skilled health worker and the coverage of clean deliveries can be expected to increase together - it is certainly desirable to examine several policies at a time in order to take account of potentially complementary health-MDG actions. This chapter, therefore, adds to this relatively small literature on the impact of MDG interventions, and empirically investigates the impact of sets of key interventions on neonatal, child and maternal mortality.

Another weakness of the existing literature is a lack of attention to contextual variables. It is well understood that it is crucial to include factors such as political stability, government effectiveness and literacy when analyzing policy instruments because the environment in which they are implemented will inevitably affect their effectiveness (Chapter 1 of this thesis; Gupta (1999); Houweling et al. (2005); Menon-Johansson (2005); Rajkumar and Swaroop (2008); Ruger (2006); Wagstaff et al. (2004)). The work of this chapter takes particular care to include contextual variables in order to identify the impact of MDG interventions on mortality.

This chapter focuses on the twelve main MDG interventions targeting child and maternal mortality. The results suggest directions for policy that tailor the interventions to the specific conditions in given countries or group of countries. Whereas the existing approach to MDG policy implements all instruments in all countries, the work of this paper suggests a more nuanced strategy would be more effective and helps to identify policy levers that would be the most effective in different countries as they seek to achieve the MDG goals.

The chapter is organized as follows. Section 2.2 reviews papers which have examined the determinants of neonatal, child and maternal mortality. Section 2.3 describes the methodology used. Section 2.4 describes the data. Section 2.5 briefly explains the interpretation of coefficients. Section 2.6 presents, interprets and discusses the results, while section 2.7 contains policy implications and concluding remarks.

2.2 Literature review

In order to get a general idea of the literature on the effectiveness of health-MDG interventions, three databases were used: EconLit, ProQuest and PubMed. The main key words utilised were MDG, Millennium Development Goals, health policy/interventions, effectiveness, efficiency, impact, neonatal mortality/survival, child mortality/survival and maternal mortality/survival. The various searches of published papers and grey literature indicate that even though medical causes of neonatal, child and maternal mortality have been extensively studied, there is little specific attention given to the effectiveness of sets of health MDG interventions.[1] In an attempt to discern patterns across the selected papers on the topic at hand, documents are separated into two categories: those that use a country-level analysis and those that are based on cross-sectional data. In each of these sections, papers are compared based on the methodology used and variables included in their analysis.

Whereas the main focus of this section is to review the existing literature on the effectiveness of health-MDG interventions, it turns out to also be useful to provide a brief introduction to the application of the Finite Mixture Model to the analysis of economic data. As the Finite Mixture Model is not as well understood as Maximum Likelihood Estimation procedures, it is helpful to get some understanding of contexts where it has been successfully applied.

2.2.1 Single country studies

Appendices G and H present a list of papers that undertake single-country studies of the factors which affect mortality rates, and summarize the findings. For ease of comparison, papers are

[1]Perhaps not surprisingly, most of the literature reviewed on neonatal, child or maternal mortality has been authored by public health specialists, epidemiologists and medical specialists; only a few economists have approached this topic.

separated into two groups: those which study neonatal, infant and child mortality, and those which study maternal mortality.

Single country studies are useful because they can take account of the particularities associated with a given jurisdiction. Additionally, there is less concern about the comparability of data, as it is generally assumed that they are collected in a similar manner over time. Single country studies are favored when one needs to estimate the determinants of regional mortality rates and trends (Chowdhury et al. (2007); Nakamura et al. (2011)). Single-country studies are often used by research groups to inform *domestic* policies and to build national strategic plans (Ministry of Health of Ghana (2008); Ministry of Health and Social Welfare of Tanzania (2008)). However, in the context of the development of a global health agenda, single-country studies have obvious limitations. These studies are performed at different points in time, and use variables and methodologies which differ across jurisdictions, thus rendering it difficult to discern patterns or trends in mortality across countries and regions. Additionally, many country-level studies are based on regional data which may not necessarily reflect the overall realities of the country as a whole.

There is a striking lack of agreement in the literature on how best to model empirically the determinants of neonatal, infant and child mortality. Slightly over half of the papers reviewed used logistic regressions. Epidemiologist and public health specialists often favor this method because it allows for a straightforward calculation of the odds ratios and relative risk ratios associated with given regressors (Agha et al. (2010); Andargie et al. (2013); Anyamele (2009); Binka et al. (1995); Chowdhury et al. (2010); D'Souza (2003); Eisele et al. (2005); Fuchs and Lutz (2010); Gordon (2009); Kamal (2012); Landes et al. (2012); Mondal et al. (2009); Muhuri and Preston (1991); Muhuri (1996); Rico et al. (2011); Titaley et al. (2008); Yaqoob et al. (1998); Zanini et al. (2011)). By contrast, economists tend to favour other techniques, like ordinary least squares for continuous variables (Benefo and Schultz (1996); Kumar et al. (2012); Sepulveda et al. (2006); Zimba et al. (2012)) or more sophisticated econometric techniques such as Cox regressions, Poisson regressions, or principal component analyses (Feng et al. (2012); Gayen and Raeside (2010); Godson (2012); Hossain, Phillips, and Pence (Hossain et al.); Jahn et al. (2010); Kembo and Van Ginneken (2009); Kumar et al. (2012); Mekonnen et al. (2013); Nakamura et al. (2011); Omariba et al. (2007); Ombok et al. (2010); Taha et al. (2012)). These techniques allow economists to answer a variety of questions about mortality. For example, Cox regressions deal with the incidence of death and allows one to determine the probability of dying in period t+1 given that one survived until time t.

Irrespective of the technique employed, no clear pattern emerges regarding the identification of key factors which affect neonatal, infant and child mortality. There is no consensus with respect to the set of determinants that should be used, nor is there agreement as to which variables matter (economic significance). Close to half of the selected papers use only socio-demographic factors as independent variables, and there are conflicting findings regarding their impact on mortality. For example, several studies (Agha et al. (2010); Godson (2012); Hossain, Phillips, and Pence (Hossain et al.); Kembo and Van Ginneken (2009); Kumar et al. (2012); Omariba et al. (2007); Zanini et al. (2011)) include maternal education (or female literacy) and find it is not a significant factor in the analysis of neonatal or child mortality while others (Andargie et al. (2013); D'Souza (2003); Fuchs and Lutz (2010); Gayen and Raeside (2010); Jahn et al. (2010); Kamal (2012); Mekonnen et al. (2013); Mondal et al. (2009); Muhuri and Preston (1991); Nakamura et al. (2011); Sepulveda et al. (2006); Taha et al. (2012)) find the opposite result. Similarly, Iram and Butt (2008) finds that maternal education is a significant determinant of neonatal and infant mortality but not of child mortality, whereas Mondal et al. (2009) find it to be significant for neonatal and child mortality but not infant mortality; Chowdhury et al. (2010) finds it significant for infant and child mortality, but not for neonatal.

Findings are mixed regarding the impact of a number of other commonly used explanatory variables, including maternal age (Iram and Butt (2008); Kamal (2012); Kembo and Van Ginneken (2009); Ombok et al. (2010); Titaley et al. (2008); Yaqoob et al. (1998)), birth order (Hossain, Phillips, and Pence (Hossain et al.); Kamal (2012); Kembo and Van Ginneken (2009); Mekonnen et al. (2013); Mondal et al. (2009); Muhuri and Preston (1991); Nakamura et al. (2011)), income (Chowdhury et al. (2010); Godson (2012); Gordon (2009); Iram and Butt (2008)), urban versus rural residence (Anyamele (2009); Benefo and Schultz (1996); Fuchs and Lutz (2010); Gordon (2009); Iram and Butt (2008); Jahn et al. (2010); Kamal (2012); Kembo and Van Ginneken (2009); Mekonnen et al. (2013); Mondal et al. (2009); Nakamura et al. (2011)) and marital status (Andargie et al. (2013); Landes et al. (2012); Mekonnen et al. (2013); Nakamura et al. (2011); Omariba et al. (2007); Zanini et al. (2011)).

Relatively few studies of the determinants of mortality include measures of the policy instruments put in place to combat these problems. For example, a number of authors consider HIV prevalence in the analysis of mortality (Landes et al. (2012); Sattler and Shandra (2009); Shandra et al. (2012); Zimba et al. (2012)), but they do not include antiretroviral therapy coverage or funds spent on primary, secondary or tertiary prevention of sexually transmitted infections (including HIV/AIDS). A limited number of studies do, however, include one or two MDG interventions alongside socio-demographic factors (Andargie et al. (2013); Binka et al. (1995); D'Souza (2003); Eisele et al. (2005); Godson (2012); Iram and Butt (2008); Kamal (2012); Kumar et al. (2012); Mekonnen et al. (2013); Mondal et al. (2009); Nakamura et al. (2011); Sepulveda et al. (2006); Titaley et al. (2008); Zanini et al. (2011)). However, once again there is a lack of consensus regarding the impact of these interventions. For example, immunization variables (like neonatal tetanus vaccine, measles-containing vaccine and oral polio vaccine) are significant in reducing neonatal or child mortality in studies done by Andargie et al. (2013), Mekonnen et al. (2013) and Sepulveda et al. (2006), whereas Iram and Butt (2008)'s results varied according to the dependent variable used (neonatal, infant or child mortality). The presence of skilled attendants at birth is found to reduce neonatal and child mortality in analyses undertaken by Titaley et al. (2008), but not in those done by Binka et al. (1995); Kamal (2012); Zimba et al. (2012). Breastfeeding is found to be a statistically significant determinant of neonatal mortality by Iram and Butt (2008); Feng et al. (2012); Mondal et al. (2009); Nakamura et al. (2011) but not by Landes et al. (2012).

In short, comparing single-country studies of the determinants of neonatal, infant and child mortality is very difficult: not only there is no consensus with respect to methodology nor with respect to the explanatory variables that should be included, but the reported results vary greatly. Even when researchers report results for the same country, their findings are often conflicting. For example, in studies using Ghanaian data, Nakamura et al. (2011) and Osei-Kwakye et al. (2010) find that antenatal care does not reduce neonatal and child mortality, whereas Afari et al. (2005) reports it leads to reductions in mortality rates. Although these differences in results may be attributable to the fact that they use data drawn from different regions of Ghana, covering different time periods, the bottom-line message is that single country studies do not provide clear insights into the determinants of neonatal, infant and child mortality in those countries, and are of limited guidance to the development of global health strategies designed to attain MDG4. As with neonatal, infant and child mortality, there is also a lack of agreement on the best empirical approach to take when studying maternal mortality, and on the appropriate choice of explanatory variables. Whereas most analyses of this issue use logistic regressions (Bloom et al. (2001); Celik and Hotchkiss (2000); Conde-Agudelo et al. (2000); Furuta and Salway (2006); Gebrehiwot and Liabsuetrakul (2009); Martin et al. (1982)), a few use more sophisticated econometric techniques (Du et al. (2009); Koblinsky et al. (2009); Illah et al. (2013); Hussein et al. (2011)). The vast majority of these papers ignore the context in which interventions are implemented: other than the occasional inclusion of GNI per capita and literacy rate (Du et al. (2009); Hussein et al. (2011)), environmental and institutional factors are neglected. As with the papers dealing with neonatal and child mortality, there is no consistent message that emerges from the literature with respect to the significance of factors which affect maternal mortality.

2.2.2 Cross-country analysis

Since the review of country-level studies fails to identify a clear pattern as to which factors have an impact on mortality, the next step is to examine whether cross-country studies are more informative. Here again, the literature is divided into those dealing with neonatal, infant and child mortality, and those on maternal mortality (listed in Appendix I and Appendix J).

A cross-country approach typically uses one observation at one period of time for each country. This approach is particularly useful when country-level time series data is not available. A weakness of this approach, however, is that cross-country studies usually assume that the health production function of all of the countries under investigation is identical. If countries differ from each other by more than just fixed factors, the resulting estimated coefficients on other factors may be biased. Perhaps not surprisingly, there is a similar lack of consensus in the cross-country literature as in the single-country literature regarding both the appropriate methodological framework and the appropriate set of determinants that should be considered in the analysis of neonatal, infant and child mortality, nor is there agreement regarding the effectiveness of various health interventions. However, there is somewhat more agreement regarding the impact of different variables when they are found to be statistically significant. Some papers focus solely on the role played by interventions and omit the role of other factors (Akachi and Atun (2011); Boschi-Pinto et al. (2009)). Interventions used in such papers include malaria control, prevention and treatment of respiratory infections or diarrhea related conditions, exclusive breastfeeding, family planning and physician density. Whereas the statistical significance of these factors vary across papers, there is one element of consensus: whenever these interventions are found to be statistically significant, they do in fact reduce mortality. Other papers include only socio-demographic or contextual factors, and omit the role of interventions (Fayissa (2001); Hojman (1996); Sattler and Shandra (2009)). Once again, none of these broad environmental and institutional variables (like public health expenditures, maternal education, rural residence, debt burden, recipient of International Monetary Fund (IMF) structural adjustment loans, or democracy index) are always identified as having a statistically-significant impact on neonatal, infant and child mortality. However, once again, whenever factors are statistically significant, their coefficients are always of the expected sign and the economic significance of any one variable does not overshadows that of others.

Relatively few papers simultaneously include interventions, socio-demographic indicators and contextual variables (Fay et al. (2005); Lawn et al. (2012); Muldoon et al. (2011); Shandra et al. (2012); Wang (2003)). Of these papers, Lawn et al. (2012) stands out because it includes several interventions and contextual variables in the analysis. It also uses a more complex technique, the elastic net algorithm (ENA), to measure the extent to which the average annual rates of change (AARC) of interventions between the years 2000 and 2010 causes changes in neonatal mortality in various regions. The authors find that, for sub-Saharan African countries, tetanus toxoid immunization is the only intervention which has a statistically significant impact, and that it has a negative coefficient. In contrast, female literacy, HIV prevalence, general fertility rate, teen fertility rate, total expenditure on health, government effectiveness, political stability, skilled attendants at birth and DPT3 vaccination (3 doses of diphtheria, pertussis and tetanus) are not statistically significant. For developing countries that are not in SSA, two interventions are found to be statistically significant (skilled birth attendants and family planning), and are found to accelerate reductions in mortality.

The review of the literature leads to the conclusion that there is no clear consensus as to which variables are systematically significant at reducing neonatal mortality, although there is agreement regarding the direction of impact when variables are significant. Inconsistencies may be partially (or largely) attributable to differences in the empirical strategies used by different researchers. An empirical methodology that takes better account of underlying heterogeneity in the health production technology can potentially generate new insights.

Just as in the previous section, there is no clear message which emerges regarding the statistical significance of factors which affect maternal mortality. Different researchers make very different choices with respect to the appropriate set of interventions or contextual variables (e.g. proper water and sanitation, family planning, HIV/AIDS control, GDP per capita, control of corruption, and so on), and these factors are found to be statistically significant in some papers and not in others. However, once again, there is agreement that whenever these variables are significant, they decrease mortality (Ahmed et al. (2012); Conde-Agudelo et al. (2005); DerSarkissian et al. (2013); Gil-Gonzàlez et al. (2006); Karlsen et al. (2011); Liotta et al. (2013); Montoya et al. (2014); Muldoon et al. (2011); Souza et al. (2013); Sudhir and Bärnighausen (2004)). Dealing with the underlying heterogeneity in the health production technology may help to better identify the factors which affect maternal mortality.

2.2.3 Finite Mixture Models

Finite mixture models (FMM) are an example of latent class analysis methods and are used to test for unobserved heterogeneity in the data: is a given population formed of distinct sub-populations? (McLachlan and Peel (2000); Mengersen et al. (2011)). If this is the case, then a standard regression model, which assumes that there is a unique production technology for the entire dataset, may be inappropriate. The FMM, which is essentially an extension of maximum likelihood estimation, endogenously categorises observations into similar groups/components (see Appendix K for detailed calculation of FMM). The method has been used to discern the existence of subgroups in various fields of study including education and health.

For example, Ding (2006) studies the impact of grades, children's personal assessment of mathematical knowledge, and professor ratings, on student proficiency in mathematics. He finds that there are three different subgroups, and that the way in which the three exogenous variables interact to generate proficiency in mathematics varies across these subgroups. Similarly, Dardanoni et al. (2009) analyze the path of transmission of knowledge from parents to children given their social environment. The FMM suggests that the role of the social environment varies across population groups of unobserved educational endowment.

Finite mixture modeling is nor new nor rare in the health field. As indicated in *Medical Applications of Finite Mixture Models* by Schlattmann (2009), FMM is used in the health sector to analyze subgroups formed by unobserved heterogeneity in pharmacokinetics, illness spell analysis, disease mapping, genetic mutation studies... Deb and Trivedi (1997) use FMM to discern whether elderly people's demand for healthcare is subject to unobserved heterogeneity. Trivedi and Deb (2002) use FMM to assess health care utilisation because variation in the long term health status of patients may lead to unobserved heterogeneity that is not captured when categorizing populations by health condition and self reported health status at a specific point in time. D'Uva (2006) compares the performance of a number of different models to assess healthcare utilisation and finds that latent class models (FMM and FMM derivatives) fit the data more accurately than alternative models such as the hurdle model.

2.3 Methodology

This chapter seeks to assess the relationship between the change in the scope of interventions implemented between 2000 and 2008 and the reduction of child and maternal mortality during that period. The underlying idea is that interventions such as malaria nets are inputs into the health production (or, equivalently, mortality reduction) function, and that the effectiveness of these interventions will also be influenced by contextual factors. As per the seminal paper of Grossman (1972), health is seen as a capital stock which depreciates with time, but can be built up through appropriate investments. Health is therefore *produced* by individuals based on their consumption of health services and time allocated to generating better health, while also being influenced by broader environmental factors and being conditional on education levels. Additionally, several papers built on the frameworks proposed by Mosley and Chen (1984) and McCarthy and Maine (1992) for the study of child and maternal mortality, and include broad environmental and institutional factors in their analysis. This papers follows along the same lines by including environmental factors such as political stability, control of corruption, and literacy in addition to health interventions in the empirical strategy.

Before turning to a discussion of the techniques to be applied, two issues need to be addressed. The first concerns how best to use the data set to capture the contribution of the interventions towards achieving the MDGs which, as noted above, identify specific targets with respect to the overall reduction of mortality and with respect to the speed at which the mortality drops. The vast majority of papers analyze the impact of interventions on mortality while disregarding the fact that MDGs are to be attained by 2015. Thus, these papers effectively regress a measure of mortality on interventions and/or other factors, as follows:

$$Mortality_i = \beta_1 X_i + \beta_2 Z_i + \varepsilon_i \tag{2.1}$$

where X_i represents a *vector* of socio-economic factors of country i (political stability and absence of violence, voice and accountability...), and Z_i is a *vector* of its interventions (family planning, immunization, pneumonia treatment...). This is, of course, a static model, and implicitly assumes that changes in the values of explanatory variables result in contemporaneous changes in the values of mortality. Because it has been widely used elsewhere, this chapter also estimates such an equation using a maximum likelihood procedure (which is a simplified version of the Finite Mixture Model used in this chapter).

Another approach that might appear to be a natural strategy for addressing the analysis of the factors influencing the reduction of mortality would be to simply take differences between 2000 and 2008 values of mortality, interventions and contextual variables, as in Equation (2.2).

$$Mortality_{i,2008} - Mortality_{i,2000} = \beta_1(X_{i,2008} - X_{i,2000}) + \beta_2(Z_{i,2008} - Z_{i,2000}) + \varepsilon_i \qquad (2.2)$$

This approach, however, is inappropriate in the current context because the intensity of effort needed to decrease mortality by a fixed number of deaths varies with the initial mortality level. For instance, for a country that has an initial mortality level of 1000, a reduction in mortality by 100 deaths represents a 10% decrease in mortality. In contrast, for a country with a mortality level of 220, 100 averted deaths represent a 45% decrease. To take account of the effort needed to reduce mortality, papers represent changes in mortality in terms of percentages (which is particularly useful in the current study because MDG mortality targets are expressed in terms of percentage change from 1990). Equation (2.2) is never used in studies of mortality reduction and is therefore not estimated in this chapter.

Given that our dataset contains information for the years 2000 and 2008, rather than for two adjacent years, a compound rate of change has to be used to measure the annual rate of change of mortality and other variables of interest. This chapter follows the methodology previously employed by several researchers (e.g. Lawn et al. (2012), Binkin et al. (2011) and Dearth-Wesley et al. (2011)) by calculating the average annual rate of change (AARC) of the variables of interest, rather than average percentage changes. The AARC is calculated by using the standard equation for compound rates of change:

$$r = \left[\left(\frac{variable_T}{variable_0} \right)^{1/T} - 1 \right] * 100 \tag{2.3}$$

where the numerator represents the variable in the last period (in this case, 2008), the denominator the variable in the initial period (2000) and T is the lapse of time (here 8 years). Over the period of interest to this study, mortality always falls. To ease the interpretation of results, the AARC of mortality is multiplied by minus one; consequently, the AARC of mortality depicts the average annual rate of *reduction* of mortality. The estimating equation[2] can be expressed as:

$$AARC\ mortality_i = \beta_1(AARC\, X_i) + \beta_2(AARC\, Z_i) + \varepsilon_i \tag{2.4}$$

Equation (2.4) can be estimated using a maximum likelihood procedure (MLE). However, a MLE procedure using cross-country observations is based on the assumption that the health production technology is the same for all countries. Thus the vector β_1, for instance, reflects the impact of the elements of the vector AARC X on (the average annual rate of change of) maternal mortality irrespective of whether the population is located in Kenya or Malawi. As previously discussed, there is reason to believe that this assumption is not valid. A variant on the MLE technique, known as the Finite Mixture Model (FMM), can capture potential differences across groups of countries. The finite mixture model is essentially an extension of the MLE procedure to settings in which there is underlying heterogeneity. FMM is an endogenously

[2]Initial levels of mortality (mortality rate in 2000) are not included as a independent variable because they are already included in the calculation of the left-hand side variable. Additionally, inclusion of initial mortality rate creates scaling issues as all other variables are expressed in percentages and leads to lack of convergence of the FMM.

weighted maximum likelihood approach which takes account of the potential different production functions present within a population. It also reports the probability that each observation belongs to a given subpopulation (commonly referred to as *component*). For example, assuming there are K components, the density function of any observation y_i is the weighted sum of its density in each of the sub-populations:

$$f(y_i) = \sum_{k=1}^{K} \lambda_k \ f_k(y_i, \theta_k) \tag{2.5}$$

where λ_k is the endogenously determined weight and θ_k represents, as per standard MLE nomenclature, the vector of parameters (mean and variance) of group (k).

FMM is therefore a maximum likelihood estimation where there is more than one sub-group. A one-component FMM is an MLE, a 2-component FMM assumes that at least two distinct production functions characterize the data. FMM is run in a sequential manner, for example, a three-component FMM cannot be run before a 2-component FMM. Therefore if a K-component FMM converges but a (K+1)-component FMM fails to converge, it means that the dataset contains K distinct health production functions. However, the FMM also has its limitations. The FMM algorithm is slow to converge and can present a local maximum solution through the likelihood maximization process, a problem which occurs mainly when a large number of components is present. The robustness of the results reported in this study is tested by checking to see whether different initial values lead to different results. If different starting values lead to the same results then it is very likely that the solution is a global maximum. Despite these concerns, FMM is the most appropriate choice of technique as it is potentially able to uncover underlying heterogeneity in the health production technology in the 32 countries of sub-Saharan Africa that constitute the focus of this chapter; as noted above, underlying heterogeneity of the production technology is a potential explanation for the striking lack of consensus in the literature regarding the key determinants of child and maternal mortality.

To test the validity of the methodology proposed in this chapter, MLE and modified MLE (FMM) approaches are applied to the dataset used by Lawn et al. (2012). The objective is to test if MLE can reproduce the results of their paper and if FMM can infer the presence of unobserved heterogeneity and potentially distinct health production functions in their data and subsequently in the dataset used in this chapter.

2.4 Data sources and Variables

In 2000 the United Nations created a list of eight development objectives (Millennium Development Goals) to be attained by 2015. This international initiative promotes specifically 12 interventions to combat child and maternal mortality. Although two mortality groups are explicitly stated in the MDGs, neonatal mortality is also widely studied as it accounts for close to 40% of deaths of children under five. Thus, this chapter examines three measures of mortality: neonatal, under-5 and maternal. As mentioned, all countries that are included in this study experienced a decrease in mortality between 2000 and 2008 (see Tables 2.1 and 2.2); the average annual rate of change in mortality is therefore the average annual rate of *reduction* of neonatal, child and maternal mortality (its AARC is multiplied by *minus one*). The next paragraphs describe the data sources and the data.

2.4.1 Data sources

A dataset on the UN health policy instruments targeting MDGs was constructed using publicly available data from UNICEF and augmented by information from the World Bank, the World

Health Organization, the Organisation for Economic Co-operation and Development (OECD) database as well as from data provided by Dr. J. Lawn from Save the Children. Contextual factors were extracted from the Global Insight Business Risk and Conditions database as well as from the United Nations database and from National Health Accounts available through the World Health Organization. Table 2.3 provides details of all the interventions and contextual variables used in this analysis and their sources.

2.4.2 Contextual Variables

Contextual variables represent the environment in which interventions are implemented. These broad environmental and institutional factors can be grouped into three categories: economic indicators, women empowerment through knowledge and worldwide governance indicators (Table 2.3). Initially, four economic indicators (expressed in 2011 USD) were considered for this research: gross national income per capita and three measures of per capita expenditure on health (government, private and total). However these three measures of expenditures on health were highly correlated and consequently, only GNI and government expenditures on health were retained as variables to be used in subsequent regressions; the latter because it had relatively lower correlation with other variables[3] (Table 2.4 provides all the correlations between the variables used in this analysis). These variables were selected because the literature indicates that at *levels* they are factors which are associated with reductions in mortality rates. It is, however, very possible that the speed at which mortality is reduced may not be associated with speed at which context is changing. For example, the literature indicates that countries with a higher gross national income per capita have lower mortality rates; however, given that countries usually have small changes in GNI over the short period of time studied here, the rate of change in GNI could fail to be significant at impacting the rate of change of mortality. Additionally, since none of

[3]GNI was excluded from the regression due to multicollinarity, with a variance inflation factor of its AARC greater than 5, and it displayed little variation in its average annual rate of change across countries.

the sub-Saharan countries studied experienced an economic boom, rates of change of GNI are likely quite homogenous across sub-Saharan Africa, and not a useful economic indicator for a *cross-country* study on *rates of change* of mortality and factors associated with it.

Another variable that was frequently employed by researchers is a measure of literacy. As female literacy captures both education and gender concerns, it was selected for this study. Female literacy is defined as the literacy rate of women between 15 and 24 years of age. Given that the variable captures much more than just literacy rates, it is referred to here as the "empowerment of women through knowledge" variable.

A set of six worldwide governance indicators (WGI) is often used as contextual variables. These indicators are: *political stability and absence of violence* - a measure of civil unrest and terrorism threat; *voice and accountability* - the representativeness of a population in the political arena and institutional permanence; *government effectiveness* - the quality of the bureaucratic system, policy consistency and forward planning; *rule of law* - judicial independence and likelihood for a business of being the subject of criminal acts; *regulatory quality* - tax effectiveness and business laws and, *control of corruption*. Table 2.5 provides a more detailed explanation of the WGI. As in the case of expenditures on health, here too variables are highly correlated. The correlation values reported in Table 2.4 show that rule of law, regulatory quality and control of corruption are highly correlated with voice and accountability and government effectiveness (correlation values vary between 0.527 and 0.654).[4] Consequently, only political stability and absence of violence, voice and accountability and government effectiveness are included in the regressions. All three excluded variables capture elements of bureaucracy that may be included in government effectiveness and the discussion of this variable reflects these exclusions.

[4]Correlation scores greater than 0.5 are considered high because most variables used in Chapter 2 have correlation values which range from 0.009 to 0.4.

Descriptive statistics of the average rate of change of contextual factors are reported in Table 2.6. Notice that the mean values for the AARC of government expenditure on health vary between 7.2% and 8.3% across the three mortality studies. These means are much larger than the means of female literacy rates, which range between 2.1% and 2.3%. Prevention of malaria has a large mean average annual rate of change, approximately 10% across all mortality group, as does HIV funding with an AARC which varies between 38% and 42% across mortality groups.

2.4.3 Neonatal Mortality Variables

Neonatal mortality is defined as the number of newborns who die before reaching 28 days of age per 1,000 live births. The literature suggests that several interventions and health system inputs may be important in reducing neonatal mortality. Exclusive breastfeeding (EBF), the kangaroo method[5], placental malaria control, antenatal care, prevention of mother to child transmission of HIV/AIDS (PMTCT), clean deliveries, medical personnel density, institutional deliveries and skilled birth attendants are the factors that are consistently promoted by UNICEF and its counterparts. Unfortunately not all of these factors could be used in the current analysis. As explained below, certain variables had to be omitted due to problems with collinearity or due to lack of data for either the year 2000 and/or 2008. Some variables were replaced by proxies. Behavioral activities such as exclusive breastfeeding and the kangaroo method are highly promoted by public health organizations to combat neonatal mortality. However, data on the latter are very scarce hence exclusive breastfeeding (EBF) represents behavioral activities which aim to reduce neonatal mortality. Data on placental malaria, on the percentage of pregnant women sleeping under insecticide treated nets or receiving anti-malarial treatment is also quite scarce. As placental malaria leads to extremely low birth weight, a measure of

[5]The kangaroo method is a skin-to-skin method of caring a newborn (especially a preterm or underweight baby) to increase its survival chances via effective thermal control in settings where there are no incubators.

the latter is used here to represent neonatal malaria despite the fact that it may also capture the effect of other health issues. Another variable which was difficult to incorporate in the study is antenatal care (ANC). Three ANC visits is the minimum recommended by the World Health Organization. However, due to data limitations the percentage of pregnant women who had at least one ANC visit is used in this study. Data on medical personnel and the utilization of health services is represented by the percentage of births in a presence of a skilled birth attendant (SBA). Table 2.3 provides detailed information on these variables and their sources.

Correlation scores shown in Table 2.4 indicate that immunization (MCV) and antennal care are moderately correlated (0.323) as are government effectiveness and government expenditure on health (0.324). Additionally, they have similar correlation with political stability. Descriptive statistics provided in Table 2.6 show that although for the vast majority of countries the coverage of interventions increased between 2000 and 2008, some had reductions (e.g. Guinea-Bissau had a 9% decrease in EBF; Côte d'Ivoire had a 0.43% decrease in ANC). Surprisingly, the mean of the change of number of neonates that weighed more than 2,500g at birth is very low (0.045).

2.4.4 Child Mortality Variables

Child mortality is defined as the number of deaths that occur before five years of age expressed per 1,000. Based on the literature reviewed and the health actions advocated by UNICEF and its counterparts, a large set of variables was initially considered to address child mortality. Six basic child immunizations (BCG, PAB, Hib, DPT3, MCV, Polio)[6], HIV interventions, malaria interventions targeted at children under-five, medical personnel density, as well as interventions related to pneumonia and diarrheal conditions were initially considered as independent variables in the analysis of child mortality. Unfortunately insufficient data on Hib were available. The

[6]The six basic child immunization are 1) BCG: Bacillus Calmette-Guérin; 2) PAB: prevention at birth (neonatal tetanus vaccine); 3) Hib: *Haemophilus influenzae* type b; 4) DPT: diphtheria, pertussis and tetanus; 5) MCV: measles containing vaccine; 6) Polio

interventions related to pneumonia and diarrheal conditions are crucial because, in 2000 and 2008 the majority of deaths of children under five were due these complications.

As shown in Table 2.4, the immunization interventions are highly correlated with each other for the simple reason that they are often delivered simultaneously. In order to resolve correlation issues the five basic child immunizations are omitted from regressions and are instead represented by the measles vaccination (MCV).[7] The latter therefore represents "basic child immunization". As per the methods used by WHO and UNICEF, one vaccine (usually MCV or DPT3) represents all immunization coverage. Although a principal component analysis (PCA) of immunization variables was considered, the size of the sample is too small to pass the PCA stability test: a minimum of a 10:1 ratio of observations to independent variables is required (Osborne and Costello (2004)).

Just as in the previous section, there is insufficient data on HIV interventions aimed at children under five, and so data on official development assistance for control of sexually transmitted infections including HIV/AIDS is used to analyse the effect of changes in interventions aimed at mitigating the effects of HIV/AIDS on mortality rates. Fortunately, there are specific data for 2000 and 2008 on medical personnel and on interventions aimed at combating child malaria. These factors are respectively represented by physician density and the number of children under five (out of 100) who are sleeping under a net. Density of nurses and midwives was initially considered; however, due to data unavailability for certain years, only physician density is used.

Although deaths of children under five can be mostly attributed to pneumonia or diarrheal related complications, there is no consistent data over the period of this study on the treatment of these conditions. Pneumonia treatment is proxied here by the percentage of children under five

[7]MCV had low correlation with the other variables in the regression.

suspected of having this condition and taken to a healthcare facility for treatment. As diarrheal related conditions are highly correlated with access to clean water, the intervention for preventing diarrhea is represented by the percentage of urban population using improved drinking water.

Table 2.4 reveals that, unlike neonatal interventions, child interventions are weakly correlated with each other and with contextual variables. Table 2.6 also shows that although the mean percentage change of interventions is below 5% over the period 2000-2008, the mean average annual rate of bed nets and HIV funding is 10% and 40% respectively.

2.4.5 Maternal Mortality Variables

Maternal mortality is defined as the number of women who die during pregnancy and childbirth per 100,000 live births. International organizations which support health-MDGs advocate for greater maternal health, and in particular, they promote interventions such as antenatal care, skilled attendants at birth, emergency obstetric care, clean deliveries, family planning and reduction of teen fertility. These actions address the main clinical reasons for maternal mortality like hemorrhaging, sepsis, hypertension and eclampsia/pre-eclampsia and, indirect causes such as malaria, anemia, HIV and medical complications due to contaminated water.

Interventions are categorized as to how they address these medical reasons. For example, severe bleeding can be attended to by trained medical personnel with oxytocin injections. Consequently, the presence of skilled attendants at birth addresses the issue of death due to severe blood loss. Data on clean deliveries would address maternal death due to sepsis, but that information is not readily available. Deliveries supervised by a skilled birth attendant are performed in clean settings because they have standard clean delivery kits; the SBA variable also captures elements linked to combating infections. Antenatal care addresses several of the indirect medical causes of maternal mortality as well as the health status related to eclamptic conditions. However, due to multicollinearity issues, ANC was taken out of the regression. SBA therefore represents *general maternal care*. Obstetric complications are more likely to occur (and are often more severe) in adolescent pregnancies. Detailed data on interventions is not available by age group, nonetheless, teen pregnancies is useful here to capture unmet family planning.

Data on interventions which address indirect medical causes of maternal mortality are scarce. Access to clean water is the only action aimed at addressing indirect medical causes for which data is readily available. Additionally, due to the vast amount of money spent on research, prevention and control of HIV/AIDS (another indirect medical reason for maternal death worldwide), HIV funding is included as a determinant. A preferred regressor would have been coverage of antiretroviral therapy however that data is not readily available.

Descriptive statistics provided in Table 2.6 indicate that the mean of the average rate of change of interventions was relatively low (0.2% to 4.0%) for all interventions except HIV which had a mean of 42%. Additionally, interventions and contextual variables have low correlations.

2.5 Interpretation of coefficients when using average annual rates of change

Before turning to the results per se, it is important to ensure that one understands how to interpret the estimated coefficients when working with average annual rates of change (AARC). To this end the following provides a couple of simple examples to assist in interpreting the results. The interpretation of the coefficients obtained from the FMM regression when both the dependent and explanatory variables are expressed as average rates of change is quite different from the interpretation of these coefficients when variables are measured in levels. A maintained assumption throughout this analysis is that increases in interventions can do no harm (although reductions in interventions may increase mortality). As will be demonstrated below, right hand side variables -such as interventions- may have negative coefficients even when an increase in these variables has contributed to a decrease in mortality.

Example 1: Positive coefficient from a regression of AARC of mortality on AARC of an intervention

mortality	**AARC Mortality**	Intervention	**AARC intervention**
400		15.00	
360	**10**	15.15	**1**
317	**12**	15.45	**2**
272	**14**	15.92	**3**
229	**16**	16.55	**4**
188	**18**	17.38	**5**

Example 1 illustrates how a positive coefficient is obtained (notice that as the levels of the intervention are rising, mortality levels are decreasing). As the *change* in the AARC of intervention increases by 1, the rate of reduction of mortality increases by 2. In other words, the relationship between the $AARC_{mortality}$ and $AARC_{intervention}$ is positive and has a value of 2 (β= 2). This means that as the AARC of the intervention goes up by 1, the AARC of mortality goes up by more, in this case 2. Because we are looking at changes in the average annual rate of change in variables, we are effectively looking at the change in the gradient of the function by which reductions in mortality are obtained. When the coefficient is positive the aforementioned gradient is convex in the right hand side variable.

In contrast, Example 2 shown below, presents a scenario leading to negative coefficient. As before, an increase in the AARC of the right hand side variable leads to a reduction in mortality. However, here the *change* in the AARC of the right hand side variable is greater than that of the AARC of mortality, and so β= -2. This implies that, locally, the gradient of the technology by which reductions in mortality is obtained is concave in the right hand side variable.

Example 2: Explaining a negative coefficient of an intervention

mortality	**AARC Mortality**	Intervention	**AARC Intervention**
400		15.00	
360	**10**	15.15	**1**
331	**8**	15.45	**2**
311	**6**	15.92	**3**
299	**4**	16.55	**4**
293	**2**	17.38	**5**

The reasons for which a rapid expansion of interventions (and therefore a high AARC) may be associated with a less rapid drop in mortality (and therefore a negative coefficient) may be related to the direct effectiveness of the intervention (e.g. a large increase in deployment of malaria nets would be less effective in countries where malaria strains are less virulent); to a low baseline level of mortality (making additional reductions harder to obtain); or because the health system and broader context is such that interventions are rendered relatively less effective.

As noted in Section 3.4, however, there were in fact negative AARC for some variables for some countries between 2000 and 2008 (and, in particular, there was a decline in access to clean water in many countries during this period). If a decline in interventions leads to an increase in mortality, this will also lead to a negative coefficient. This renders the interpretation of negative coefficients more delicate, as it will typically not be clear whether the sign of the coefficient is attributable to decreased coverage in some countries, or to decreasing returns to scale in countries which had an increase in coverage, or to a combination of these effects.

The sign and magnitude of the coefficients matters for identifying those policy levers which, at least locally, are best suited for being used to rapidly decrease mortality. If the regressor has a positive coefficient then a marginal increase in its average annual rate of change leads to a marginal reduction in mortality at a rate equal to the average annual rate of reduction of mortality plus β. In contrast, if a regressor has a negative coefficient but there was an expansion in interventions (so that the negative coefficient is attributable to diminishing returns) then an expansion in this variable will also result in a *marginal* reduction in mortality, but at a rate equal to the average annual rate of change less β. However, when negative coefficients - particularly large negative coefficients - are attributable to the harm done by *reductions* in interventions, then these may also be effective policy levers for pursuing MDG targets.

2.6 Estimation Results and Discussion

2.6.1 Results obtained when using Lawn et al. (2012)'s dataset

As was noted in the review of the literature on the effectiveness of interventions at reducing mortality, only one paper (Lawn et al. (2012)) includes a large number of interventions and contextual factors. In its study of neonatal mortality, Lawn et al. included 4 interventions (neonatal tetanus, DPT3 vaccination, skilled birth attendants, adolescent fertility rate) and 8 contextual factors (GNI, female literacy rate, HIV prevalence, general fertility, total expenditure on health, government effectiveness, political stability) and concluded that only one intervention mattered - neonatal tetanus. However, this paper used an unusual empirical technique, the Elastic

Net Algorithm (ENA)[8], so the question naturally arises as to whether the results obtained are largely a consequence of the technique employed, or whether similar findings would have been obtained had a different technique been used. Lawn et al. graciously provided their dataset. Re-estimation of their model using Maximum Likelihood Estimation (MLE) again finds that only tetanus vaccination matters ($\hat{\beta}$=0.201; p-value= 0.005); the other interventions that are included in the dataset are not found to have a statistically-significant impact on the rate of reduction in mortality. As discussed in the literature review, it seems possible that the fact that so few interventions are statistically significant might possibly be attributable to the fact that there is heterogeneity in the manner in which the health production functions (equivalently, child and maternal mortality reduction functions) transform health inputs, such as interventions, into health outputs, such as reductions in mortality, across sub-Saharan African countries. In particular, if the marginal association between interventions is positive for one group of countries, and negative for the other, then this would typically lead to an erroneous conclusion that the intervention did not have a statistically-significant effect. To investigate this hypothesis, a FMM regression was run on Lawn et al.'s data, and the procedure converged with two components, strongly suggesting that there are indeed two distinct health production functions. For one group of countries changes in neonatal tetanus immunization and teen fertility were the only statistically significant interventions ($\hat{\beta}_{tetanus}$ =0.170 and $\hat{\beta}_{teenfertility}$=0.097). For the second group of countries all interventions were statistically significant between 0.1% and 10% ($\hat{\beta}_{tetanus}$=0.045, $\hat{\beta}_{teenfertility}$=0.339, $\hat{\beta}_{DPT3}$=0.032 and $\hat{\beta}_{SBA}$=-0.234).

It is important to note that it is not possible to discriminate between two competing hypotheses: that the convergence to two components is attributable to the fact that there are two underlying production functions, or to the fact that one group of countries is operating at the efficiency

[8]ENA is a regression technique that consisted here of a 1000 times 10-fold cross-validation by LASSO (the least absolute shrinkage and selection operator) and Tikhonov regularization. Estimation are provided only for the values which are estimated as having an impact on the dependent variable.

frontier, whereas the other group is simply inefficient. What is important, however, is that the results of the FMM procedure do suggest that the change in the scope of interventions may indeed have had more of an impact on mortality reduction than appears to be the case when relying on the application of MLE.

The results obtained assign both positive and negative coefficients to the interventions. What is evident is that the ENA and MLE approaches both mask the effectiveness of various interventions: because these methods both implicitly assume that the relationship between mortality and interventions is the same across the region, they simply cannot capture the fact that intervention may have differing (marginal) links with mortality in different countries. To better explore the importance of potential underlying heterogeneity in the health technology which links mortality and interventions across sub-Saharan Africa, this chapter estimates the relation between 11 interventions, 5 contextual variables and three measures of mortality: neonatal, under-5, and maternal, using the standard MLE procedure and using the Finite Mixture Model (FMM). Tables 2.7, 2.9 and 2.11 present these results for these three mortality measures, using both procedures, which are discussed in the following three sub-sections.

2.6.2 Regression results for neonatal mortality

Table 2.7 reports the results obtained from applying the maximum likelihood estimation procedure with the number of neonatal deaths per 1,000 as the dependent variable. The independent variables are measures of interventions and contextual variables. These variables are the ones that will be regressed, with the FMM method, on rates. The estimation on levels is shown for comparative reasons; as noted earlier, as some explanatory variables, and most particularly contextual variables, may change very little in value over the time period considered, there is good reason to expect that such variables may be significant at levels but not at rates. MLE regression on levels shows that two interventions are significantly linked to the neonatal mortality rate: antenatal care ($\hat{\beta}_{ANC} = 0.2451$) and exclusive breastfeeding ($\hat{\beta}_{EBF} = -0.1098$). The coefficient for antenatal care is positive, implying that an increase in the prevalence of antenatal care (ANC) increases mortality, which is unexpected. This result is, however, consistent with (Mathai (2011)), who notes that a significant change occurred in the pattern of delivery of ANC during this period. It must be recalled that ANC represents the proportion of pregnant women that had one or more antenatal care visit, whereas three or more visits is conventionally viewed as the minimum recommended number of appointments. Significantly, over the 2005-2007 period a goal-oriented, reduced-visits care approach was introduced in several African countries, which was later found to be successful in rich countries but not in resource constrained countries, where it was linked to a 15% higher probability of neonatal mortality than the standard ANC model (Mathai (2011)). Unfortunately, due to cost savings generated by the alternative goal-oriented antenatal care, primary health care systems had implemented it quite rapidly, creating a measurement problem in the dataset. What the regression is likely capturing is the effect of the rapid rollout of ANC with just one visit or with reduced numbers of visits as compared to countries which mainly maintained the standard model of antenatal care. The coefficients of political stability and government effectiveness are -0.1540 and -0.2829. Female literacy is also significant ($\hat{\beta} = -0.1622$). These results should be interpreted with caution, since, at levels, government effectiveness passes the multicollinearity test at the limit.

The second column of Table 2.7 reports the MLE.[9] This conclusion holds for all three mortality groups analysed in this chapter. Results use the AARC of the explanatory and dependent variables, rather than levels. As discussed in the Methodology section, above, using AARC is more natural when the objective is to understand how the various interventions and other variables of interest are effective at the *margin* in reducing mortality. However, the MLE procedure implicitly assumes that the underlying health production technology is the same throughout the region.

[9] As expected, the OLS regression estimated coefficients are the same as the ones obtained with the maximum likelihood estimation because of the normality assumption. Additionally, all variables maintain their 1%, 5% and 10% significance levels across MLE and OLS.

These results suggest that antenatal care is the only statistically significant intervention. The negative coefficient indicates that, at the margin, an increase in the rate of expansion of antenatal care reduces mortality, but at a rate lower than the AARC of mortality. It is important to stress that if the underlying assumption that interventions do no harm holds (an assumption which is justified by the fact that the literature shows interventions to have either no effect or the anticipated positive effect), and interventions do in fact increase between 2000 and 2008, then positive and negative coefficients only represent the relationship, at the margin, between the rate at which interventions are expanded and the rate at which mortality is reduced. However, if interventions decreased in enough countries over the period in question, a negative coefficient may also be attributable to the harm done, i.e., the increase in mortality caused by a reduction in the interventions. To investigate whether or not the association between interventions and mortality outcomes is being masked by the implicit requirement in MLE that health production be the same across the region, the FMM approach is applied to this data set. The FMM procedure converged with two components, and so estimates are reported in columns 3 and 4 of Table 2.7. Convergence of the FMM along with lower values of Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) than those obtained when using MLE on rates, support using FMM results in preference to those obtained using MLE (see Table 2.8 for numerical values).

A closer look at the FMM results shows that there are 15 countries in the first component: Angola, Burundi, Cameroon, Central African Republic, Ethiopia, Ghana, Guinea-Bissau, Liberia, Madagascar, Mali, Mozambique, Namibia, Niger, Nigeria and South Africa. In this group, antenatal care, medical personnel density and control and prevention of placental malaria all have negative estimated coefficients. As explained above, negative coefficients may be driven by decreases in interventions, or by decreasing returns to scale with respect to increases in interventions. It is certainly plausible that the negative coefficient is due to decreasing returns:

although several countries belonging to this component have high initial mortality rates[10] these countries also had high initial levels of interventions. It is therefore not surprising that, at the margin, there may be diminishing returns to further increases in these interventions. Component One also includes countries such as Nigeria, Ethiopia and Mozambique (amongst others) which are known to have inefficient health systems, weak primary healthcare, weak laboratories and lacks in qualified health workforce (Lawn et al. (2012); WHO Publications on Tuberculosis (2005)). For these countries that had a high initial mortality rate and yet where little change in mortality was observed despite increased interventions and increased government expenditure on health, it is likely that the ineffectiveness of the health systems resulted in a situation where the increased inputs did not generate significant reductions in mortality, consistent with a negative coefficient. The negative sign of government effectiveness (GE) is likely driven by diminishing returns. Twelve out of fifteen countries show improvement in government effectiveness. The mean rate of change of that variable is higher for these countries than for those that had worsening in GE (3.89 for increases in GE and, -1.70 for decreases in GE). Similarly, the negative sign on the AARC of antenatal care is also likely attributable to diminishing returns. Thirteen countries had increases in coverage of ANC (mean value of increase in AARC of ANC is 1.42) while only 3 had decreases (mean value of change in rate of coverage -0.69). In contrast, the sign of skilled birth attendants and, in particular, placental malaria prevention and control may in fact be attributable to reductions in those interventions. Although only four countries show decreases in coverage of SBA, their average value of AARC is -3.63 versus 2.41 for those who exhibit increases. Even more strikingly, close to half of the countries had decreases in placental malaria prevention and control. With an average value of -0.57 versus 0.26 for those with increases in coverage of that intervention, it is very likely that diminishing returns do not explain the negative sign of this intervention in this component.

[10]There are many more countries with relatively high initial mortality rate in group 1 than in group 2.

In contrast, a positive coefficient was obtained for female empowerment. A careful review of female literacy rates for countries in component 1 shows that initial female literacy rates are typically relatively low.[11] A modest increase in female literacy might then be linked to quite significant changes in behaviours and practices that affect neonatal mortality, explaining the positive sign for this variable.

Quite a different picture emerges when considering the 16 countries (Benin, Burkina Faso[12], Côte d'Ivoire, Comoros[12], Eritrea, Gambia, Malawi, Mauritania, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zambia and Zimbabwe) which form component 2. For these countries, there are four factors which have an estimated positive coefficient suggesting that, at the margin, an expansion in these interventions is strongly associated with a large positive impact on the rate of reduction of neonatal morality. Control and prevention of placental malaria has the biggest effect ($\hat{\beta}_M = 0.2793$) followed by government expenditure on health, political stability and government effectiveness ($\hat{\beta}_{GEH} = 0.2327$;, $\hat{\beta}_{PS} = 0.0615$; $\hat{\beta}_{GE} = 0.0273$). The positive coefficient for placental malaria is all the more interesting given that a number of component 2 countries, like Rwanda, Tanzania, Malawi and Sierra Leone, have directed very significant efforts to malaria prevention by implementing programs like *Roll Back Malaria* and platforms like *World Malaria Day*. Even though there is general agreement that these initiatives have been successful at promoting malaria preventative measures, it is possible that there might be decreasing returns to increased malarial prevention efforts at the margin. However, these are all countries in which initial rates of mortality attributable to malaria were high, and so there was potential for rapid drops in mortality if anti-malarial interventions expanded rapidly.

[11] There are many more countries with high initial female literacy rates in component 2.

[12] The probability of belonging to component 2 is between 80% and 90% for Burkina Faso and Comoros. Even without the inclusion of these countries conclusions on country grouping and statistical significance of variables remain the same.

For countries in component two, women empowerment through knowledge and voice and accountability both have a negative and statistically significant estimated coefficients, meaning that while they reduced mortality, the rate of reduction in NMR was slower than the rate of change in these factors. The fact that several countries in this group have high initial levels of female literacy but low or moderate initial levels of mortality levels suggests that there are diminishing returns to increased female literacy in this group of countries. Additionally, no country in this component experienced a decrease in the female literacy rate between 2000 and 2008. Conversely, the negative coefficient on the AARC of voice and accountability (VA) may in fact be attributable to the reduction of this factor between 2000 and 2008. Although only five countries had drops in values of the voice and accountability variable, the mean value of the drop in VA is a lot higher than that of countries which had increases in this variable (-24.5 versus 4.65). For the remaining significant interventions (ANC, EBF and SBA), negative coefficients are likely capturing diminishing returns. The vast majority of countries had increased coverage for these interventions and the mean value of the AARC of those variables is much higher (in absolute terms) for countries which expanded those interventions between 2000 and 2008.

Although these explanations of the signs of the coefficients generated by the FMM is necessarily speculative, what is clear is that there are significant differences between the FMM results and those obtained from the application of MLE, whether on levels or rates. The FMM procedure suggests that there may indeed be significant underlying heterogeneity in the association between mortality reduction in sub-Saharan Africa and coverage of interventions, and is indicative of the fact that the interventions are more strongly associated to neonatal mortality reduction than appears to be the case when using estimation procedures which implicitly constrain the technology to be the same across the region.

2.6.3 Regression results for under-five mortality

This subsection examines the results from applying the MLE and FMM procedures to the study of the factors linked to child mortality. Column 1 of Table 2.9 presents the results for the MLE regression on 2008 data at level.[13] The only significant intervention, access to clean water, decreases mortality but barely makes the 10% cut-off for significance level. In contrast, when MLE is run on AARC for all variables, access to clean water still has a negative coefficient - whereas pneumonia has a positive coefficient - indicating that the expansion of access to pneumonia treatment was highly effective in reducing under-5 mortality. Turning to contextual variables, voice and accountability has a negative coefficient, whereas government expenditure on health and government effectiveness both have positive coefficients.

To test the implicit assumption that there is the same relationship between interventions and reduction in under-5 mortality in all 29 SSA countries studied, the FMM was applied. Once again, the FMM saturates at 2 components, and has lower AIC and BIC values as compared to the MLE procedure (see Table 2.10 for numerical values). The differences between the FMM and MLE results are striking, strongly suggesting that MLE may be masking the effectiveness of certain interventions.

The FMM procedure assigns 16 countries to component 1 (Benin, Burkina Faso[14], Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Eritrea, Ethiopia, Gambia, Ghana, Madagascar, Mozambique, Nigeria, South Africa, Sudan and Zimbabwe). For these countries malaria prevention and women empowerment through knowledge have positive and statistically significant coefficients ($\hat{\beta}_M = 0.0948$; $\hat{\beta}_{Lit} = 0.5401$), whereas all other statistically significant

[13]Because there is very little variability in the 2000 data, nor the latter nor pooled data are used in the MLE regression at levels.

[14]Burkina Faso has a 64% chance of belonging to the second group. Even without the inclusion of Burkina Faso, conclusions on country grouping and statistical significance of variables remain the same.

variables (immunization, HIV prevention and control, clean water, pneumonia treatment, political stability and absence of violence, government expenditure on health, and voice and accountability) have negative coefficients. Countries in component 1 are mainly characterized by high initial coverage of interventions and low initial mortality values. It is therefore not particularly surprising that these countries may have faced strong diminishing returns to interventions: rapidly expansion in coverage of interventions was not necessarily going to be associated with significant changes in mortality rates, at the margin. Given these facts, what is in fact interesting is that malaria prevention has a positive coefficient. Although countries in this group had relatively higher coverage for malaria preventative measures, in absolute terms the coverage rate was still low (below 40%).

Although immunization and HIV funding both have negative coefficients, very few countries show decreases in coverage of these interventions. Coverage of pneumonia treatment decreased in only 5 countries for which the mean value of AARC of that intervention is much lower than for those countries which showed increases in coverage (-0.97 versus 3.27). The negative coefficient in all three cases therefore seems most likely to be attributable to diminishing returns, rather than to the adverse impact of reduced interventions. In contrast, there was a fall in access to clean water in seven of these countries over the period studied, so it is highly possible that the negative coefficient on clean water is in fact due to the harm done by the reduction in this intervention. In absolute terms, the mean value of change of access to clean water was 1.12 in countries with decreased coverage versus 1.55 for the remaining ones. The same pattern is found for voice and accountability (VA): although only four countries had decreases in VA, their mean value was -28.3, which is a lot higher than in countries which improved that factor over the studied period (mean value: 2.36). Conversely, the mean values of AARC political stability and government expenditure on health are higher in countries which expanded those values from 2000 to 2008, potentially indicating that the negative coefficient is due to diminishing returns to scale.

Conversely, for the second group of countries (13 countries: Angola, Guinea-Bissau, Malawi, Mali, Mauritania, Namibia, Niger, Rwanda, Senegal, Tanzania, Togo, Uganda and Zambia), the FMM procedure generates a positive coefficient for pneumonia treatment, malaria prevention immunization, and HIV funding ($\hat{\beta}_{pneumonia} = 0.4150$, $\hat{\beta}_{Imm} = 0.1861$, $\hat{\beta}_{M} = 0.0604$ and $\hat{\beta}_{HIV} = 0.0575$), and only clean water has a negative coefficient. Compared to component 1, there are more countries in this component which have high initial mortality levels, and low initial coverage of interventions, so it is not surprising that increasing interventions is coupled with rapid decreases in mortality. What is surprising is to see a negative coefficient associated with clean water, because one of the main causes of child mortality is diarrheal related conditions caused by drinking unsafe water. Both components have relatively high initial coverage of access to clean water. Only two countries out of 11 have decreases in coverage of access to clean water. Their mean value of AARC of access to clean water was -0.72 while countries which expanded coverage had a mean value of change of 2.65. It therefore seems likely, that there are actually diminishing returns to access to clean water for countries belonging to this component.

Turning to contextual variables, there is a positive coefficient for government expenditure on health (not significant for NMR) and for voice and accountability ($\hat{\beta}_{GEH} = 0.1731$, $\hat{\beta}_{VA} = 0.0606$), whereas there is a negative coefficient for political stability and female literacy. In this group, most countries have low initial expenditures on health and high initial mortality rates, so it seems reasonable that modest expansions in health expenditure could be associated with very significant drops in mortality. For voice and accountability, the pattern is not as crisp, but is still consistent with the basic idea that these countries have increasing returns to voice and accountability. The negative signs of female literacy and political stability once again appear to almost certainly be due to diminishing returns. None of the countries in this component had decreases in literacy rates between 2000 and 2008. Additionally, only three countries had reductions in political stability but their mean value of change was -2.15 versus 5.59 for the 10 countries which improved their stability.

Again, although explanations as to why the signs of particular coefficients are positive or negative are necessarily speculative, application of the FMM strongly suggests that there is significant heterogeneity in the underlying relation between reduction of under-5 mortality and health MDG interventions. Whereas expanding efforts to combat malaria is clearly correlated with reduction of child mortality across sub-Saharan Africa, pneumonia treatment is the only other relatively powerful intervention linked to under-5 mortality reduction in component 1 countries whereas in component 2 countries four out of five interventions had positive coefficients, indicating that expansion of these interventions is strongly associated with improved health outcomes in this group of countries.

2.6.4 Regression results for maternal mortality

As in the two previous sections, the first step in the analysis of factors associated with maternal mortality consisted of running MLE regressions on levels and rates. As expected, MLE regressions on levels (first column of Table 2.11) show that the availability or utilisation of skilled medical personnel, HIV funding and control of indirect medical causes of mortality are all associated with statistically significant reductions of maternal mortality. In contrast, when MLE is performed on average annual rates of change, the only health policy intervention which is statistically significant (and positive) is family planning ($\hat{\beta}_{FP} = 6.1440$). Moreover, the magnitude of the marginal change in the AARC of family planning greatly exceeds that of the only other significant variable, government expenditure on health ($\hat{\beta}_{GEH} = 0.1512$). As above, however, it may be suspected that the relationship between interventions and mortality is masked by the MLE procedure, and so it is useful to apply the FMM. The FMM regression once again converges (and saturates) at two components and its information criterion values are lower than that of MLE (see Table 2.12 for numerical values). This supports the usage of FMM in preference to MLE. The first FMM group is formed of 13 countries: Benin, Burundi[15], Côte d'Ivoire[15], Ethiopia, Ghana, Madagascar, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Sudan and Zambia. For these countries, the coefficients on family planning ($\hat{\beta}$ = 3.3074), control of indirect medical causes of maternal mortality ($\hat{\beta}$ = 0.4887) and availability or utilisation of skilled medical personnel ($\hat{\beta}$ = 0.4534) are positive, indicating that the rate of change of mortality rates was greater than the rate of change of these interventions. The impact of family planning on the reduction of maternal mortality is close to 7 times greater than that of the second most effective intervention. Compared to countries of group 2, this group is characterized by more countries with low initial maternal mortality rates. As will be seen below, the sign for family planning and for the availability of skilled medical personnel is positive for both components, suggesting that these are potentially powerful levers throughout the region for reducing maternal mortality. The coefficient for HIV funding for component one countries is negative, although with a coefficient of -0.0041 it is only slightly below zero (implying that there were almost constant returns to scale for HIV funding since all countries had expansions in HIV funding between 2000 and 2008). Contextual factors also affect reductions in maternal mortality in component one countries. Empowerment of women through knowledge has a positive coefficient for both components, indicating that this contextual factor is potentially, like met family planning and access to medical personnel, an effective lever throughout the region: providing women with greater knowledge could allow them to make choices that reduce their mortality, even in the absence of health system resources. At the margin, faster rates of increase of government expenditures on health; voice and accountability; and government effectiveness are linked with even more rapid increases in the average annual rate of reduction of maternal mortality. Both voice and accountability and government expenditure on

[15]The probability of belonging to component 1 is between 50% and 60% for Burundi and 60% and 90% for Côte d'Ivoire. Even without the inclusion of these countries the set of statistically significant variables remains the same.

health are linked with high initial levels of coverage and low initial mortality rates, which suggest that there may be diminishing returns to scale to these inputs. It is impossible to discern if the negative coefficient of AARC of political stability (PS) is due to worsening of stability observed in close to half of the countries of the group (6 countries, mean AARC of PS of -3.35 versus 7 countries with a mean AARC of PS of 4.13) or to diminishing returns.

The second FMM group has 12 countries (Burkina Faso, Cameroon, Central African Republic, Gambia, Guinea-Bissau, Malawi, Mali, Mauritania, Niger, Tanzania, Togo and Uganda). A marginal increase in the coverage of all interventions leads to an even greater change in the average rate of reduction of mortality. The economic significance of family planning, with a coefficient of 10.7411, overshadows that of all the other variables ($\hat{\beta}_{health\,workforce}$= 0.3746, $\hat{\beta}_{HIV}$=0.0115, $\hat{\beta}_{water}$=0.1191), and is in fact three times larger than that obtained for countries in group 1. The gradient of the function by which mortality reduction is formed is also convex in government expenditure on health and, voice and accountability. Women's empowerment through knowledge has a negative coefficient. This is very likely due to diminishing returns as only one out of 12 countries had a small reduction of female literacy (-0.077 versus the average change of 3.08 observed in the other countries of this component). A similar pattern characterizes government effectiveness. Three countries had worsening of effectiveness (with a mean value of -1.69) while the remaining nine showed large increases in this governance indicator (mean value of 2.5). The positive sign of coefficients of AARC of government expenditure on health and voice and accountability can be explained by their low initial levels in settings where mortality rates are high. These variables exhibit increasing returns to scale. In summary, application of the FMM procedure generates results which strongly suggest that the link between maternal mortality reduction and health interventions varies across the 25 sub-Saharan African countries studied. Whereas met family planning and access to skilled medical personnel were found to be strongly associated with maternal mortality reduction throughout the region, as was women's empowerment through knowledge, the coefficients for other interventions differ between component 1 and component 2 countries, suggesting that expansions in interventions need to be thoughtfully targeted.

2.7 Conclusions and Policy Implications

This chapter analyzes the effectiveness of Millennium Development Goal health interventions in sub-Saharan Africa. The main objective is the empirical examination of the extent to which United Nations interventions are linked to the reduction of neonatal, child and maternal mortality in 32 sub-Saharan African countries. Although there is a large body of literature on the clinical causes of mortality, a relatively smaller number of papers address the actual effectiveness of MDG interventions taken to better health outcomes. The literature review of single- and cross-country studies reveals little consensus as to the actual effectiveness of actions taken to reduce mortality: there are no interventions which are consistently found to be effective, and most interventions are typically ineffective. This chapter explores a potential explanation for this lack of consensus: perhaps the implicit assumption that the relation between mortality reduction and change in intervention coverage is identical across sub-Saharan African countries masks the potential effectiveness of interventions.

The results of this chapter are indeed suggestive that there may be underlying heterogeneity in the nature of the relationship between mortality and interventions across the region, regardless of whether one is interested in child or maternal mortality. Countries are consistently sorted into two groups (the composition of each group differs depending on the mortality variable selected), and the estimated impact of most interventions varies across these groups. It must be stressed that the application of the FMM methodology does not allow us to discriminate between three potential competing explanations for this heterogeneity. The fact that the procedure converges into two components is consistent with the possibility that there are two distinct health production technologies, and as discussed above, there are good reasons to believe that similar intervention strategies may be differently effective in different countries. However, it is also possible that this reflects differences in the efficiency of SSA countries in using their health resources: one component may be relatively efficient, and the other relatively inefficient. Strikingly however, there does not appear to be any significant overlap between the composition of the countries in each component, and the groupings of countries on the efficiency frontier in Chapter 1. A third potential explanation is that, although there is only one production technology, the countries in each of the components are in a 'different part' of the production function. From a practical point of view, however, this does not lead to different policy guidance with respect to the recommendation that would be provided if one believes that production technologies are in fact different: in both cases, what is important is that the results suggest that interventions may be more effective than what the literature has suggested, and that a 'one size fits all' approach to implementing interventions is inappropriate.

This chapter also contributes to the relatively small literature which analyze several interventions at a time. It simultaneously includes several interventions, and finds that they are typically significant. Furthermore, unlike the majority of papers, this chapter includes multiple contextual factors alongside interventions and shows that indeed they too are significant.

Interventions are not necessarily equally effective across all countries which suggests that policies geared at mortality reduction should be tailored to the context in which they are implemented. For example, increasing immunization is highly effective in countries like Togo and Uganda but appears to exhibit diminishing returns in countries like Ghana and South Africa.[16]

[16] Although several factors were analysed (e.g. financial barriers in accessibility captured by gasoline prices; geographical limitations represented by landlocked situations; differences in usage of technological advances such as internet and mobile technology; population size; colonization history) in an attempt to identify what drives the component formation, nothing stood out as helping to shed light on the country groupings observed in this chapter.

Based on these associations, a decision to increase coverage of an intervention across all countries may not be an effective policy. For example, for certain group of SSA countries, neonatal mortality reduction is faster when the rate of change of placental malaria control was increased, whereas in other countries, a greater expansion of that intervention appears to generate much lower returns. Similarly, in some countries expanded immunization coverage and treatment for pneumonia appear to be the most effective tools for reducing child mortality, whereas other countries may be facing diminishing returns to these interventions.

Policies geared at reduction of child morality should also take note of the fact that, of all the interventions considered, only prevention of malaria had a positive coefficient for countries in both components. Also, although several maternal health interventions are associated with the reduction of mortality, family planning is by far the most effective measure across all the countries analyzed. In one group of countries, family planning is linked to a seven times greater mortality reduction the next intervention with the highest coefficient, while in the other group of countries, the relationship is close to 30 times greater.

Although the current study offers promising insight into what could lead to better health outcomes in the developing world, there is room for improvement. With more and better data collected more frequently, future studies would not have to rely on proxies for certain variables nor on average annual rates of change; annual data would provide much more useful insight for guiding the health agenda, and particularly for tailoring it to the specific features of individual countries. Additionally, as more recent data becomes available, the study could be performed by using the 2008 data as a baseline. The advantage being that due to strong suggestions made by international organizations, after evaluating MDG at the mid-point of the initiative, it is likely that coverage of interventions had only increased since 2008. Using a dataset where interventions have only positive rates of change over time would greatly facilitate the interpretation of negative coefficients.

It must also be stressed that the results presented in this chapter are merely correlations: there is no claim of causality. It is of course evident that the scale and scope of interventions are the result of policy decisions. In countries with high rates of HIV prevalence, it may be anticipated that Ministries of Health and international funding agencies will make a particular effort to combat this scourge, whereas in countries with a lesser problem, fewer resources will be devoted to this fight. Whereas the results of the FMM procedure, applied both to the dataset constructed for this study and to Lawn et al.'s dataset, consistently point to underlying heterogeneity, this does not by any means exclude the possibility that another reason for the inconsistent message in the existing literature on the effectiveness of interventions is that this is attributable to endogeneity.

Although mortality did fall in the region between 2000 and 2008, the rate of change of morality observed during that period is, for the vast majority of countries, insufficient to reach MDG targets; only five countries, Rwanda, Malawi, Niger, Madagascar and Ethiopia, can hope to attain the child mortality target, and, at the rates of change observed between 2000 and 2008, no country will reach the maternal mortality target. The current chapter examines the effectiveness of interventions without taking account of their relative cost. The next chapter investigates cost minimizing strategies for attaining MDG mortality targets.

2.8 Tables

Table 2.1: Under-5 mortality rates (per 1,000) for 1990, 2008 & 2012 and MDG targets

country	U5MR 1990	U5MR 2008	U5MR 2012	Target for 2015	Reduction 1990-2008	Reduction 1990-2012
Angola	243	167	164	81	31%	32%
Benin	177	115	90	59	35%	49%
Burkina Faso	208	155	102	69	26%	51%
Burundi	183	146	104	61	20%	43%
Cameroon	145	132	95	48	9%	34%
Central African Republic	169	167	129	56	1%	23%
Côte d'Ivoire	151	121	108	50	20%	36%
Eritrea	138	75	52	46	46%	62%
Ethiopia	198	90	68	66	54%	66%
Gambia	165	108	73	55	34%	56%
Ghana	121	83	72	40	31%	40%
Guinea-Bissau	210	166	129	70	21%	39%
Madagascar	161	71	58	54	56%	64%
Malawi	227	102	71	76	55%	69%
Mali	257	185	128	86	28%	50%
Mauritania	125	114	84	42	9%	33%
Mozambique	226	119	90	75	47%	60%
Namibia	73	54	39	24	26%	47%
Niger	314	145	114	105	54%	64%
Nigeria	214	139	124	71	35%	42%
Rwanda	156	76	55	52	51%	65%
Senegal	136	79	60	45	42%	56%
South Africa	62	67	45	21	-7%	27%
Sudan	123	91	73	41	26%	41%
Tanzania	158	82	54	53	48%	66%
Togo	147	115	96	49	22%	35%
Uganda	178	102	69	59	43%	61%
Zambia	193	106	89	64	45%	54%
Zimbabwe	79	82	90	26	-3%	-14%

Source: The World Bank (http://data.worldbank.org/)

Table 2.2: Maternal mortality rates (per 100,000 live births) for 1990, 2008 and MDG targets

country	MMR 1990	MMR 2008	Target for 2015	Reduction 1990-2008
Benin	790	410	198	48%
Burkina Faso	770	560	193	27%
Burundi	1200	970	300	19%
Cameroon	680	600	170	12%
Central African Republic	880	850	220	3%
Côte d'Ivoire	690	470	173	32%
Ethiopia	990	470	248	53%
Gambia	750	400	188	47%
Ghana	630	350	158	44%
Guinea-Bissau	1200	1000	300	17%
Madagascar	710	440	178	38%
Malawi	910	510	228	44%
Mali	1200	830	300	31%
Mauritania	780	550	195	29%
Mozambique	1000	550	250	45%
Namibia	180	180	45	0%
Niger	1400	820	350	41%
Nigeria	1100	840	275	24%
Rwanda	1100	540	275	51%
Senegal	750	410	188	45%
Sudan	830	750	208	10%
Tanzania	880	790	220	10%
Togo	650	350	163	46%
Uganda	670	430	168	36%
Zambia	390	470	98	-21%

Source: The World Bank (http://data.worldbank.org/)

Table 2.3: Description of interventions and contextual variables

VARIABLE	DESCRIPTION	SOURCE
Contextual variables		
Economic indicator		
GGEH	General government expenditure on health per capita (2011 USD)	National Health Accounts (WHO)
PEH	Private government expenditure on health per capita (2011 USD)	National Health Accounts (WHO)
TEH	Total government expenditure on health per capita (2011 USD)	National Health Accounts (WHO)
Gender related issues		
Female Literacy rate (FLR)	Literacy rates of 15-24 years old women	United Nation (http://data.un.org/)
Governance indicators		
Political stability and absence of violence (PS)	Index of commonality of political unrest and terrorist threat (continuous variable between 0 and 100); lower values indicate less stability	Global Insight Business Risk and Condition (info.worldbank.org/governance/wgi/pdf/WMO.xlsx)
Voice and accountability (VA)	Institutional permanence Representativeness (continuous variable between 0 and 100) lower values indicate lower performance and representativeness)	Global Insight Business Risk and Condition

Description of interventions and contextual variables

VARIABLE	DESCRIPTION	SOURCE
Government effectiveness (GE)	Policy consistency & forward planning (continuous variable between 0 and 100) ; lower values indicate less effectiveness	Global Insight Business Risk and Condition
Regulatory quality (RQ)	Tax and legislative effectiveness (continuous variable between 0 and 100); lower values indicate less effectiveness	Global Insight Business Risk and Condition
Rule of Law (RL)	Level of distortion in the legal system and criminality (continuous variable between 0 and 100) ; lower values indicate more distortion	Global Insight Business Risk and Condition
Control of Corruption	Measure of bureaucracy, red tape and corruption (continuous variable between 0 and 100) ; lower values indicate more corruption	Global Insight Business Risk and Condition
Interventions that address neonatal mortality		
Neonatal mortality (NMR)	Number of neonates dying before reaching 28 days of age, per 1,000 live births in a given year (neonatal mortality rate)	The World Bank (http://data.worldbank.org/)
Behavioral activities		
Exclusive breastfeeding (EBF)	Percentage of children less than six months old who are fed breast milk alone (exclusive breastfeeding)	The State of the World's Children 2005 & 2010

Description of interventions and contextual variables

VARIABLE	DESCRIPTION	SOURCE
Preventative and antenatal care		
HIV	Commitment of official development assistance for control of sexually transmitted infections including HIV/AIDS (2011 USD)	Creditor Reporting System OECD data
Placental malaria control	Number of newborns out of 100 live births who weight more than 2,500 gram	The World Bank (http://data.worldbank.org/)
Antenatal care (ANC)	Percentage of women aged 15-49 years attended at least once during pregnancy by skilled health personnel	The State of the World's Children 2005 & 2010
Medical personnel		
Skill birth attendants (SBA)	Percentage of births with skilled birth attendant	The State of the World's Children 2005 & 2010

Interventions that address under-5 mortality

Under-5 mortality rate (U5MR)	Number of deaths before five years of age expressed per 1,000 live births	The World Bank (http://data.worldbank.org/)
Immunization		
Measles vaccination (MCV)	Percentage of one-year-olds who have received at least one dose of measles-containing vaccine	The State of the World's Children 2005 & 2010

Description of interventions and contextual variables

VARIABLE	DESCRIPTION	SOURCE
Preventative, antenatal and perinatal care		
HIV	Committed official development assistance for control of sexually transmitted infections including HIV/AIDS	Creditor Reporting System OECD data
Malaria control	Proportion of children aged 0-59 months sleeping under a net of any type	UNICEF Global Database
Pneumonia treatment	Percentage of under-fives with suspected pneumonia taken to an appropriate health-care provider	The State of the World’s Children 2005 & 2010
Clean water	Percentage of urban population using improved drinking water sources	The State of the World’s Children 2005 & 2010
Medical personnel		
Physicians	Physicians density (per 10,000 population)	Global Health Observatory (WHO)
Interventions that address maternal mortality		
Maternal mortality ratio (MMR)	Number of women who die during pregnancy and childbirth, per 100,000 live births	The World Bank (http://data.worldbank.org/)

Description of interventions and contextual variables

VARIABLE	DESCRIPTION	SOURCE
Primary and secondary care		
HIV	Committed official development assistance for control of sexually transmitted infections including HIV/AIDS (2011 USD)	Creditor Reporting System OECD data
Clean water	Percentage of urban population using improved drinking water sources (indirect causes of mortality)	The State of the World's Children 2005 & 2010
Medical personnel		
Malaria control	Proportion of children aged 0-59 months sleeping under a net of any type	UNICEF Global Database
Skill birth attendants (SBA)	Percentage of births with skilled birth attendant	The State of the World's Children 2005 & 2010
Reproductive care		
Met family planning	Successful family planning calculated as avoided teen pregnancies (from teen fertility rates): number of women, of ages 15-19, out of 1,000 that are not pregnant	Dr. J Lawn's extrapolated World Bank data

Table 2.4: Correlations between changes in interventions and contextual variables

Neonatal mortality

	dNMR	dBCG	dDPT3	dPolio	dMCV	dTetanus	dANC	dPhys	dEBF	dnet	dGNI	dGGEH
dNMR	1											
dBCG	-0.048	1										
dDPT3	-0.181	0.535	1									
dPolio	-0.052	0.506	0.923	1								
dMCV	-0.169	0.363	0.782	0.682	1							
dTetanus	-0.015	0.843	0.536	0.430	0.482	1						
dANC	-0.177	0.074	0.224	0.253	0.323	0.109	1					
dPhys	0.140	0.004	0.043	0.079	-0.143	0.159	-0.381	1				
dEBF	0.041	-0.206	0.144	0.102	0.302	-0.055	0.135	-0.011	1			
dnet	0.399	0.016	-0.085	-0.129	-0.032	0.085	-0.115	0.170	0.044	1		
dGNI	0.087	0.043	0.155	0.094	0.049	-0.007	-0.202	0.232	0.401	0.046	1	
dGGEH	0.558	-0.027	0.179	0.329	0.009	-0.092	0.274	0.016	0.161	0.250	-0.047	1
dPEH	0.276	0.282	0.331	0.343	0.151	0.170	0.186	-0.059	0.205	0.162	0.340	0.530
dTEH	0.407	0.062	0.225	0.328	0.051	-0.071	0.249	-0.042	0.216	0.276	0.236	0.806
dstability	0.129	0.281	-0.049	-0.097	-0.149	0.531	0.163	-0.146	-0.129	0.028	-0.156	0.178
dGE	0.351	0.428	0.163	0.167	0.163	0.557	-0.086	0.173	0.295	0.342	0.254	0.324
dVA	0.176	0.055	0.005	0.031	-0.133	0.229	-0.088	0.328	0.359	0.114	0.388	0.340
dRQ	0.416	0.304	0.210	0.268	0.133	0.208	-0.157	0.226	0.118	0.303	0.266	0.500
dLaw	0.304	0.242	0.071	0.110	-0.057	0.499	-0.076	0.463	0.151	0.048	0.148	0.394
dCorrupt	0.069	0.119	0.132	0.175	-0.094	0.421	-0.057	0.353	0.097	0.016	0.171	0.354
dFLR	-0.087	0.058	0.171	0.152	0.243	0.105	0.184	0.080	0.062	-0.313	-0.265	-0.042
dHIV	-0.098	0.045	0.020	-0.143	-0.138	-0.203	-0.113	-0.016	-0.357	-0.081	0.005	-0.178
dFPlan	-0.154	0.077	0.176	0.054	0.140	0.193	-0.084	0.282	0.142	0.090	0.156	0.022
dPMalaria	0.035	-0.165	-0.121	-0.142	0.042	0.103	-0.038	-0.070	0.121	0.076	0.085	-0.035

Note: *Immunizations: BCG, DPT3, Polio, MCV & tetanus; ANC: antenatal care; Phys: physicians; EBF: exclusive breastfeeding; net: malaria bednets; GGEH: government expenditure on health; GE: government effectiveness; VA: voice & accountability; RQ: regulatory quality; Law: rule of law; Corrupt: control of corruption; FLR: female literacy rates; dFPlan: family planning; PMalaria: placental malaria.*

Correlations between changes in interventions and contextual variables

	dPEH	dTEH	dStability	dGE	dVA	dRQ	dLaw	dCorrupt	dFLR	dHIV	dFPlan	dPMal.
dPEH	1											
dTEH	0.892	1										
dStability	0.195	0.172	1									
dGE	0.278	0.288	0.218	1								
dVA	0.436	0.482	0.422	0.537	1							
dRQ	0.456	0.500	-0.047	0.654	0.366	1						
dLaw	0.262	0.230	0.340	0.594	0.647	0.448	1					
dCorrupt	0.284	0.289	0.261	0.527	0.653	0.333	0.653	1				
dFLR	-0.275	-0.259	-0.194	-0.009	-0.209	-0.001	0.059	-0.107	1			
dHIV	-0.112	-0.202	-0.148	-0.196	-0.158	-0.151	-0.005	-0.265	0.022	1		
dFPlan	0.094	0.053	0.331	-0.037	0.424	0.187	0.231	0.260	-0.044	-0.099	1	
dPMalaria	-0.024	0.008	0.357	0.141	0.289	-0.053	0.304	0.054	-0.282	-0.127	0.111	1

Child Mortality

	dU5MR	dBCG	dDPT3	dPolio	dMCV	dSBA	dANC	dPhys	dEBF	dNet
dU5MR	1.000									
dBCG	-0.093	1								
dDPT3	-0.189	0.632	1							
dPolio	-0.083	0.635	0.937	1						
dMCV	-0.078	0.420	0.769	0.720	1					
dSBA	-0.096	0.809	0.668	0.593	0.614	1				
dANC	-0.453	0.383	0.551	0.420	0.721	0.336	1			
dPhys	0.056	0.114	0.134	0.115	-0.009	0.001	-0.265	1		
dEBF	0.075	-0.262	0.141	0.152	0.177	0.143	-0.036	0.172	1	
dNet	0.457	0.021	-0.145	-0.186	-0.060	0.029	-0.155	0.201	-0.018	1

Note: *PEH: private expenditure on health; TEH: total expenditure on health;GE: government effectiveness; VA: voice & accountability; RQ: regulatory quality; Law: rule of law; Corrupt: control of corruption; FLR: female literacy rates; dFPlan: family planning;* PMalaria: placental malaria

Correlations between changes in interventions and contextual variables

	dU5MR	dBCG	dDPT3	dPolio	dMCV	dSBA	dANC	dPhys	dEBF	dNet	dHIV	dPneum.
dHIV	-0.111	0.063	0.082	-0.080	-0.128	-0.060	-0.118	0.019	-0.295	-0.101	1	
dPneum.	0.405	0.032	0.173	0.194	0.071	0.081	-0.083	0.343	0.206	0.171	-0.100	1
dwater	-0.088	0.395	0.184	0.087	0.053	0.534	0.243	-0.094	-0.134	0.111	0.031	0.104
dGNI	0.093	0.018	0.218	0.197	-0.043	-0.123	-0.332	0.361	0.408	-0.003	0.107	0.141
dGGEH	0.442	-0.021	0.241	0.354	0.088	0.254	0.395	-0.032	0.291	0.223	-0.133	0.452
dPEH	0.315	0.307	0.325	0.382	0.044	0.173	0.065	0.071	0.130	0.130	-0.070	0.179
dTHE	0.471	0.093	0.221	0.344	-0.021	0.201	0.194	0.040	0.186	0.234	-0.157	0.323
dVA	0.198	-0.025	0.016	0.040	-0.103	0.475	-0.067	0.321	0.425	0.154	-0.182	0.008
dGE	0.393	0.181	0.160	0.180	0.270	0.366	-0.096	0.181	0.361	0.478	-0.249	0.044
dRQ	0.402	0.157	0.280	0.328	0.276	0.097	-0.101	0.189	0.245	0.388	-0.164	0.131
dLaw	0.189	0.019	0.132	0.164	0.089	0.494	0.041	0.450	0.311	0.176	-0.053	0.172
dCorrupt	0.006	0.089	0.183	0.180	0.108	0.482	0.175	0.176	0.268	0.153	-0.304	-0.066
dFLR	-0.118	-0.002	0.168	0.144	0.284	0.308	0.219	0.078	0.078	-0.316	-0.007	0.278
dStability	0.084	0.130	-0.070	-0.106	-0.154	0.421	0.178	-0.165	-0.162	0.061	-0.167	-0.144

	dwater	dGNI	dGGEH	dPEH	dTEH	dVA	dGE	dRQ	dLaw	dCorrupt	dFLR	dStability
dwater	1											
dGNI	-0.008	1										
dGGEH	0.145	0.083	1									
dPEH	0.181	0.319	0.641	1								
dTEH	0.135	0.254	0.881	0.900	1							
dVA	0.130	0.361	0.346	0.506	0.580	1						
dGE	0.059	0.162	0.288	0.320	0.349	0.527	1					
dRQ	0.046	0.293	0.499	0.596	0.628	0.336	0.546	1				

Note: *Immunizations:BCG, DPT3, Polio, MCV & tetanus; SBA: skilled birth attendants; ANC: antenatal care; Phys: physicians; EBF: exclusive breastfeeding; Pneum: pneumonia; GGEH: government expenditure on health; PEH: private expenditure on health; TEH: total expenditure on health; GE: government effectiveness; VA: voice & accountability; RQ: regulatory quality; Corrupt: control of corruption; FLR: female literacy rates.*

Correlations between changes in interventions and contextual variables

	dwater	dGNI	dGGEH	dPEH	dTEH	dVA	dGE	dRQ	dLaw	dCorrupt	dFLR	dStability
dLaw	-0.081	0.095	0.386	0.401	0.365	0.646	0.486	0.259	1			
dCorrupt	0.154	0.134	0.274	0.452	0.405	0.658	0.623	0.213	0.603	1		
dFLR	0.098	-0.260	-0.069	-0.282	-0.261	-0.232	-0.087	-0.061	0.014	-0.137	1	
dStability	0.241	-0.227	0.149	0.191	0.179	0.456	0.068	-0.212	0.261	0.290	-0.245	1

Maternal Mortality

	dMMR	dSBA	dHIV	dWater	dFPlan	dANC	dPhys	dGGEH	dPEH
dMMR	1								
dSBA	0.219	1							
dHIV	-0.109	-0.099	1						
dWater	0.136	0.413	0.004	1					
dFPlan	0.227	-0.323	-0.075	-0.023	1				
dANC	-0.302	0.445	-0.140	0.043	-0.250	1			
dPhys	0.136	0.029	0.036	-0.062	0.133	-0.106	1		
dGGEH	0.347	0.208	-0.353	0.053	-0.292	0.301	0.002	1	
dPEH	0.309	0.079	-0.207	0.078	-0.215	0.019	0.142	0.482	1
dTHE	0.415	0.161	-0.319	0.032	-0.295	0.177	0.142	0.827	0.871
dVA	0.317	0.403	-0.215	-0.050	-0.190	0.043	0.394	0.344	0.484
dGE	0.319	0.403	-0.272	0.069	-0.101	0.102	0.179	0.302	0.332
dRQ	0.370	0.117	-0.327	0.037	0.032	0.106	0.300	0.306	0.489
dRL	0.238	0.544	-0.109	-0.121	-0.217	0.108	0.471	0.334	0.389
dCorrupt	0.093	0.462	-0.345	0.080	-0.391	-0.005	0.192	0.238	0.449

Note: *SBA: skilled birth attendants; Fplan: family planning; ANC: antenatal care; Phys: physicians; GGEH: government expenditure on health; TEH: total expenditure on health; VA: voice & accountability; GE: government effectiveness; PEH: private expenditure on health; RQ: regulatory quality; Law: rule of law; Corrupt: control of corruption; FLR: female literacy rates.*

Correlations between changes in interventions and contextual variables

	dMMR	dSBA	dHIV	dWater	dFPlan	dANC	dPhys	dGGEH	dPEH
dFLR	-0.099	0.409	0.001	0.207	0.077	0.467	0.029	-0.095	-0.298
dStability	0.259	0.233	-0.223	-0.149	0.087	-0.093	-0.192	0.365	0.287
dGNI	-0.100	-0.192	0.098	-0.084	-0.483	-0.129	0.397	0.061	0.316

	dTHE	dVA	dGE	dRQ	dRL	dCorrupt	dFLR	dStability	dGNI
dTHE	1								
dVA	0.524	1							
dGE	0.389	0.572	1						
dRQ	0.481	0.321	0.616	1					
dRL	0.444	0.790	0.506	0.292	1				
dCorrupt	0.404	0.658	0.628	0.198	0.661	1			
dFLR	-0.235	-0.179	-0.111	-0.029	-0.046	-0.143	1		
dStability	0.365	0.324	0.150	-0.108	0.426	0.333	-0.223	1	
dGNI	0.257	0.339	0.171	0.328	0.099	0.126	-0.229	-0.466	1

Note: *TEH: total expenditure on health; VA: voice & accountability; GE: government effectiveness; PEH: private expenditure on health; RQ: regulatory quality; Law: rule of law; Corrupt: control of corruption; FLR: female literacy rates.*

Table 2.5: World Governance Indicators

Voice and Accountability

Institutional permanence: An assessment of how mature and well-established the political system is. It is also an assessment of how far political opposition operates within the system or attempts to undermine it from outside.

Representativeness: How well the population and organised interests can make their voices heard in the political system. Provided representation is handled fairly and effectively, it will ensure greater stability and better designed policies.

Political Stability and Absence of Violence

Civil unrest: How widespread political unrest is, and how great a threat it poses to investors. Demonstrations in themselves may not be cause for concern, but they will cause major disruption if they escalate into severe violence. At the extreme, this factor would amount to civil war.

Terrorism: Whether the country suffers from a sustained terrorist threat, and from how many sources. The degree of localisation of the threat is assessed, and whether the active groups are likely to target or affect businesses.

Government Effectiveness

Bureaucracy : An assessment of the quality of the country's bureaucracy. The better the bureaucracy the quicker decisions are made and the more easily foreign investors can go about their business.

Policy consistency and forward planning: How confident businesses can be of the continuity of economic policy stance - whether a change of government will entail major policy disruption, and whether the current government has pursued a coherent strategy. This factor also looks at the extent to which policy-making is far-sighted, or conversely aimed at short-term economic advantage.

Regulatory Quality

Tax Effectiveness: How efficient the country's tax collection system is. The rules may be clear and transparent, but whether they are enforced consistently. This factor looks at the relative effectiveness too of corporate and personal, indirect and direct taxation.

Legislation: An assessment of whether the necessary business laws are in place, and whether there any outstanding gaps. This includes the extent to which the country's legislation is compatible with, and respected by, other countries' legal systems.

Rule of Law

Judicial Independence: An assessment of how far the state and other outside actors can influence and distort the legal system. This will determine the level of legal impartiality investors can expect.

Crime: How much of a threat businesses face from crime such as kidnapping, extortion, street violence, burglary and so on. These problems can cause major inconvenience for foreign investors and require them to take expensive security precautions.

Control of Corruption

Corruption : An assessment of the intrusiveness of the country's bureaucracy. The amount of red tape likely to countered is assessed, as is the likelihood of encountering corrupt officials and other groups.

Source: Global Insight Global Risk Service website

Table 2.6: Descriptive statistics

Neonatal mortality

	dNMR	dBCG	dDPT3	dPolio	dMCV	dTetanus	dANC	dPhys	dEBF	dNet	dGNI	dGGEH
Mean	1.757	2.539	3.226	3.147	2.509	8.103	1.057	3.889	3.131	10.643	-4.298	7.165
SD	1.298	3.571	3.819	3.709	3.109	6.281	1.273	6.178	8.600	11.778	4.449	6.133
Min	0.000	-2.477	-2.351	-2.562	-2.442	0.138	-1.028	-14.185	-10.899	-4.393	-16.732	-8.045
Max	5.923	9.735	11.259	11.795	9.964	21.820	4.364	13.294	23.877	55.791	2.534	22.928

	dPEH	dTEH	dStability	dGE	dVA	dRQ	dLaw	dCorrupt	dFLR	dHIV	dFPlan	dpMal.
Mean	4.812	6.121	2.718	1.905	2.198	1.192	1.159	2.359	2.152	38.522	1.694	0.045
SD	5.350	5.020	6.992	4.210	6.375	3.335	3.720	5.061	1.956	57.712	2.692	0.5727
Min	-5.569	-6.739	-5.426	-4.215	-16.338	-7.849	-6.030	-8.300	-0.077	-8.471	-2.398	-2.105
Max	18.100	20.156	23.806	12.023	13.324	9.051	12.023	14.910	7.871	306.218	10.886	1.450

Child Mortality

	dU5MR	dBCG	dDPT3	dPolio	dMCV	dSBA	dANC	dPhys	dEBF	dNet	dHIV	dPneum.
Mean	3.180	2.257	3.515	3.457	2.587	2.329	1.076	3.818	3.698	10.878	40.154	1.976
SD	2.171	3.202	4.003	3.888	2.985	3.461	1.191	5.958	8.428	12.164	57.300	3.675
Min	0.390	-2.477	-2.351	-2.562	-2.200	-6.790	-1.028	-14.185	-10.822	-4.393	-8.471	-3.267
Max	10.432	9.250	11.259	11.795	9.964	9.471	4.364	13.294	23.877	55.791	306.218	9.051

	dWater	dGNI	dGGEH	dPEH	dTEH	dVA	dGE	dRQ	dLaw	dCorrupt	dFLR	dStability
Mean	1.164	-4.163	7.393	4.991	6.407	1.708757	1.249	0.835	0.459	1.525	2.125	2.139
SD	2.652	4.761	6.266	5.331	5.158	6.433066	3.695	3.059	3.155	4.605	2.006	6.882
Min	-2.253	-16.732	-8.045	-5.569	-6.739	-16.3384	-4.942	-7.849	-6.030	-8.300	-0.077	-5.426
Max	9.447	4.944	22.928	18.100	20.156	13.3238	9.051	7.322	6.487	9.051	7.871	23.806

Note: *d(variable): average annual rate of change; Immunization: BCG, DPT3, polio, MCV; ANC: antenatal care; Phys: physicians; EBF: exclusive breastfeeding; Pneum: pneumonia; GGEH: government expenditure on health; PEH: private expenditure on health; TEH: total expenditure on health; VA: voice and accountability; GE: government effectiveness; RQ: regulatory quality; Law: rule of law; Corrupt: control of corruption; FLR: female literacy rates; FPlan: family planning; pMal: placental malaria (underweight newborns).*

Descriptive statistics

Maternal Mortality

	dMMR	dSBA	dHIV	dWater	dFPlan	dANC	dPhys	dGGEH	dPEH	dTEH	dVA	dGE
Mean	3.129	2.169	42.250	0.962	0.247	2.199	4.042	8.291	5.360	6.660	1.272	1.409
S.D.	1.787	3.371	60.601	2.484	0.156	2.677	6.324	5.124	4.910	4.463	6.370	3.962
Min.	0.328	-6.790	-8.471	-2.253	0.043	-0.942	-14.185	-2.649	-2.592	-2.369	-16.338	-4.942
Max.	8.510	9.471	306.218	9.447	0.640	10.173	13.294	22.928	18.100	20.156	12.023	9.051

	dRQ	dRL	dCorrupt	dFLR	dStability	dGNI
Mean	1.134	0.714	1.636	2.300	0.837	-4.347
S.D.	2.740	3.121	4.833	2.073	4.999	4.983
Min.	-3.372	-6.030	-8.300	-0.077	-5.426	-16.732
Max.	7.322	6.487	9.051	7.871	7.036	4.944

Note: *d(variable): average annual rate of change; FPlan: family planning; ANC: antenatal care; Phys: physicians; GGEH: government expenditure on health; PEH: private expenditure on health; TEH: total expenditure on health; VA: voice and accountability; GE: government effectiveness; RQ: regulatory quality; Law: rule of law; Corrupt: control of corruption; FLR: female literacy.*

Table 2.7: Regression Results for Neonatal Mortality Rate

	MLE 2008 Level (1)	MLE Rate (all) (2)	FMM C1 Rate (3)	FMM C2 Rate (4)
Antenatal Care	0.2451*	-0.3123*	-0.4595**	-0.3504**
Exclusive Breastfeeding	-0.1098†	-0.0077	-0.0250	-0.0220**
Skilled Birth Attendants	-0.1588	-0.0629	-0.3678**	-0.1101**
Control of Placental Malaria	-0.1800	0.1208	-1.3998**	0.2793**
Political Stability/ Absence of Violence	-0.1540*	-0.0337	0.0612	0.0615**
Female Literacy	-0.1622**	-0.0178	0.4117**	-0.0830**
Government expenditure on health	-0.0010	0.1988**	-0.0214	0.2327 *
Voice & Accountability	0.2226†	-0.0355**	0.0817**	-0.0251**
Government Effectiveness	-0.2829†	0.0600	-0.1668**	0.0273**
Constant	64.8415**	0.8301*	1.9023**	0.8955**

n= 31; Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%

Table 2.8: Information Criterion for NMR data

	MLE	FMM
AIC	100.2218	31.026
BIC	121.1729	74.424

Table 2.9: Regression Results for Under-five Mortality Rate

	MLE 2008 Level (1)	MLE Rate (all) (2)	FMM C1 Rate (3)	FMM C2 Rate (4)
MCV	0.2523	-0.1163	-0.0700**	0.1861**
Physicians	7.0008	-0.0644	0.0033	0.0190
HIV	-0.0135	0.0034	-0.0058**	0.0575**
Water	-0.6817†	-0.1864†	-0.6176**	-0.3280**
Pneumonia treatment	-0.2452	0.1941†	-0.0676**	0.4150**
Malaria Prevention	0.4661	0.0441	0.0948**	0.0604**
Political Stability/ Absence of Violence	0.1215	-0.0075	-0.1135**	-0.1200**
Female Literacy	-1.0783**	-0.0412	0.5401**	-0.6411**
Government expenditure on health	0.0223	0.1232†	-0.0538**	0.1731**
Voice and Accountability	0.9041†	-0.0318†	-0.0276**	0.0606*
Government Effectiveness	-2.2378*	0.1963*	-0.0241	-0.0698
Constant	256.19**	1.8330*	1.1868**	0.2334

n= 29; Significance levels: $\dagger$: 10%, $*$: 5%, $**$: 1%

Table 2.10: Information Criterion for U5MR data

	MLE	FMM
AIC	137.8833	75.572
BIC	158.4036	118.078

Table 2.11: Regression Results for Maternal Mortality Rate

	MLE 2008 Level (1)	MLE Rate (all) (2)	FMM C1 Rate (3)	FMM C2 Rate (4)
Medical personnel	-9.5042**	0.1977	0.4534**	0.3746**
HIV	-0.5669*	0.0041	-0.0041**	0.0115**
Clean water	-9.7533**	0.0069	0.4887**	0.1191**
Family planning	-1.065	6.1440**	3.3074**	10.7411**
Political stability/ Absence of Violence	-1.9664	-0.0351	-0.1434**	-0.0278
Female Literacy	-1.2842	-0.2157	0.1491*	-0.3191**
Government expenditure on health	1.2096**	0.1512*	0.1239**	0.1957**
Voice and Accountability	2.8111	0.0292	0.0314†	0.0864**
Government Effectiveness	-8.7426†	0.0254	0.0085	-0.2314**
Constant	3316**	0.2047	1.3693**	-2.8411**

n= 25; Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%

Table 2.12: Information Criterion for MMR data

	MLE	FMM
AIC	116.1233	92.164
BIC	131.1636	123.612

Chapter 3

Cost minimizing simulations for attaining MDG 4 and 5.

3.1 Introduction

The first chapter of this thesis used 2008 data to examine the relative efficiency of countries at using health interventions to combat child and maternal mortality. The second chapter studied the association between the rates of change of both interventions and contextual factors and the rate of change of under-5 and maternal mortality. Whereas the results of this analysis suggest that a number of interventions have an economically and statistically significant impact on these mortality rates, they do not provide guidance to policy-makers because the potential costs associated with interventions are not taken into consideration. The present chapter discusses several distinct cost-minimizing scenarios for attaining specific child and maternal mortality targets in 27 sub-Saharan African countries.

As noted in the previous chapters, there exists a large literature on MDGs. However, most papers study the effectiveness of interventions without considering their (relative) costs. This is perhaps unsurprising given that few papers consider more than one intervention, and so the issue of whether it is better to expand a less effective, but less costly, intervention more rapidly than a more effective, but more costly, intervention does not naturally arise. The first - and main - contribution of this chapter is to link the relation between interventions and health outcomes (MDGs) with the costs associated with each intervention. In this way, I am able to set out options for policy makers for mortality reduction agendas.

A second issue associated with the work that has been done to date concerns the likely endogeneity between interventions and outcomes. It is highly plausible that there exist reverse causality between interventions and mortality rates. For instance, in countries with high initial rates of maternal mortality it is more likely that there will be particular effort made to invest in interventions targeting this particular MDG, whereas in countries with lower initial rates of maternal mortality, it is possible that these interventions will be lesser priorities. Omitted variable bias is another potential source of endogeneity however dealing with this problem is limited by data availability, and hence it is not adequately treated in this chapter. This chapter, however, does attempt to improve upon the endogeneity associated with reverse causality. It is important to keep endogeneity issues in mind to properly interpret the results by acknowledging that the relation studied is one of correlation and not causality.

In order to present cost-minimizing scenarios for attaining MDG goals, the strategy used in this chapter is to regress mortality rates on lagged values of the interventions because it takes time for interventions to have an effect on mortality. The resulting estimates are then employed to determine six cost minimizing scenarios for attaining MDG targets. The second contribution of this chapter is therefore to push forward our understanding of the link between interventions and outcomes by disconnecting the contemporaneous associations between these two elements.

This paper is organized as follows: section 3.2 reviews the literature on the costs of health MDG interventions; section 3.3 describes the methodology used; section 3.4 describes the data; section 3.5 presents and interprets the results while section 3.6 contains a discussion of results, policy recommendations and concluding remarks. A key message of the analysis presented in this chapter is that the enormous lack of physicians in sub-Saharan Africa is a significant impediment to attaining child and maternal mortality targets. Significant increases in coverage of physicians are needed to reach MDG4 and MDG5. However, it is also clear that the context in which the interventions are implemented matters a lot. In particular, improving female literacy or political stability lead to the attainment of mortality targets at much lower cost.

3.2 Literature review

The majority of papers studying the health Millennium Development Goals have been published by public health specialists. Consequently, their main focus is on assessing the effectiveness of interventions rather than on their costs. A relatively small literature undertakes cost-benefit analyses or applies cost effectiveness criteria to assess the desirability of specific interventions. The current chapter focusses on cost-minimizing scenarios for attaining Millennium Development Goals. Because there is no specific literature on this topic, the next few paragraphs describe the literature that is closest to this topic: cost-benefit and cost effectiveness analyses.

A cost-benefit analysis (CBA) compares the costs of a given action to a monetized measure of the benefits accruing as a result of this action. Examples of the use of CBA can be found in papers which address one of the targets of MDG7, *improvement of access to clean water and basic sanitation* (Hutton and Bartram (2008); Jeuland and Whittington (2009); Pattanayak et al. (2010); Uneze et al. (2012)). Direct benefits are the monetized value of time saved by using, for example, borehole water supplies or piped water instead of fetching it. Indirect benefits are measured by monetizing reductions in morbidity and mortality. A dollar amount is put on these actions by taking into account the average wage of unskilled labour and the cost of illness. Although the literature review reveals that CBA has been used in the analysis of actions taken to combat specific medical conditions (e.g. Jeuland et al. (2009): cholera vaccination; Goodchild et al. (2011): tuberculosis; Holtgrave et al. (1993): HIV), the vast majority of papers (especially the more recent ones) focus on the cost-effectiveness of interventions.

A cost-effectiveness (CE) approach relates the costs of an action (e.g. a health intervention) to the outcomes it generates (e.g. cases prevented, lives saved, disability-adjusted life years (DALY), quality-adjusted life year (QALY)). Unlike CBA, the cost-effectiveness of health interventions does not monetize outcomes but rather presents them in their natural health units. Several papers have done CE analysis on single health MDG interventions. For example, Babigumira et al. (2011) use WHO's "Comprehensive Multi Year Plan" data on costs of immunization and project that elimination of measles in Uganda (2050 time horizon) would cost $284 per DALY averted.

Tate et al. (2009) undertake a cost-effectiveness analysis of the rotavirus vaccination in Kenya and find that including it in routine vaccination programmes would cost $2.1 million and would prevent over 2,000 deaths, 5,724 hospitalizations and over 800,000 clinical visits. Additionally, annually, rotavirus would save 58 DALY per 1,000 children. Numerous papers perform cost-effectiveness analyses of paediatric vaccines by following the methodologies mentioned above (Bourdin-Trunz et al. (2006); Cowgill et al. (2006); Sinha et al. (2007); Wu et al. (2012)). A CE analysis on single health interventions may also occur: some examples include a focus on DALY and lives saved by interventions which combat HIV/AIDS (Freedberg et al. (2001); Goldie et al. (2006); Sweat et al. (2000)) and malaria (Bhatia et al. (2004); Conteh et al. (2004); Hanson et al. (2003)) just to name a few.

The vast majority of papers deal with single interventions and not sets of MDG health initiatives. Evans et al. (2005) stands out as an exception, and undertakes a CE analysis of interventions aimed at preventing and controlling malaria, tuberculosis and HIV/AIDS. Cost-effectiveness was measured using the WHO's tool for cost analysis, which has also been employed by Adam et al. (2005) and Johns et al. (2003) to analyze simultaneously the cost-effectiveness of multiple interventions. The algorithm behind WHO's tool resembles John Hopkins Medical school's Lives Saved Tool (LiST) and UNICEF's Marginal Budgeting for Bottlenecks (MBB) approach where one enters data on coverage and estimated costs, and obtains results on costs and lives saved. As stated in Bitran and Associates (2008)'s *Final Reports of Technical Review Of Costing Tools*, WHO's cost analysis program does not include a health production function in its algorithm: effectiveness is measured by algorithm-defined interactions between interventions and, significantly, contextual variables (political stability, GNI,...) are not taken into account by this program. Although, these types of cost-effectiveness tools are user-friendly and generate rapid results, the methodology employed by these various tools does not appear to be clearly grounded in econometric analysis.

This paper builds on the existing work on the cost-effectiveness of interventions aimed at increasing child and maternal survival. It adds to the literature by taking into account the fact that interventions are policy instruments, and that the differences in the scale and scope of particular interventions may be a response to differences in underlying patterns of morbidity and mortality. Consequently, the econometric model underlying the current analysis takes into consideration the potential reverse causality between mortality and interventions. Secondly, the current chapter proposes several cost minimizing scenarios for attaining MDG child and maternal mortality targets by finding the optimal coverage of sets of effective interventions. Lastly, this chapter includes the role of contextual factors in the cost minimizing scenarios.

3.3 Methodology

In order to develop scenarios that identify the combinations of interventions which minimize the costs associated with attaining MDG4 and MDG5, I begin by estimating the link between mortality rate outcomes and various interventions. To accomplish this, the following equation is estimated for 37 countries for MDG4 (child mortality) and 29 for MDG5 (maternal mortality):

$$M_{i,t+j} = \beta_0 + \beta X_{i,t} + \gamma Z_{i,t} + \varepsilon_{i,t} \tag{3.1}$$

where M is the mortality rate observed at time t+j in country i, X is a vector of the coverage of MDG health interventions and Z is a vector of contextual variables both observed at time t . The coverage of an intervention is defined as the number of children out of 100 receiving a specific health action. For example, malaria prevention coverage represents the number of children out of 100 that sleep under bed nets.[1] Contextual variables are also measured on a scale of 100.

Notice that in Equation (3.1), the dependent variable is defined at period t+j but the independent variables are defined at period t. Looking at the impact of interventions that were implemented j years beforehand on mortality rates allows one to control for the potential reverse causality that may arise between interventions and outcomes. An ordinary least squares (OLS) procedure with robust standard errors is used to estimate this equation.

The second stage is a cost minimizing program (see Equations (3.2) to (3.12)). The objective function is comprised of all of the interventions that have a statistically significant estimated coefficient from Equation (3.1). I employ a unit cost for each of these interventions (ω_i) with adjustments for the population size (P_i) targeted by the intervention since they are expressed as coverage rates (x_i). I then solve for the optimal value of these Xs taking account of several important constraints. A Kuhn-Tucker (K-T) programming approach is used: it is estimated separately for the 27 countries for which I have cost information, for both MDGs, and for several scenarios (defined below). The general K-T program is as follows:

[1]Physician density coverage is measured as the number of doctors per 10,000 inhabitants.

$$
\begin{aligned}
\mathcal{L} =& \omega_1\left(\frac{x_1}{100}\right) * P_1 + \omega_2\left(\frac{x_2}{100}\right) * P_2 + \omega_3\left(\frac{x_3}{100}\right) * P_3 + \\
& \lambda[M - \beta_1 x_1 - \beta_2 x_2 - \beta_3 x_3 - \bar{z}] + \\
& \mu_1[100 - x_1] + \mu_2[100 - x_2] + \mu_3[100 - x_3] \\
& \nu_1[x_1 - x_{1,2008}] + \nu_2[x_2 - x_{2,2008}] + \nu_P[x_3 - x_{3,2008}]
\end{aligned} \tag{3.2}
$$

$$\lambda[M - \beta_1 x_1 - \beta_2 x_2 - \beta_3 x_3 - \bar{z}] = 0 \tag{3.3}$$

$$\lambda \geq 0 \tag{3.4}$$

$$[M - \beta_1 x_1 - \beta_2 x_2 - \beta_3 x_3 - \bar{z}] \geq 0 \tag{3.5}$$

∀ i=1,2,3

$$\mu_i[100 - x_i] = 0 \tag{3.6}$$

$$\mu_i \geq 0 \tag{3.7}$$

$$[100 - x_i] \geq 0 \tag{3.8}$$

$$\nu_i[x_i - x_{i,2008}] = 0 \tag{3.9}$$

$$\nu_i \geq 0 \tag{3.10}$$

$$[x_i - x_{i,2008}] \geq 0 \tag{3.11}$$

$$\bar{z} = \beta_0 + \sum_{j=4}^{n} \beta_j x_j \tag{3.12}$$

The constraints in this program are extremely important. Constraints (3.3) and (3.5) use the estimated coefficients from the OLS regressions and constrain them to reach at least M, the MDG target. Equation (3.8) is the constraint which indicates that coverage of an intervention cannot exceed 100 percent.[2] Equation (3.11) is the constraint which indicates that coverage of an intervention cannot drop below that which was observed in a given year (here, 2008). This constraint explicitly prohibits a reduction in the coverage of an intervention on the assumption that such a reduction would cause harm. This assumption is in line with the work of international organizations and local governments in sub-Saharan Africa which want to increase the number of children immunized or protected by other interventions (UNICEF et al. (2009); World Health Organization (2009)). The same applies to interventions aimed at increasing maternal survival.

Many cost minimizing scenarios can be estimated using the K-T program. Here, I focus on six (which represent 312 different Kuhn-Tucker minimizations). The first scenario employs the point estimates of the β_s within a status quo context (using 2008 contextual/environmental factors). The second scenario again uses the point estimates of the β_s but this time allows for an increase in female literacy rates (one of the statistically significant contextual variables) of up to 25%.[3] This scenario takes account of the potential relation between coverage of literacy, interventions and mortality rates. It presents what effect higher literacy rates would have on attaining MDG targets at a lower cost from the perspective of the Ministry of Health. Scenario three uses the lower bound of the estimated β_s based on the standard errors of the coefficients (from Equation (3.1)), with the contextual variables at the status quo (2008) level; the fourth scenario uses the upper bound of the estimated β_s . The two final scenarios again use the point estimates of the β_s but this time the political stability coefficient is modified: its lower bound (again, based on standard errors) is used for the fifth scenario and its upper bound for the sixth.

[2]For physician density, the maximum value cannot exceed 7.3 per 10,000 which is the average physician density in lower and middle income countries; for HIV funding the upper bound limit is the maximum amount of ODA funding for HIV committed to the country between 2000 and 2008 (adjusted for population size).

[3]A 25% increase in female literacy rates is a reasonable expectation given the relatively low levels of literacy in most countries and the ~ 2% average annual rate of change of female literacy rate observed in SSA between 2000 and 2008 (as mentioned in Chapter 2).

It is important to note that effective interventions always decrease mortality, and hence their estimated coefficients are negative. This implies that the lower bound significance level represents a larger negative number. In other words, when I employ the lower bound for the estimated value, this should be viewed as an optimistic scenario. Conversely, coefficients at their upper bound significance level are less negative hence these are referred to as the conservative scenario.

3.4 Data

In 2000 the United Nations launched the Millennium Development Goals initiative, which includes two health objectives: 1) $2/3^{rds}$ reduction of under-five mortality between 1990 and 2015 (MDG4), and 2) $3/4^{th}$ reduction of maternal mortality between 1990 and 2015 (MDG5). For the attainment of these goals, the MDG agenda focuses strongly on the promotion of 12 health interventions. For the purposes of the analysis conducted in this chapter, I exploit publicly available data from UNICEF as well as information from the World Bank, the World Health Organization, the United Nations, the Organisation for Economic Co-operation and Development (OECD) and Mills et al. (2011). The MDG4 analysis includes 37 countries while the MDG5 includes 29 countries. Table 3.1 provides details of all variables used in this analysis and their sources. I turn now to a discussion of the main contextual variables which describe the environment in which the interventions were implemented, followed by a description of the MDG4 and MDG5 interventions. The last subsection discusses how unit costs were established for these interventions.

3.4.1 Contextual variables

The broad environment in which interventions are implemented is represented here by a number of contextual variables. These include economic and governance indicators and measures of the empowerment of women through knowledge.[4]

To ensure that economic indicators are linked to health, this chapter includes government expenditures on health (as a share of total expenditure on health) in the regressions.[5] As discussed in chapter 2, governance indicators also affect mortality. *Political stability and absence of violence* - a measure of civil unrest and terrorist threat; *voice and accountability* - the representativeness of a population in the political arena, and institutional permanence; and *government effectiveness* - the quality of the bureaucratic system, policy consistency and forward planning - were initially considered as independent variables for this analysis. As shown in Table 3.2, however, these variables are highly correlated with each other (scores vary between 0.624 and 0.826) and including all of them would cause multicollinearity problems in the regression. A principal component analysis (PCA) of governance indicators was considered but the size of the sample is too small to pass the PCA stability test (a minimum of a 10:1 ratio of observations to independent variables is required (Osborne and Costello (2004))). Consequently, only *political stability and absence of violence* is included in the regressions to represent world governance indicators, whereas women empowerment through knowledge, which likely affects child and maternal mortality, is used to capture both education and gender concerns. Descriptive statistics shown in Table 3.3 indicate that female literacy varies substantially across sub-Saharan Africa, with values ranging from 18% to 99%.

[4]To capture the unobserved heterogeneity of sub-saharan African countries, a dummy variable which captures components defined in Chapter 2 was initially included in the OLS regression. Under this specification there is however an insufficient number of observations (compared to the number of regressors) to obtain unbiased results. Upon availability of data on a greater number of countries, the hypothesis of distinct health production functions tested in Chapter 2 could be included in future iterations of the current chapter.

[5]Using GNI per capita was initially considered as a regressor. However, it was correlated with several of the variables selected for this chapter and this gave rise to problems of multicollinearity.

3.4.2 Child mortality variables

Child mortality, commonly called under-5 mortality (U5MR), is defined as the number of deaths of children under the age of five per 1,000. International organizations such as UNICEF and the World Bank, in partnership with local governments, have sought to reduce child mortality by promoting several targeted health interventions. Child vaccines promoted by the *Expanded Programme for Immunization* (EPI), interventions preventing diarrheal related conditions, treatment of pneumonia, interventions for prevention of transmission of HIV from mother to child, bednets for the prevention of malaria as well as availability of medical personnel are the main initiatives promoted by international organizations, and are therefore considered as independent variables for this study.

The World Health Organization created the *Expanded Programme for Immunization* in 1974 to facilitate immunization of children worldwide. Initially EPI included immunization for Bacillus Calmette-Guérin (BCG; for tuberculosis), diphtheria-tetanus-pertussis (DTP3), polio, and measles (MCV). On the eve of the launch of the Millennium Development Goals, international organization (e.g. UNICEF, WHO, World Bank) and private foundations (e.g. Gates Foundation) created the Global Alliance for Vaccines and Immunizations (GAVI) to combine resources and unify focus on child immunization. This unified effort lead to the rolling out of additional vaccines in several countries: yellow fever (where applicable), hepatitis B and *Haemophilus influenzae* type b (where applicable). Because immunization variables are highly correlated, papers and tools which help assess the effect of interventions (e.g. Marginal budgeting for bottlenecks by UNICEF; Lives Saved Tool by John Hopkins) usually use one vaccine (MVC or DPT3) as an indicator for immunization. Table 3.2 shows that DPT3 coverage is highly correlated with BCG (0.664), measles (0.846) and polio vaccination (0.961). Additionally, the descriptive statistics presented in Table 3.3 indicate that the mean value of coverage of DPT3 (78.4%) lies between the mean values of the other immunization variables. Consequently, in this chapter, DPT3 is chosen as a proxy for all vaccines and is referred to as the immunization variable in the regression.[6]

The two main clinical causes of child mortality are diarrheal related complications and pneumonia. To address these issues, access to clean water and treatment of pediatric pneumonia are included in the analysis. There is no systematically-collected, publicly available data on prevention and treatment of HIV/AIDS in children. Consequently, to capture the effect of initiatives taken to mitigate the effect of HIV on mortality, data on per capita official development assistance *disbursed* for prevention and treatment of HIV/AIDS and other sexually transmitted diseases is included in the analysis. It is worth noting that HIV funding per capita is positively correlated with political stability, voice and accountability, and government effectiveness which suggests that donors are reluctant to fund HIV programmes in countries where the political context is likely to diminish the effectiveness of the initiatives. Fortunately, there is child specific data on malaria prevention: number of children under-5 (out of 100) sleeping under a mosquito net. As the availability of medical personnel is also likely to decrease mortality, the density of physicians (number of physicians per 10,000 inhabitants) is used as a proxy of availability of healthcare.

3.4.3 Maternal mortality variables

Maternal mortality represents the number of pregnancy related deaths per 100,000 live births. Given the main causes of maternal mortality (e.g. hemorrhaging, sepsis, eclampsia, HIV, malaria) international organizations focused on maternal health promote interventions such as antenatal care, emergency obstetric care, clean deliveries and family planning.

[6]Just as for governance indicators, a principal component analysis (PCA) of immunization variables was considered but could not be performed due to sample size limitation.

Addressing pregnancy related complications such as haemorrhaging requires access to health professionals. Consequently, this regression includes a measure of the availability of medical personnel, represented here by the density of physicians per 100,000. Medical health personnel include community health workers (on which data are very scarce) and skilled birth attendants.[7]

Data on clean deliveries would have been the ideal measure of the prevention of sepsis. Unfortunately, that information is not readily available for all countries. To address this issue, access to clean water is used as a proxy. HIV and malaria can also create complications during pregnancy. Just as in the previous section, disbursed HIV funding per capita is used to capture the effect of HIV/AIDS prevention on maternal mortality. There is no readily available data on malaria prevention specifically for pregnant women hence, following the same approach as for HIV, ODA funding disbursed for the control and prevention malaria is used as a proxy.

Family planning plays an important role in combating maternal mortality. Pregnancies avoided at a young age due to sexual education and provision of contraceptives, as well as birth spacing and safe termination of unwanted pregnancies, impact maternal mortality. The literature indicates that there are several ways of measuring successful family planning: time elapsed between pregnancies, number of children per woman, the difference between the number of children per woman in a country and the highest reported number of the dataset and number of avoided teen pregnancies. This chapter uses avoided teen pregnancies (number of women, of ages 15-19, out of 1,000 that are not pregnant due to successful family planning) because it is the variable for which data is available across all countries studied.[8]

[7]Information is collected on the percentage of births assisted by a skilled birth attendant and not on the density of specific categories of medical personnel.

[8]Data on family planning was provided by Dr. J. Lawn from Save The Children.

Table 3.4 shows that, as expected, family planning is positively correlated with female literacy and ODA funding for the control and prevention of HIV/AIDS (0.605 and 0.230 respectively). The correlation between ODA funding on HIV and ODA for malaria is negative (-0.060) but weak. This suggests that there is potential crowding out between ODA funding for these interventions since both are provided by the same donors. Summary statistics shown in Table 3.5 indicate that there is a large variation in HIV funding per capita: the minimum value is $0.46 and the maximum is $42.84 (2011 USD).

3.4.4 Unit costs

Unit costs of interventions are required in order to determine the cost minimizing strategies for attaining MDG4 and MDG5. Solid data on unit costs is hard to come by, and in many cases were arrived at by searching many different sources and, where necessary, making (clearly specified) assumptions regarding the appropriate way to break down the best available data on costs. Country data on the costs of immunization children under-five is taken from the World Health Organization which provides cost information on the Expanded Programme for Immunization. Most sub-Saharan African WHO member states have an "Immunization Programme Comprehensive Multi-year Plan" (cMyp) document which shows the actual total cost of immunization for a baseline year (usually 2008 or 2010). Data collection and reporting is quite standard across country documents since, although they are produced by national Ministries of Health, this process is guided by the WHO. Several papers use cMyp data for economic evaluations and cost estimates of vaccinations. For example, Kim and Lee (2010) use the WHO data to assess the cost of the pneumococcal conjugate vaccine per disability-adjusted life year while Babigumira et al. (2011) use the data for a cost-effectiveness analysis of the measles containing vaccine in Uganda.

The cost of immunization reported by the WHO includes the price of vaccines, injection materials, advocacy and communication and shared health systems costs. Although the price of a single dose of several vaccines is extremely low (for example, a single dose of MCV vaccine can cost as low as $0.1930 and DPT3: $0.1410), the actual cost of actions which make vaccination possible substantially raise the cost of immunization. The African Field Epidemiology Network reports that costs of full routine immunization per child varied between $15 and $25 in Uganda, USAID reports a value of $16.63 for Ghana while Mathers (2006) and Jamison et al. (2008) state that the average cost per fully immunized child in sub-Saharan Africa (SSA) is around $14 (2001 USD). Indeed, although Brenzel et al. (2006) also find that on average in SSA it costs $14.21 to fully vaccinate a child, the cost is substantially higher, $26.82, when one includes immunization campaign fees. This chapter uses unit costs of immunization per dose because data per fully immunized child is not readily available. The total cost of immunization is divided by the number of vaccinated children under-five to obtain the unit cost of immunization (Appendix L)

To calculate the effective cost of immunization from the total cost of immunization reported in cMyp and the immunization coverage of the corresponding year, it is assumed that if annual spending continues at the level observed at time t, and if the population remains constant, then the same coverage as that observed at time t will be maintained. An example of the calculation of effective unit cost is provided in Appendix L. The data indicates that the average unit cost of immunization is $15.27. Note that there are more immunized children than fully immunized children, which explains why the cost per fully immunized child reported in the literature is higher than the unit costs used in this study.

The cost of prevention of malaria in children under-five is based on the cost of long lasting insecticide treated nets (LLITN) and malaria campaign costs. There are three types of WHO approved pyrethroid insecticides for bed nets: alpha-cypermethrin, deltamethrin and permethrin. In countries which do not show signs of malaria vectors which are resistant to pyrethroid, LLITNs with permethrin are used. Countries which exhibit signs of resistance to permethrin use nets with deltamethrin incorporated into the material. Malaria vectors of a subset of African countries (mainly western African ones) have shown strong resistance to the standard insecticides. Consequently, for Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Ethiopia, Kenya, Senegal and Uganda, the cost of malaria prevention includes the costs of alpha-cypermethrin LLITNs sprayed with chlorfenapyr (N'Guessan et al. (2014)).

The unit cost of LLITNs is reported by the UNICEF procurement bureau as part of UNICEF's transparency agenda. The 2012 unit cost of LLITN is \$4.90 for permethrin treated nets, \$5.58 for deltamethrin treated nets and \$7.68 for alpha-cypermethrin LLITNs sprayed with chlorfenapyr. The costs reported by UNICEF are in line with the common statement made by international organizations and non-governmental organizations that the unit cost of a bed net is between \$5 and \$8. In order to obtain the unit cost of malaria prevention, the costs of LLITNs are supplemented by the cost of malaria campaigns per net. Following in the steps of Briet et al. (2013), the average cost of a campaign per net used in this chapter is \$1.94 (2012 USD). Consequently, there are three different costs for malaria prevention used in this study: \$6.70, \$7.37 and \$9.43 (2011 USD). The unit cost of nets were higher in 2008, and so the 2008 cost of malaria prevention associated with a single net is \$9.71 for permethrin and for deltamethrin[9] treated nets and \$11.25 for alpha-cypermethrin LLITNs (2011 USD). Costs of a net per child is further adjusted because on average two to three children sleep under the same net. Appendix L provides a detailed explanation of the calculation of the unit and total cost of malaria prevention for children under the age of five.

The unit cost per physician, information useful for MDG4 and MDG5 cost minimizing strategies, consists of two elements: 1) physician salaries and 2) the cost incurred by the

[9]The same cost is used for permethrin and for deltamethrin because suppliers of permethrin treated nets refused to have cost published for 2008.

government for the education of the physician. WHO cMyp country documents provide information concerning the gross monthly salary[10] of medical doctors while Mills et al. (2011) reports the total education cost per physician, from elementary to medical school, in nine sub-Saharan African countries. For the purposes of this chapter, the educational cost is amortized over the entire working life of the medic: a 3% amortization is coupled with the assumption that a physician works for a period of 30 years. For the countries for which educational costs are not reported, the average of all nine educational costs is used.

Since the relationship between HIV and maternal mortality is captured by the disbursed ODA amount on HIV/AIDS and other STIs, the unit cost is simply the amount spent per adult in the population.[11] The information is not prorated for pregnant women as HIV prevention (and, to a lesser extent, treatment) relates to both the male and female populations.

The unit cost of family planning is the total amount of ODA directed to family planning, divided by the 15 to 39 years old population. The outcome of successful family planning is measured by the number of avoided teen pregnancies and is calculated based on the female population that is 15 to 19 years of age. Appendix L provides details of the calculation of the unit cost and total cost of family planning.

3.5 Results and discussion

Table 3.6 reports the OLS estimates of Equation (3.1) when the dependent variable is the under-5 mortality for the year 2012: i.e., the number of deaths of children under-5 per 1,000. The

[10]For the few countries which do not have a cMyp document, the monthly salary of physicians was taken from online sources such as local newspapers and Ministry of Health documents; the data was validated across several sources.

[11]Analysis with ODA HIV funding per capita and with per adult population generate the same conclusions.

independent variables are measures of interventions and contextual factors (as previously defined) from the year 2008.[12]

The results indicate that, as expected, the independent variables have negative estimated coefficients as they lead to reductions in mortality. Three of the six interventions included in the regression were statistically significant: immunization per 100 children under five; physician density per 10,000 inhabitants; and malaria net coverage. A one percentage point increase in the immunization coverage decreases the under-5 mortality rate by 0.5673. One more physician per 10,000 individuals would decrease by 5.53 the number of deaths of children per 1,000. The results also indicate that a one percentage point increase in the coverage of usage of malaria bed nets decrease the under-5 mortality by 1.8506. Additionally, as expected, malaria prevention has a non-linear effect on mortality: not only, on average, between two to three children sleep under a bed net but the insecticide with which the nets are treated kill *Anopheles* mosquitoes, preventing them from causing malaria even in children who do not sleep under the net. The positive sign on the squared term of malaria prevention indicates that there are decreasing returns to malaria prevention.

Certain variables however, are not statistically significant. For example, spending on HIV prevention and treatment is not found to have a statistically significant impact on child mortality. Although efforts are made to prevent mother-to-child transmission of HIV due to its impact of child morbidity, HIV accounts for only a small portion of paediatric mortality. This could explain the lack of statistical significance of the sign. Surprisingly, however, access to clean water and pneumonia treatment are not statistically significant. This result is unexpected because diarrheal related conditions caused by drinking unsafe water and pneumonia are the two main causes of child mortality. Upon closer inspection of these variables, there is little variation in access to

[12]The OLS regression model specified in this chapter passes the Ramsey Regression Equation Specification Error test (omitted variable test) at 10% significance level.

clean water and pneumonia treatment across the sub-Saharan African countries. Indeed, other than Angola, Eritrea, Liberia, Mauritania, Mozambique and Nigeria which have low coverage of access to clean water (between 62% and 74%), other countries have relatively homogeneous and high coverage. Similarity, pneumonia treatment of children under-5 shows little variability across the majority of countries.

All three contextual variables have statistically significant estimated coefficients, and the expected negative sign. Table 3.6 shows that a 1% increase in female literacy, defined as the percentage of literate women of ages 15 to 24, decreases mortality ($\hat{\beta}_{Lit}$=-0.3279).[13] Furthermore, the share of government expenditure on health (GEH) also decreases mortality but it is conditional on its level as indicated by its significant squared term. A one percent increase in GEH decreases child mortality ($\hat{\beta}_{GEH}$ = -3.2831) but does so at an decreasing rate as indicated by the positive values of the coefficient of its squared term (0.0326). Political stability is unlikely to be subject to the endogeneity problem that arises with the other variables: there is no reason to believe that high mortality rates would lead to changes in political stability. Whether this variable is used for years 2008 to 2012 OLS results are robust. Table 3.6 shows that a one percentage point increase in political stability decreases under-5 mortality rate by 0.4208.

Moreover, the regression results indicate that in the absence of interventions, child mortality rates would range from 144 to 206 per 1,000. These numbers are consistent with child mortality rates observed in several countries prior to the launch of the MDG initiative.[14]

[13]Unlike education, literacy does not have non-linear effects.

[14]In 1999, several countries (Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Dem. Rep., Côte d'Ivoire, Equatorial Guinea, Ethiopia, Guinea, Guinea-Bissau, Liberia, Malawi, Mozambique, Nigeria, Rwanda, Senegal, Somalia, South Sudan, Uganda and Zambia) had child mortality rates similar to the rate estimated by the OLS regression in the absence of interventions. Three countries (Mali, Niger and Sierra Leone) had even higher child mortality rates.

In order to undertake the six cost-effectiveness scenarios, I focus on the three interventions that were statistically significant, namely: immunization, physicians and malaria prevention. The results from running the Kuhn-Tucker program (Equation (2)) for all 27 countries for under-five mortality are reported in Table 3.7.

Scenario 1 indicates that, when using point estimates of coefficients, only Malawi could reach its child mortality target if continuing at the 2008 coverage of interventions. (It could in fact attain 66 deaths per 1,000, which is 10 lower than the MDG target). This result suggests that, for the vast majority of the sub-Saharan African countries, continuing with a status quo policy would be an ineffective strategy - something has to change in order to attain MDG4 by 2015. For three countries there is no feasible combination of interventions which would allow them to reach their child mortality targets: Congo, Guinea-Bissau and Mauritania. The first two countries already have higher than average coverage of immunization and malaria prevention (the two less expensive interventions) and would be required to halve their 2008 mortality rate to reach the target. The third country, Mauritania, has a low coverage of malaria, a relatively inexpensive intervention, and requires a decrease of less than 50 deaths per 1,000 to reach the target, which is a small change relative to what other countries have to attain. For all other countries, under Scenario 1, there exists a feasible combination of interventions which allows them to reach the MDG4 target in a cost-effective manner. Countries can be categorized into three groups: those that require increases in coverage of all three interventions, those that only require increases in immunization and physician density and those that only require an increase in malaria coverage.

Fifteen countries[15] require increases in all three of the statistically-significant interventions. Additionally, to attain the mortality objective, full immunization of children under-5 is necessary.

[15] In order to reach mortality targets, increases in all three of the statistically-significant interventions are required in Angola, Burkina Faso, Burundi, Cameroon, Comoros, Côte d'Ivoire, Eritrea, Gambia, Nigeria, Rwanda, Senegal, Sudan, Tanzania, Uganda and Zimbabwe.

This group is also characterised by large increases in expenditure on physicians which range from 109.7% (Gambia) to 801.7% (Rwanda). Table 3.9 indicates that for these 15 countries the mean marginal cost of the increased immunization program and physician labour force required to attain MDG4 are quite similar: $63,920,000 and $70,392,000 respectively. However compared to the 2008 spending on these interventions, spending on immunization would be required to increase, on average, by ~ 20% increase whereas expenditure on physicians would have to increase by more than 100%. One country, Nigeria, stands out in the group as it actually requires that the physician labour supply be increased to the maximum number of physicians per 10,000 allowed in the cost minimization exercise (7.3).

Seven countries can reach MDG4 objective by changing the coverage of only two interventions.[16] They all keep the same malaria coverage but require full child immunization and an increase in density of physicians. For Benin and Madagascar this represents relatively small marginal increases in the costs of immunization (70.4% and 41.8% respectively) and physicians (21.2% and 61.7%). For the other countries of this group increases in expenditures on physicians ranges from 256% (Mali) to 1,378% (Togo). Table 3.9 documents the total costs and marginal costs required to reach MDG4 targets and indicates that, on average, a very significant increase in expenditure on physicians (as compared to the 2008 spending) would be required (2008 cost $5,384,000 and marginal cost $23,487,000) . Interestingly, the minimum marginal costs of malaria is negative (-$1,535,000) indicating that, due to the fall in costs of providing nets reported earlier in Section 3.4, the same level of coverage of bednets can be at much lower overall cost, and this would therefore generate savings compared to 2008 values.

[16]Benin, CAR, Madagascar, Mali, Mozambique, Rwanda and Togo can attain their child mortality targets by modifying only two of the statistically interventions.

As shown in Table 3.7, only one country, Niger, could reach the child mortality target by adjusting the coverage of one intervention: malaria. Doubling it would allow Niger to go from 143 deaths per 1,000 to 105. This number is still high (highest in the countries studied here) but represents a $2/3^{rds}$ decrease in child mortality from 1990.

The results of Scenario 2 (which assumes an increase in female literacy rates of up to 25%) are shown in Table 3.7 in the last two lines of each country grouping. To allow easy comparison of coverage and costs between Scenario 1 and Scenario 2, results are shown in the same table. The savings generated by increases in literacy are shown in the last column. Results indicate that of the three countries which could not reach MDG4 under Scenario 1, Congo, despite a 25% increase of female literacy rate, still is unable to reach MDG4 objectives. In contrast, under Scenario 2, Guinea-Bissau can now attain its target if the density of physicians were to go from 0.5 per 10,000 inhabitants to 7.24 (a value that is below the average density of doctors in low and middle income countries -7.3 - and is used as the upper bound constraint in the Kuhn-Tucker). This increase represents a 1,607% increase in cost of medical personnel. Additionally, Guinea-Bissau would have to move from a 70% immunization coverage in 2008 to full immunization coverage, which would require an increase in cost of 80.4%. The third country which could not meet MDG4 under Scenario 1, Mauritania, can now do so if, in addition to the increase in female literacy rates, there is also full immunization coverage (from a 2008 value of 74), an increase of density of physicians (from 1.3 to 6.58) and an increase in coverage of malaria prevention (from 30.8 to 37.5). Results also indicate that increasing female literacy rates would allow Angola, Gambia and Uganda to reach their mortality targets while using *lower* coverage of immunization, physician density and malaria prevention than that required when female literacy is at the 2008 levels. This represents savings of $143,238,000 for Angola, $529,000 for Gambia (that can now reach the mortality target with 2008 coverage values) and $5,074,000 for Uganda. Table 3.9 shows that for these three countries the mean marginal cost for the required number of physicians is relatively low ($4,070,000) compared to the average amount of money spent on doctors in 2008 ($16,003,000). Additionally, in these countries Scenario 2 generates average savings of $47,421.000 on physicians compared to Scenario 1. Benin could reach its targets by decreasing the coverage of two interventions- the required number of physicians and immunization- and generate savings of $2,451,000. Increases in female literacy would allow Côte d'Ivoire and Central African Republic to reach MDG4 by lowering the required physician density and increasing malaria coverage. This would generate savings of $21,459,000 and $3,271,000 respectively. The only two countries for which an increase in female literacy does not change the required coverage of physicians are Niger and Nigeria. This is because the most cost-effective way for them to reach their targets is by adjusting only one intervention, malaria and immunization respectively. However, an increase in female literacy would still allow Niger to save $492,000 on malaria interventions, while Nigeria would benefit from a $121,361,000 saving on immunization spending. For all the other countries, a 25% increase in female literacy leads only to a decrease in the number of physician density required to reach MDG4 objectives. The savings generated in that group of countries varies between $44,000 (Madagascar) to $81,521,000 (Tanzania). As shown in Table 3.9, countries from this subgroup reach MDG4 target saving, on spending on interventions, on average, by $12,836,000 as compared to the spending required when the female literacy rate was at the 2008 level.

Scenarios 3 and 4 present cost-minimizing scenarios for the optimistic (lower bound values) and conservative (upper bound values) view of the effectiveness of interventions and contextual variables. The results indicate that, for all countries, these scenarios are too extreme to be realistic. Under the optimistic scenario of the effectiveness of interventions there would be no child mortality at all, while under the conservative scenario, no country could attain its MDG4 targets.

To assess the impact of context on mortality in a more realistic manner, the cost minimization exercise is carried out under the assumption that all variables, with the exception of political stability, are best captured by their point estimates. In Scenario 5 the coefficient of political stability is at its lowest value (upper bound value of coefficient) and hence this scenario generates insight into how interventions and context affect mortality in an environment where stability plays a weaker role. For each country grouping, the first two lines of Table 3.8 show the coverage and costs required under weak political effectiveness (the second line indicates percentage changes in coverage and cost from 2008). The results indicate that 15 countries[17] would not be able to reach the mortality target. This is 12 more than if political stability is used in the cost minimization procedure using its point estimate value. This implies that contextual variables play an important role in child mortality reduction. Table 3.9 indicates that weakly effective political stability is costly: attaining MDG4 requires on average large increases in costs of immunization ($13,701,000), of physicians ($ 59,307,000) and malaria prevention ($846,000).

The last two lines of each country grouping shown in Table 3.8 show coverage and costs of interventions when political stability is highly effective at reducing child mortality (Scenario 6). Under this scenario, three countries surpass their MDG4 target: Malawi, Madagascar and Tanzania. As for the other countries, they attain their target at much lower costs than under weakly effective political stability. As shown in the last column, savings generated are substantial and range from $4,856,000 (Gambia) and $151,038,000 (Ethiopia). Just as in Scenario 2, in which context was improved by increasing female literacy rates, Scenario 6 shows that improvements in context generate substantial savings, mainly by reducing expenditure on physicians. Table 3.9 indicates that stronger effectiveness of political stability at reducing child mortality allows

[17] List of countries that, under Scenario 5, would not meet their MDG4 target: Angola, Cameroon, Comoros, Congo, Côte d'Ivoire, Guinea-Bissau, Madagascar, Mauritania, Mozambique, Nigeria, Senegal, Sudan, Tanzania, Togo and Zimbabwe.

reaching MDG4 targets while saving, on average, \$4,611,000 in immunization cost, \$50,984,000 in physician cost and \$418,000 on malaria prevention.

Turning now to a discussion of the cost-minimizing scenarios as they pertain to MDG5 (maternal mortality), Table 3.10 reports the relevant OLS estimates of Equation (1) with the maternal mortality rate for the year 2013 as the dependent variable. The independent variables are as previously defined and are from the year 2008.[18] Once again, as expected, the estimated coefficients for the independent variables are negative, indicating they lead to mortality reduction. The results indicate that three out of five interventions are statistically significant: physician density, HIV funding and family planning (captured here by avoided teen pregnancies). One more physician per 100,000 inhabitants decreases the maternal mortality rate by 9.2. Similarly, increasing ODA funding for HIV by one dollar per 100 inhabitants[19] leads to a decrease in maternal mortality that is dependent on the share of government expenditure on health due to the interaction between these two variables. Increasing ODA funding for HIV in countries in which the government covers a larger portion of expenditure on health leads to a lower effect on maternal mortality rate ($\hat{\beta}_{HIV}$= -0.522; $\hat{\beta}_{HIV*GEH}$=0.010). Unlike for HIV, ODA funding for malaria is not statistically significant. As expected, successful family planning is both statistically and economically significant: one more avoided teen pregnancy (per 1,000 women of age 15 to 19) decreases the maternal mortality rate by 1.361.

The estimated coefficients of several variables (water, female literacy, share of government expenditure on health at level and squared) do not have a statistically impact on maternal mortality

[18]The maternal mortality OLS estimated regression passes the Ramsey Regression Equation Specification Error test (omitted variable test) at 5% significance level.

[19]Using ODA HIV funding per adult population or per capita does not alter the conclusion derived from the OLS regression.

rates. Strikingly, political stability[20] is not merely the only contextual variable that plays a statistically significant role, but it is also economically significant. A one percentage point increase in stability leads to a 3.729 reduction of the maternal mortality rate.

In the absence of interventions, these results indicate that maternal deaths per 100,000 live births would range from 1,889 to 2,535. These numbers are similar in magnitude to the maternal mortality rates observed in Sierra Leone and Sudan in the 90's. Because World Bank does not present data on maternal mortality from earlier decades, one can only speculate that the absence of interventions represents the historical maternal mortality rates in a greater number of countries.

The six cost-minimizing scenarios described in the methodology section focus on the three statistically significant interventions at reducing maternal mortality: physician density, HIV funding and family planning (captured by avoided teenage pregnancies). Table 3.11 shows Kuhn-Tucker cost minimization results for 26 of the 29 countries used in the OLS regression. Due to lack of data on costs, there are no cost-minimization scenarios presented for Djibouti, Gabon and Sierra Leone.

Scenario 1 (where the effectiveness of interventions is measured by the OLS point estimates) indicates that Angola and Namibia could make significant strides in maternal mortality reduction simply by reducing teen pregnancy. In Angola, if the number of women aged 15 to 19 who are not pregnant, out of 1,000, were to go from 833 to 977 (a 17.3% increase in successful family planning) the maternal mortality rate would fall from 650 to 250. This represents a 48.2% increase from 2008 levels in the costs of family planning aimed at young women. Notice that, due to the anticipated population increase between 2008 and 2015, to maintain the density of physicians

[20]Just as for the child mortality analysis, political stability is unlikely to be subject to the endogeneity problem that besets other variables; results are robust for stability values from 2008 to 2012.

and same level of HIV funding as in 2008, requires a 24.6% increase in expenditures on these interventions. Similarly, a 3% increase in successful family planning, which would only require a 12.5% increase in expenditures on *teen* family planning, would allow Namibia to reach its MDG5 target of 45. Maintaining coverage of physicians and HIV funding at the same levels as in 2008, while accounting to population growth, means that these expenditures would nonetheless increase by 13.3%. For the other countries, attaining maternal mortality targets requires increases in physician density and in family planning. As shown in Table 3.13, the mean marginal amount required to be spent on physicians is $30,060,000. This implies that on average, expenditures on physicians would more than double compared to 2008 in order to reach MDG5 targets. Necessary increases in expenditures of ODA for HIV funding and family planning are more modest ($16,937,000 compared to $78,174,000 in 2008 on HIV; $225,000 compared to $700,000 in 2008 on prevention on teen pregnancies).

Unlike for the child mortality regression, female literacy is not a statistically significant determinant of maternal mortality. Because of this fact, Scenario 2, could not be studied for the maternal mortality K-T.

Scenarios 3 and 4, which represent conservative and optimistic cost-minimizing scenarios, do not generate interesting results, and for essentially the same reasons as was the case when considering the child mortality Kuhn-Tucker. When the coefficients of all intervention are at their upper bound values, interventions are too weak to enable countries to attain the desired mortality target. Conversely, at lower bound values interventions are too effect to represent a realistic mortality scenario.

Table 3.12 shows changes in costs and coverage needed to attain MDG5 targets when upper (Scenario 5) and lower (Scenario 6) bound values of the coefficient of political stability are coupled with point estimates of other variables. The lowest effectiveness of political stability generated by its standard error is -0.176 while the highest is -7.28. The latter is economically significant compared to the other extreme value of effectiveness of stability. Scenario 5 reveals that only Botswana fails to reach its maternal mortality target when political stability is weakly effective. However, all countries then require the maximum number of avoided teen pregnancies (980 per 1,000) and significant increases in physician density to reach their MDG5 targets. The percentage increase in physician density ranges from 117.5% (Namibia) to 1,219% (Togo). Similarly there is a dramatic increase in expenditures required to supply the necessary physician density, ranging from 266.3% (Comoros) to 1,481% (Togo). Table 3.13 reveals that for the 25 countries which can attain their MDG5 target under this scenario, the mean marginal amount of money required to be spent on physicians ($68,287,000) is close to three times the total amount spent in 2008 ($23,122,000). Much smaller increases are required for ODA for HIV and prevention of teen pregnancies ($16,850,000 and $126,000 respectively).

In contrast, when the upper bound value for political stability is used in the cost-minimization exercise, Scenario 6 does not generate particularly realistic results in two countries: zero rates of maternal mortality in Botswana and Namibia. Given the large negative coefficient of political stability, this result is not surprising. High effectiveness of political stability allows ten countries[21] to surpass their MDG5 at the 2008 levels of physician density, HIV funding and family planning. For these countries the 20% increase in costs associated with that scenario are attributable solely to increases in population size between 2008 and 2015.

For the remaining 13 countries, even when the political stability variable is assumed to take on its upper bound value, control of teen pregnancy and physician density still needs to be

[21] Under the assumption of high effectiveness of political stability, Angola, Benin, Burkina Faso, Ghana, Malawi, Mozambique, Rwanda, Senegal, Tanzania and Zambia surpass their maternal mortality targets.

increased to meet maternal mortality targets. Family planning is binding for all these countries (980 per 1,000) while increases in physician density from 2008 vary from 15.5% (Nigeria) to 273% (Central African Republic). As shown in Table 3.13, on average for these 13 countries the necessary marginal increase in expenditures on physicians is $20,454,000 while the mean marginal increase in HIV funding is $15,375,000. Mean marginal increases in expenditures on family planning are negligible ($122,000). Scenario 6 is of course less costly than Scenario 5. Savings generated when political stability is highly effective at impacting maternal mortality range from $1,114,000 (Comoros) to $258,503,000 (Tanzania). As shown in Table 3.13, the mean value of savings between Scenario 5 and 6 is $44,261,000. Just as in the child mortality cost-minimizing scenarios, these results strongly suggest that a shortage of physicians is a key determinant of observed maternal mortality rates. Results also indicate that in order to meet MDG5 goals at the least possible incremental cost (of physicians, HIV and family planning), all countries would maintain the same amount of ODA for HIV per 100 inhabitants as in 2008. HIV funding would only increase to cover population growth which represent increases in cost ranging from 6.3% (Botswana) to 30.7% (Niger).

In summary, all the 312 Kuhn-Tucker cost minimization procedures performed consistently indicate that an increase in physician density would greatly assist in achieving the MDG goals.[22] As shown in Tables 3.9 and 3.13, this represents significant increases in cost that can be mitigated by improvements of broad contextual factors such as political stability or female literacy.

Additionally, for child survival, immunization is a key factor as it is binding across most countries. Similarly, family planning is also a cost-effective measure as it also reaches its maximum value (980) in most cost-minimizing scenarios across the majority of countries. Moreover,

[22]Conclusions cited in this chapter are consistent across the 312 K-T programs in spite of the fact that ranges of costs are not used (due to lack of availability of such data) in the analysis.

improving the context within which interventions are implemented, especially increases in female literacy or in effectiveness of political stability, lead to substantial savings in expenditures on interventions required to attain child and maternal mortality targets.

3.6 Conclusions and policy recommendations

This chapter assesses the relation between health MDG interventions and child and maternal mortality rates, and presents cost minimizing scenarios for attaining mortality targets set by the Millennium Development Goal initiative. The two main objectives of this chapter were to: 1) obtain useful estimates of the association between interventions and mortality rates, and 2) present scenarios of optimal coverage of interventions that allow meeting MDG targets at a minimum cost. The first objective was met by running OLS regressions of 2012 child mortality rates for 37 sub-Saharan countries on interventions and contextual variables measured at 2008 values. Similarly, 2013 maternal mortality rates of 29 countries are regressed on 2008 data. Having dependent and independent variables measured at different time periods is an effective technique for addressing the fact that the pattern of interventions may vary contemporaneously with mortality rates. Although the effectiveness of interventions has been addressed in a multitude of papers (as stated in chapter 2), this potential reverse causality has not been addressed elsewhere in the literature. The role of contextual factors is also addressed in this chapter by analyzing how increases in female literacy and levels of effectiveness of political stability lead to attainment of mortality objectives at a lower cost.

Table 3.14 summarizes the main findings. When the point estimates for the values of the coefficients are used, most countries (24 out of 27) require expansion of coverage of immunization, physician density and malaria prevention in order to attain MDG4. Similarly, attaining MDG5 requires expansion of physician density and family planning in all 26 countries analyzed in this subgroup. Moreover, increases in physician density are critical to attaining both child and maternal Millennium Development Goals. Substantial increases in the number of doctors of course entails large increases in expenditures. However, the results also establish that there is a tradeoff between direct expenditure on interventions, and investments that would lead to improvement in the values of contextual variables. In particular, there exists a trade-off between female literacy rates and physician density. If female literacy rates are increased by up to 25% (a strategy that is arguably more feasible in the short-term than the dramatic increases required in physician density), then child mortality objectives can be attained with lower levels of interventions, generating savings in expenditures on these policies. And the effort (and cost) required to meet the MDG goals is also shown to be highly sensitive to the value of the political stability variable. When effectiveness of political stability is low, 15 out of 27 countries fail to meet their MDG4 objective whereas, several countries surpass the MDG4 target when political stability has a stronger effect on child mortality. High political stability leads to substantial reductions in the interventions, and therefore the expenditures, required to attain the desired reductions in child mortality. Findings on the effectiveness of political stability at reducing maternal mortality are only slightly different. Results also indicate that at the low level of effectiveness of stability, only one country would fail to reach MDG5. Conversely, at high level of effectiveness of political stability, 10 countries can reach maternal mortality targets at the 2008 levels of coverage of interventions while 14 require expanding coverage of their interventions. It is again evident that high levels of political stability substantially reduce the effort required to attain the maternal mortality target. Table 3.13 indicates that although the mean value of savings generated when political stability plays a stronger role in maternal mortality reduction is $44,261,000, the maximum savings observed is much larger, $219,587,000 (Nigeria). Most importantly, and across both mortality objectives analysed, improving context (increase in female literacy or stronger effectiveness of political stability) reduces the number of additional physicians required to meet MDG mortality targets.

The clear message that emanates from this study is that a lack of physicians is the biggest impediment to reaching mortality targets. This is particularly striking in view of the fact that international organizations which address MDG objectives focus mainly on health interventions which generate relatively rapid results (e.g. immunization and clean deliveries) at the expense of investments in health workforce (i.e. physicians) which in the long run would generate sustainable reductions in child and maternal mortality. Although training physicians is a timely and costly endeavour, it is by far the most effective approach for reaching MDG mortality targets in sub-Saharan Africa. In the countries studied the average number of physicians per 10,000 is 1.5 whereas the average for lower and middle income countries the comparable figure is 7.3. This research supports other findings which indicate that there is a clear shortage of medics in sub-Saharan Africa (Kinfu et al. (2009)). In order to address the problem in a less expensive and more timely manner, international organizations have proposed task shifting between doctors and other health workers (Lehmann et al. (2009); World Health Organization (2007)). Because there are more nurses and community health workers than there are doctors[23], a potential solution is to train them at offering some of the specialised care that is currently under medics' jurisdiction. Pending the evaluation of the quality of the care that can be offered by task shifting, the current research advocates an increase in physician density.

Although the current paper suggests several cost minimizing scenarios for attaining child and maternal mortality targets set by the MDGs, improvements can be made. First, if data on more countries were available, this would render more precise the estimated coefficients underlying the analysis. Additionally, more data on relevant interventions would reduce reliance on proxies. For example, using data on oral rehydration therapy and zinc supplementation for treatment of diarrheal related conditions (one of the main causes of child mortality) would

[23] World Bank data shows that, in 2010 in sub-Saharan Africa, there were on average 1.11 nurses and midwives per 1,000 inhabitants and 0.19 physicians per 1,000 inhabitants.

give more accurate estimates than those presented here, which use access to clean water as a proxy. Similarly, pneumonia is the second main clinical cause of child mortality. Precise data on prevention and treatment of pneumonia, instead of using the percentage of children taken to a health facility due to suspected pneumonia, might also improve the measure of effectiveness of that factor. Information on community health workers and precise cost data on skilled birth attendants and the estimated number of pregnancies attended by each would allow using measures of health workforce which are more available to the population than are physicians.

Ideally, instead of performing a cross-country study, country-level data obtained at various time points or from different regions of the country would allow one to formulate country-specific policy recommendations. Availability of annual data on specific causes of mortality would also sharpen the precision of cost minimizing scenarios because measures of effectiveness of interventions would be directly linked to causes of mortality. Access to better data would enormously improve the quality of future work on cost-minimizing scenarios for reaching Millennium Development Goals targets, as well as new goals established as part of the post 2015 agenda ("*MDG plus*").

3.7 Tables

Table 3.1: Description of interventions, contextual variables and cost data

VARIABLE	DESCRIPTION	SOURCE
Child mortality		
Under-5 mortality in 2012	Number of deaths under-5 years of age per 1,000	The World Bank (http://data.worldbank.org/)
Immunization	Percentage of one-year-olds who have received three doses of DPT3	UNICEF (http://www.unicef.org/statistics/index_countrystats.html)
Malaria	Proportion of children aged 0-59 months sleeping under a net	UNICEF (http://www.unicef.org/statistics/index_countrystats.html)
Pneumonia	Under-fives with suspected pneumonia taken to an appropriate health-care provider	State of the World's Children 2010
Maternal mortality		
Maternal mortality rate in 2013	Number of women who die during pregnancy and childbirth, per 100,000 live births	The World Bank (http://data.worldbank.org/)
Malaria	Official development assistance disbursement for the prevention and control of malaria (2011 USD)	Creditor Reporting System OECD data
Successful family planning	Successful family planning calculated as avoided teen pregnancies (from teen fertility rates): number of women, of ages 15-19, out of 1,000 that are not pregnant	Dr. J Lawn's extrapolated World Bank data

Description of interventions, contextual variables and cost data

VARIABLE	DESCRIPTION	SOURCE
Variables common to both groups		
HIV	Official development assistance disbursement for control of sexually transmitted infections including HIV (2011 USD)	Creditor Reporting System OECD data
Physician	Physicians density (per 10 000 population)	Global Health Observatory (WHO)
Clean water	Percentage of urban population using improved drinking water sources	UNICEF Global Database
Contextual variables		
Female literacy	Literacy rates of 15-24 years old women	United Nations (http://data.un.org/)
Government expenditure on health	General government expenditure on health (GHE) as percentage of total health expenditure	National Health Accounts (WHO)
Political stability and absence of violence	Index of commonality of political unrest and terrorist threat (continuous variable between 0 and 1); lower values indicate less stability	Global Insight Business Risk and Condition

Description of interventions, contextual variables and cost data

VARIABLE	DESCRIPTION	SOURCE
Variables used for costing scenarios		
Immunization cost	Annual amount spent on immunization	WHO (http://www.who.int/immunization/programmes_systems/financing/countries/en/)
Physician salary	Monthly salary of physicians	WHO (http://www.who.int/immunization/programmes_systems/financing/countries/en/)
	Monthly salary of physicians in Namibia	Namibian Sun newspaper (2011-04-12)
	Monthly salary of physicians in Zambia	Zambian Health Workers Retention Scheme (2005)
Cost of education of a physician	Cost incurred by various sub-Saharan African governments for training a physician from elementary to medical school	Mills et al. (2011)
Cost of bednets	Cost of insecticide treated nets & of their provision	UNICEF (http://www.unicef.org/supply/index_59717.html)

Description of interventions, contextual variables and cost data

VARIABLE	DESCRIPTION	SOURCE
Variables used for costing scenarios		
Cost of family planning	Official development assistance disbursement for family planning (2011 USD)	Creditor Reporting System OECD data
Estimated population size by country in 2008 and 2015	Total population; under-5 population; population aged 15-39; female population 15-19	United Nations (http://data.un.org/)

Table 3.2: Correlation of MDG4 variables

	Immunization coverage				*Physicians*	*HIV funding*	*Water*	*Pneumonia*	*Malaria*	*Female literacy*	*GHE*[1]	*Governance indicators*		
	BCG	*DPT3*	*Polio*	*MCV*								*PS*[2]	*VA*[3]	*GE*[4]
BCG	1													
DPT3	0.664	1												
Polio	0.589	0.961	1											
MCV	0.580	0.846	0.840	1										
Physicians	-0.092	-0.092	-0.083	-0.136	1									
HIV	0.169	0.191	0.209	0.161	0.209	1								
Water	0.130	0.088	0.014	-0.003	0.176	0.371	1							
Pneumonia	0.073	0.003	0.041	0.062	0.084	-0.027	-0.102	1						
Malaria	0.173	0.042	0.045	0.114	-0.168	-0.188	-0.118	0.007	1					
F.Literacy	0.422	0.268	0.283	0.257	0.376	0.357	0.152	0.205	-0.112	1				
GHE	0.249	0.289	0.271	0.324	0.015	0.175	-0.008	0.039	0.066	0.075	1			
PS	0.499	0.266	0.286	0.324	0.170	0.551	0.214	0.151	0.082	0.377	0.477	1		
VA	0.252	0.075	0.088	0.086	0.436	0.430	0.331	0.088	0.056	0.155	0.272	0.690	1	
GE	0.193	0.099	0.099	0.149	0.447	0.547	0.261	-0.116	0.040	0.110	0.267	0.624	0.826	1

1. Share of government expenditure on health; 2. Political stability; 3. Voice and accountability; 4. Government effectiveness.

Table 3.3: Descriptive statistics of MDG4 variables (n=37)

	Immunization coverage											Governance indicators		
	BCG	*DPT3*	*Polio*	*MCV*	*Physicians*	*HIV funding*	*Water*	*Pneumonia*	*Malaria*	*Female Literacy*	*GHE*[1]	*PS*[2]	*VA*[3]	*GE*[4]
Mean	88.3	78.4	76.9	76.7	1.5	526.2	86.8	47.5	30.8	67.5	51.3	60.5	34.8	41.7
S.D.	8.7	14.03	15.0	10.8	1.6	793.9	10.3	16.3	16.4	22.3	16.5	21.8	17.4	13.3
Min.	64	38	31	55	0.5	46	62	14	0	18	22.6	19	0	13
Max.	99	98	97	96	7.7	4,284	100	90	73.2	99.9	81.7	100	75	75

1. Share of government expenditure on health; 2. Political stability; 3. Voice and accountability; 4. Government effectiveness.

Table 3.4: Correlation of MDG5 variables

	Physicians	HIV funding	Malaria funding	Family planning	Water	Female literacy	GHE[1]	PS[2]	VA[3]	GE[4]
Physicians	1									
HIV funding	0.404	1								
Malaria funding	-0.402	-0.060	1							
Family planning	0.361	0.239	0.078	1						
Water	0.096	0.335	-0.124	0.288	1					
Female literacy	0.467	0.433	0.074	0.600	0.292	1				
GHE	-0.007	0.204	0.123	0.041	0.142	0.104	1			
PS	-0.034	0.584	0.203	-0.020	0.171	0.189	0.450	1		
VA	0.111	0.487	0.049	0.056	0.164	0.284	0.304	0.747	1	
GE	0.177	0.638	-0.013	0.043	0.165	0.111	0.277	0.678	0.795	1

1. Share of government expenditure on health 2. Political stability; 3. Voice and accountability; 4. Government effectiveness.

Table 3.5: Descriptive statistics of MDG5 variables (n=29)

	Physician	HIV funding[1]	Malaria funding[1]	Family planning	water	Female literacy	GHE[2]	PS[3]	VA[4]	GE [5]
Mean	12.4	556.2	118.2	896.0	85.9	62.2	51.5	61.8	35.7	41.6
S.D.	10.8	881.8	99.5	43.7	12.5	22.8	17.2	21.9	15.7	12.0
Min.	5	45.5	0.1	796	49	18	22.6	13	13	13
Max.	40	4,284	377.3	978	100	95.6	81.7	100	75	75

1. per 100; 2. Share of government expenditure on health; 3. Political stability; 4. Voice and accountability; 5. Government effectiveness.

Table 3.6: Regression of 2012 under-5 mortality rate on independent variables from 2008

Under-5 mortality	Coefficients.
Immunizations	-0.5673*
	(0.2573)
Physicians	-5.5260*
	(2.3367)
HIV	-0.0307
	(0.0295)
HIV*GHE	0.0005
	(0.0005)
Water	-0.1247
	(0.4070)
Pneumonia	-0.0800
	(0.1935)
Malaria	-1.8506**
	(0.5858)
Malaria squared	0.0241**
	(0.0073)
Female literacy	-0.3279†
	(0.1633)
GHE	-3.2831*
	(1.5485)
GHE squared	0.0326†
	(0.0185)
Political stability	-0.4208*
	(0.1950)
Constant	300.696**
	(49.964)

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1% n= 37

Table 3.7: Scenarios 1 and 2 for MDG4: Effectiveness measured at point estimates of coefficients with and without increases in female literacy rates(costs expressed in thousands of constant 2011 dollars)

Country	**U5M 2008**	**U5M target**	**2008 coverage**				**Coverage (optimized)**				**2008 costs**			**Marginal Costs (optimized)**			**Marginal savings from literacy**
			Imm.	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Imm.**	**Phys.**	**Mal.**	
Angola	182.6	81	81	0.8	20.7	63.2	100	4.16	37.9	63.2	45,214	24,481	3,548	20,320	134,293	2,235	
							(23.5%)	*(420.5%)*	*(83.0%)*					*(44.9%)*	*(548.6%)*	*(63.0%)*	
↑ lit. 25%							81	0.80	21.4	79.0				7,869	6,022	-281	-143,238
							(0.0%)	*(0.0%)*	*(3.4%)*					*(17.4%)*	*(24.6%)*	*-(7.9%)*	
Benin	104.2	59	67	0.6	47.0	43.4	100	0.85	47.0	43.4	12,993	3,155	3,954	9,152	2,276	-170	
							(49.3%)	*(42.0%)*	*(0.0%)*					*(70.4%)*	*(72.2%)*	*-(4.3%)*	
↑ lit. 25%							96	0.60	47.0	54.3				8,307	670	-170	-2,451
							(43.6%)	*(0.0%)*	*(0.0%)*					*(63.9%)*	*(21.2%)*	*-(4.3%)*	
Burkina Faso	131.6	69	79	0.6	18.0	22.0	100	2.02	36.6	22.0	33,280	4,622	2,678	15,890	14,382	2,644	
							(26.6%)	*(236.5%)*	*(103.2%)*					*(47.75%)*	*(311.2%)*	*(98.73%)*	
↑ lit. 25%							100	1.69	36.6	27.5				15,890	11,311	2,644	-3,072
							(26.6%)	*(182.1%)*	*(103.2%)*					*(47.7%)*	*(244.7%)*	*(98.7%)*	
Burundi	120.2	61	92	0.5	13.3	76.3	100	3.03	36.7	76.3	21,192	2,087	980	9,236	13,779	1,731	
							(8.7%)	*(506.4%)*	*(176.1%)*					*(43.6%)*	*(660.3%)*	*(176.7%)*	
↑ lit. 25%							100	1.90	36.7	95.4				9,236	7,857	1,731	-5,922
							(8.7%)	*(280.1%)*	*(176.1%)*					*(43.6%)*	*(376.5%)*	*(176.7%)*	
Cameroon	111.2	48	84	1.9	26.5	77.5	100	5.52	36.8	77.5	39,113	20,311	4,878	14,185	50,134	1,612	
							(19.0%)	*(190.5%)*	*(38.7%)*					*(36.3%)*	*(246.8%)*	*(33.1%)*	
↑ lit. 25%							100	4.37	36.8	96.9				14,185	35,467	1,612	51,264
							(19.0%)	*(130.0%)*	*(38.7%)*					*(36.3%)*	*(174.6%)*	*(33.1%)*	

LEGEND: Imm: immunization; Phys: physician density; Mal: malaria bednets coverage; Lit: female literacy.; in parentheses: percentage difference from 2008.

Country	U5M 2008	U5M target	2008 coverage				Coverage (optimized)				2008 costs			Marginal Costs (optimized)			Marginal savings from literacy
			Imm.	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Imm.**	**Phys.**	**Mal.**	
CAR	146.7	56	54	0.8	33.1	57.3	100	5.13	33.1	57.3	8,328	2,683	1,024	8,528	17,057	-251	
							(85.2%)	*(541.1%)*	*(0.0%)*					*(102.4%)*	*(635.8%)*	*-(24.5%)*	
↑ lit. *25%*							100	4.13	37.6	71.6				8,528	13,216	-145	-3,271
							(85.2%)	*(416.4%)*	*(13.7%)*					*(102.4%)*	*(492.6%)*	*-(14.2%)*	
Comoros	87.2	40	81	1.5	36.4	84.7	100	6.30	37.0	84.7	847	445	188	318	1,721	-41	
							(23.5%)	*(319.9%)*	*(1.7%)*					*(37.5%)*	*(386.6%)*	*-(21.8%)*	
↑ lit. *25%*							100	5.39	37.0	100				318	1,408	-41	-312
							(23.5%)	*(259.4%)*	*(1.7%)*					*(37.5%)*	*(316.5%)*	*-(21.8%)*	
Congo	107.1	37	89	1	67.6	78.0		not feasible			6,730	1,684	2,087				
Côte d'Ivoire	120.8	50	74	1.4	17.1	61.0	100	7.30	33.1	61.0	20,638	26,053	2,745	12,479	132,374	2,545	
							(35.1%)	*(421.4%)*	*(93.6%)*					*(60.5%)*	*(508.1%)*	*(92.7%)*	
↑ lit. *25%*							100	6.28	37.5	76.3				12,479	110,214	3,245	-21,459
							(35.1%)	*(348.5%)*	*(119.3%)*					*(60.5%)*	*(423.0%)*	*(118.2%)*	
Eritrea	60.9	46	97	0.5	12.1	85.8	100	2.22	37.0	85.8	13,399	1,277	534	3,362	5,806	835	
							(3.1%)	*(343.1%)*	*(205.9%)*					*(25.1%)*	*(454.7%)*	*(156.3%)*	
↑ lit. *25%*							100	1.37	37.0	100				3,362	3,113	835	-2,693
							(3.1%)	*(174.6%)*	*(205.9%)*					*(25.1%)*	*(243.8%)*	*(156.3%)*	
Ethiopia	87.3	66	81	0.5	34.7	23.0	100	4.90	36.0	23.0	95,036	13,941	26,545	30,722	149,807	-1,818	
							(23.5%)	*(880.8%)*	*(3.7%)*					*(32.3%)*	*(1,074%)*	*-(6.9%)*	
↑ lit. *25%*							100	4.60	36.0	28.8				30,722	138,416	-1,818	-11,391
							(23.5%)	*(819.3%)*	*(3.7%)*					*(32.3%)*	*(992.8%)*	*-(6.9%)*	

Country	U5M 2008	U5M target	2008 coverage				Coverage (optimized)				2008 costs			Marginal Costs (optimized)			Marginal savings from literacy
			Imm.	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Imm.**	**Phys.**	**Mal.**	
Gambia	84.1	55	96	0.5	34.4	60.0	100 *(4.2%)*	0.84 *(68.0%)*	36.1 *(4.9%)*	60.0	4,204	344	558	1,251 *(29.8%)*	377 *(109.7%)*	53 *(9.5%)*	
↑ lit. 25%							96 *(0.0%)*	0.50 *(0.0%)*	34.4 *(0.0%)*	73.4				1,033 *(24.6%)*	85 *(24.8%)*	24 *(4.4%)*	-539
Guinea Bissau	145.2	70	63	0.5	73.2	63.6	not feasible				2,447	431	871	not feasible			
↑ lit. 25%							100 *(58.7%)*	7.24 *(1,349%)*	73.2 *(0.0%)*	79.5				1,967 *(80.4%)*	6,930 *(1,608%)*	-188 *-(21.5%)*	
Madagascar	69	54	82	1.6	49.4	99.9	100 *(22.0%)*	2.13 *(33.0%)*	49.4 *(0.0%)*	99.9	18,108	9,838	7,777	7,568 *(41.8%)*	6,072 *(61.7%)*	-1,535 *-(19.7%)*	
↑ lit. 25%							100 *(22.0%)*	2.12 *(32.6%)*	49.4 *(0.0%)*	100 *(0.1%)*				7,568 *(41.8%)*	6,028 *(61.3%)*	-1,535 *-(19.7%)*	-44
Malawi	95.4	76 66	91	0.5	31.2	66.0	reaches lower mortality than target with 2008 coverage				21,813	6,588	3,805	3,458 (15.9%)	1,477. (22.4%)	-461 -(12.1%)	
Mali	149.5	86	68	0.7	40.7	18.0	100 *(47.1%)*	2.02 *(188.4%)*	40.7 *(0.0%)*	18.0	30,893	7,043	4,882	26,647 *(86.3%)*	18,092 *(256.9%)*	-192 *-(3.9%)*	
↑ lit. 25%							100 *(47.1%)*	1.75 *(150.2%)*	40.7 *(0.0%)*	22.5				26,647 *(86.3%)*	14,767 *(209.7%)*	-192 *-(3.9%)*	-3,324
Mauritania	94.3	42	74	1.3	30.8	64.3	not feasible										
↑ lit. 25%							100 *(35.1%)*	6.58 *(406.5%)*	37.5 *(21.8%)*	80.4	5,782	3,076	786	3,159 *(54.6%)*	15,497 *(503.8%)*	-30 *-(3.8%)*	

Country	U5M 2008	U5M target	2008 coverage				Coverage (optimized)				2008 costs			Marginal Costs (optimized)			Marginal savings from literacy
			Imm.	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Imm.**	**Phys.**	**Mal.**	
Mozambique	111.9	40	72	0.5	42.1	40.0	100	2.74	42.1	40.0	44,303	7,204	8,283	68,906	47,093	7,036	
							(38.9%)	*(448.6%)*	*(0.0%)*					*(155.5%)*	*(653.7%)*	*(84.9%)*	
↑ lit. 25%							100	2.15	42.1	50.0				68,906	36,908	7,036	-10,185
							(38.9%)	*(330.0%)*	*(0.0%)*					*(155.5%)*	*(512.3%)*	*(84.9%)*	
Niger	143.7	105	66	0.5	15.2	23.2	66	0.50	28.2	23.2	26,626	2,667	2,217	8,737	820	1,933	
							(0.0%)	*(0.0%)*	*(85.8%)*					*(32.8%)*	*(30.7%)*	*(87.2%)*	
↑ lit. 25%							66	0.50	24.9	29.0				8,736.89	820	1,441.6	-492
							(0.0%)	*(0.0%)*	*(63.8%)*					*(32.8%)*	*(30.7%)*	*(65.0%)*	
Nigeria	141.9	71	54	4	11.9	49.0	88	7.30	37.5	49.0	752,792	303,173	15,110	758,144	368,364	29,340	
							(63.2%)	*(82.5%)*	*(215.4%)*					*(100.7%)*	*(121.5%)*	*(194.2%)*	
↑ lit. 25%							81	7.30	37.5	61.3				636,784	368,364	29,340	-121,361
							(50.1%)	*(82.5%)*	*(215.4%)*					*(84.6%)*	*(121.5%)*	*(194.2%)*	
Rwanda	76	52	97	0.5	60.2	77.4	100	3.20	60.2	77.4	11,525	5,764	4,858	2,309	46,213	-567	
							(3.1%)	*(539.1%)*	*(0.0%)*					*(20.0%)*	*(801.7%)*	*-(11.7%)*	
↑ lit. 25%							100	2.05	60.2	96.8				2,309	22,934	-567	-23,279
							(3.1%)	*(309.5%)*	*(0.0%)*					*(20.0%)*	*(397.9%)*	*-(11.7%)*	
Senegal	77.3	45	88	0.6	33.2	44.5	100	4.11	37.3	44.5	16,880	6,363	3,828	6,458	46,959	557	
							(13.6%)	*(585.3%)*	*(12.4%)*					*(38.3%)*	*(738.0%)*	*(14.6%)*	
↑ lit. 25%							100	3.45	37.3	55.7				6,458	38,391	557	-8,568
							(13.6%)	*(475.2%)*	*(12.4%)*					*(38.3%)*	*(603.4%)*	*(14.6%)*	
Sudan	82.6	41	86	3	23.1	82.7	100	6.97	36.9	82.7	30,717	44,366	6,080	7,827	75,632	1,874	
							(16.3%)	*(132.4%)*	*(59.8%)*					*(25.5%)*	*(170.5%)*	*(30.8%)*	
↑ lit. 25%							100	5.95	36.9	100				7,827	57,969	1,873	-17,664
							(16.3%)	*(98.2%)*	*(59.8%)*					*(25.5%)*	*(130.7%)*	*(30.8%)*	

Country	U5M 2008	U5M target	2008 coverage				Coverage (optimized)				2008 costs			Marginal Costs (optimized)			Marginal savings from literacy
			Imm.	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Lit.**	**Imm.**	**Phys.**	**Mal.**	**Imm.**	**Phys.**	**Mal.**	
Tanzania	71.4	53	84	0.5	36.3	76.4	100	2.02	37.8	76.4	139,598	29,135	13,142	60,790	116,439	-620	
							(19.0%)	*(304.7%)*	*(4.2%)*					*(43.5%)*	*(399.7%)*	-*(4.7%)*	
↑ lit. 25%							100	0.89	37.8	95.5				60,790	34,919	-620	-81,521
							(19.0%)	*(78.1%)*	*(4.2%)*					*(43.5%)*	*(119.9%)*	-*(4.7%)*	
Togo	105.9	49	89	0.5	40.8	67.9	100	6.17	40.8	67.9	12,440	2,003	1,910	4,008	27,609	-205	
							(12.4%)	*(1,135%)*	*(0.0%)*					*(32.2%)*	*(1,379%)*	-*(10.7%)*	
↑ lit. 25%							100	5.17	40.8	84.9				4,008	22,777	-205	-4,833
							(12.4%)	*(933.1%)*	*(0.0%)*					*(32.2%)*	*(1,137%)*	-*(10.7%)*	
Uganda	88.4	59	64	1.2	21.5	81.1	100	1.76	36.7	81.1	31,038	23,183	7,423	27,985	19,801	5,496	
							(56.3%)	*(46.8%)*	*(70.6%)*					*(90.2%)*	*(85.4%)*	*(74.0%)*	
↑ lit. 25%							97	1.20	31.3	100				25,941	6,101	3,610	-17,631
							(50.8%)	*(0.0%)*	*(45.7%)*					*(83.6%)*	*(26.3%)*	*(48.6%)*	
Zimbabwe	96.9	26	62	1.6	6.7	89.0	100	5.17	37.2	89.0	22,627	10,570	615	18,248	29,602	2,286	
							(61.3%)	*(222.9%)*	*(455.1%)*					*(80.6%)*	*(280.1%)*	*(371.6%)*	
↑ lit. 25%							100	4.51	37.2	100				18,248	24,528	2,286	-5,074
							(61.3%)	*(182.1%)*	*(455.1%)*					*(80.6%)*	*(232.1%)*	*(371.6%)*	

Table 3.8: Scenarios 5 and 6 for MDG4: Weak and strong effectiveness of political stability (costs expressed in thousands of constant 2011 dollars)

Country	PS	U5M 2008	U5M target	2008 coverage			Coverage (target)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	
Angola	Weak	182.6	81	81	0.8	20.7	not feasible			45,214	24,481	3,548	not feasible			
	Strong						93	0.8	35.6				15,959	6,022	1,887	
							(15.2%)	*(0.0%)*	*(72.0%)*				*(35.3%)*	*(24.6%)*	*(53.2%)*	
Benin	Weak	104.2	59	67	0.6	47.0	100	7.3	47.0	12,993	3,155	3,954	9,152	43,138	-170	
							(49.3%)	*(1,110%)*	*(0.0%)*				*(70.4%)*	*(1,367%)*	*-(4.3%)*	
	Strong						67	0.6	65.0				1,844	670	1,277	-48,329
							(0.0%)	*(0.0%)*	*(38.2%)*				*(14.2%)*	*(21.2%)*	*(32.3%)*	
Burkina Faso	Weak	131.6	69	79	0.6	18.0	100	6.1	36.6	33,280	4,622	2,678	15,890	52,783	2,644	
							(26.6%)	*(916.3%)*	*(103.2%)*				*(47.7%)*	*(1,142%)*	*(98.7%)*	
	Strong						79	0.6	27.4				5,564	1,026	1,317	-63,410
							(0.0%)	*(0.0%)*	*(52.5%)*				*(16.7%)*	*(22.2%)*	*(49.2%)*	
Burundi	Weak	120.2	61	92	0.5	13.3	100	4.9	36.7	21,192	2,087	980	9,236	23,308	1,731	
							(8.7%)	*(870.6%)*	*(176.1%)*				*(43.6%)*	*(1,117%)*	*(176.7%)*	
	Strong						100	1.2	36.7				9,236	4,250	1,731	-19,058
							(8.7%)	*(142.2%)*	*(176.1%)*				*(43.6%)*	*(203.7%)*	*(176.7%)*	
Cameroon	Weak	111.2	48	84	1.9	26.5	not feasible			39,113	20,311	4,878	not feasible			
	Strong						100	1.9	35.6				14,185	3,937	1,405	
							(19.0%)	*(0.0%)*	*(34.3%)*				*(36.3%)*	*(19.4%)*	*(28.8%)*	

LEGEND: PS: political stability; Imm: immunization; Phys: physician density; Mal: malaria bednets coverage; in parentheses: percentage difference from 2008.

Country	PS	U5M 2008	U5M target	2008 coverage			Coverage (target)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	
CAR	Weak	146.7	56	54	0.8	33.1	100	7.2	37.6	8,328	2,683	1,024	8,528	25,176	-145	
							(85.2%)	*(804.9%)*	*(13.7%)*				*(102.4%)*	*(938.5%)*	*-(14.2%)*	
	Strong						100	2.7	37.6				8,528	7,796	-145	-17,380
							(85.2%)	*(240.4%)*	*(13.7%)*				*(102.4%)*	*(290.6%)*	*-(14.2%)*	
Comoros	Weak	87.2	40	81	1.5	36.4	not feasible			847	445	188	not feasible			
	Strong						100	2.7	37.0				318	468	-41	
							(23.5%)	*(77.1%)*	*(1.7%)*				*(37.5%)*	*(105.2%)*	*-(21.8%)*	
Congo	Weak	107.1	37	89	1	67.6	not feasible			6,730	1,684	2,087	not feasible			
	Strong						100	5.5	67.6				2,378	9,570	-351.59	
							(12.4%)	*(454.6%)*	*(0.0%)*				*(35.3%)*	*(568.3%)*	*-(16.9%)*	
Côte d'Ivoire	Weak	120.8	50	74	1.4	17.1	not feasible			20,638	26,053	2,745	not feasible			
	Strong						100	4.0	37.5				33,118	86,346	5,991	
							(35.1%)	*(184.2%)*	*(119.3%)*				*(160.5%)*	*(331.4%)*	*(218.2%)*	
Eritrea	Weak	60.9	46	97	0.5	12.1	100.0	6.8	37.0163	13,399	1,277	534	3,362	20,477	835	
							(3.1%)	*(1,261%)*	*(205.9%)*				*(25.1%)*	*(1,604%)*	*(156.3%)*	
	Strong						97	0.5	14.1				2,859	322	-14	-21,507
							(0.0%)	*(0.0%)*	*(16.3%)*				*(21.3%)*	*(25.2%)*	*-(2.6%)*	
Ethiopia	Weak	87.3	66	81	0.5	34.7	100	7.2	34.7	95,036	13,941	26,545	30,722	226,329	-2,702	
							(23.5%)	*(1,339%)*	*(0.0%)*				*(32.3%)*	*(1,623%)*	*-(10.2%)*	
	Strong						100	2.6	36.0				30,722	74,408	-1,818	-151,038
							(23.5%)	*(429.2%)*	*(3.7%)*				*(32.3%)*	*(533.7%)*	*-(6.9%)*	

Country	PS	U5M 2008	U5M target	2008 coverage			Coverage (target)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	
Gambia	Weak	84.1	55	96	0.5	34.4	100	5.9	36.1	4,204	344	558	1,251	4,695	53	
							(4.2%)	*(1,073%)*	*(4.9%)*				*(29.8%)*	*(1,365%)*	*(9.5%)*	
	Strong*		*32*				96	0.5	34.4				1,033	85	25	-4,856
							(0.0%)	*(0.0%)*	*(0.0%)*				*(24.6%)*	*(24.8%)*	*(4.5%)*	
Guinea Bissau	Weak	145.2	70	63	0.5	73.2	not feasible			2,447	431	871	not feasible			
	Strong						100	4.5	73.2				1,967	4,188	-188	
							(58.7%)	*(809.2%)*	*(0.0%)*				*(80.4%)*	*(971.5%)*	*-(21.5%)*	
Madagascar	Weak						not feasible									
	Strong*	69	54	82	1.6	49.4	93	1.6	49.4	18,108	9,838	7,777	5,822	2,127	-1,535	
			39				*(13.7%)*	*(0.0%)*	*(0.0%)*				*(32.1%)*	*(21.6%)*	*-(19.7%)*	
Malawi	Weak	95.4	76	91	0.5	31.2	100	4.4	37.6	21,813	6,588	3,805	5,958	64,094	223	
							(9.9%)	*(776.4%)*	*(20.5%)*				*(27.3%)*	*(972.9%)*	*(5.9%)*	
	Strong*		38				91	0.5	31.2				3458.49	1477.335	-460.611	-65,800
							(0.0%)	*(0.0%)*	*(0.0%)*				*(15.9%)*	*(22.4%)*	*-(12.1%)*	
Mali	Weak	149.5	86	68	0.7	40.7	100	3.4	40.7	30,893	7,043	4,882	26,647	35,324	-192	
							(47.1%)	*(386.1%)*	*(0.0%)*				*(86.3%)*	*(501.5%)*	*-(3.9%)*	
	Strong						99.4	0.7	40.7				26,280	1,673	-192	-34,018
							(46.1%)	*(0.0%)*	*(0.0%)*				*(85.1%)*	*(23.7%)*	*-(3.9%)*	
Mauritania	Weak	94.3	42	74	1.3	30.8	not feasible			5,782	3,076	786	not feasible			
	Strong						100	4.3	37.5				3,159	9,147	-30	
							(35.1%)	*(233.4%)*	*(21.8%)*				*(54.6%)*	*(297.4%)*	*-(3.8%)*	

Legend: Strong*: mortality rates are lower than target

Country	PS	U5M 2008	U5M target	2008 coverage			Coverage (target)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	
Mozambique	Weak	111.9	40	72	0.5	42.1		not feasible		44,303	7,204	8,283		not feasible		
	Strong						72	0.5	55.9				5,309	1,380	1,068	
							(0.0%)	*(0.0%)*	*(32.9%)*				*(12.0%)*	*(19.2%)*	*(12.9%)*	
Niger	Weak	143.7	105	66	0.5	15.2	93	1	35	26,626	2,667	2,217	23,376	820	2,944	
							(41.4%)	*(0.0%)*	*(131.0%)*				*(87.8%)*	*(30.7%)*	*(132.8%)*	
	Strong*		*98*				66	0.5	15.2				8,736.89	819.92	16.80	-17,566
							(0.0%)	*(0.0%)*	*(0.0%)*				*(32.8%)*	*(30.7%)*	*(0.8%)*	
Nigeria	Weak	141.9	71	54	4	11.9		not feasible		752,792	303,173	15,110		not feasible		
	Strong						66	7.3	37.5				381,070	368,364	29,359	
							(22.5%)	*(82.5%)*	*(215.5%)*				*(50.6%)*	*(121.5%)*	*(194.3%)*	
Rwanda	Weak	76	52	97	0.5	60.2	100	7.3	60.2	11,525	5,764	4,858	2,309	96,190	-567	
							(3.1%)	*(1,355%)*	*(0.0%)*				*(20.0%)*	*(1,669%)*	*-(11.7%)*	
	Strong						97	0.5	65.2				1,894	1,243	-207	-95,002
							(0.0%)	*(0.0%)*	*(8.4%)*				*(16.4%)*	*(21.6%)*	*-(4.3%)*	
Senegal	Weak	77.3	45	88	0.6	33.2		not feasible		16,880	6,363	3,828		not feasible		
	Strong*		44				88	0.6	33.2				3,657	1,419	75	
							(0.0%)	*(0.0%)*	*(0.0%)*				*(21.7%)*	*(22.3%)*	*(2.0%)*	
Sudan	Weak	82.6	41	86	3	23.1		not feasible		30,717	44,366	6,080		not feasible		
							100	5.6	36.9				7,827	51,816	1,872	
	Strong						*(16.3%)*	*(86.3%)*	*(59.8%)*				*(25.5%)*	*(116.8%)*	*(30.8%)*	
Tanzania	Weak	71.4	53	84	0.5	36.3		not feasible		139,598	29,135	13,142				
	Strong							not feasible								

Legend: Strong*: mortality rates are lower than target

Country	PS	U5M 2008	U5M target	2008 coverage			Coverage (target)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	Imm.	Phys.	Mal.	
Togo	Weak	105.9	49	89	0.5	40.8		not feasible		12,440	2,003	1,910		not feasible		
	Strong						100	1.6	40.8				4,008	5,596	-205	
							(12.4%)	*(216.8%)*	*(0.0%)*				*(32.2%)*	*(279.4%)*	*-(10.7%)*	
Uganda	Weak	88.4	59	64	1.2	21.5	100	5.8	36.7	31,038	23,183	7,423	27,985	119,344	5,496	
							(56.3%)	*(386.7%)*	*(70.6%)*				*(90.2%)*	*(514.8%)*	*(74.0%)*	
	Strong						68	1.2	31.3				8,925	6,101	3,611	-134,189
							(5.8%)	*(0.0%)*	*(45.7%)*				*(28.8%)*	*(26.3%)*	*(48.6%)*	
Zimbabwe	Weak	96.9	26	62	1.6	6.7		not feasible		22,627	10,570	615		not feasible		
	Strong						95.2	1.6	36.099				16,272	1,870	2,200	
							(53.5%)	*(0.0%)*	*(438.8%)*				*(71.9%)*	*(17.7%)*	*(357.8%)*	

Table 3.9: Summary statistics of costs for attaining MDG4 target per scenario(in thousands of 2011 USD)

Scenario 1

Statistics of countries which require changes in coverage in all 3 optimized interventions (n=15)

	2008 Costs			Marginal Costs		
	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria
Mean	78,871	33,478	4,478	63,920	70,392	3,332
S.D.	189,259	75,763	4,501	192,639	94,400	7,363
Min.	847	344	188	318	377	-620
Max.	752,792	303,173	15,110	758,144	368,364	29,340

Statistics of countries which require changes in coverage in 2 optimized interventions (n=7)

	2008 Costs			Marginal Costs		
	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria
Mean	19,799	5,384	4,670	18,160	23,487	588
S.D.	13,083	2,880	2,715	23,752	17,862	2,885
Min.	8,328	2,003	1,024	2,309	2,276	-1,535
Max.	44,303	9,838	8,283	68,906	47,093	7,036

Scenario 2

Statistics of countries for which increases in female literacy rates lower the rates of all 3 optimized interventions compared to Scenario 1 (n=3)

	2008 Costs			Marginal Costs from 2008			Marginal savings compared to Scenario 1			
	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria	Total
Mean	26,819	16,003	3,843	11,614	4,070	1,118	-4,905	-47,421	-1,477	-53,802
S.D.	20,828	13,576	3,442	12,870	3,450	2,164	6,599	70,338	1,293	77,923
Min.	4,204	344	558	1,033	85	-281	-12,451	-128,271	-2,515	-143,238
Max	45,214	24,481	7,423	25,941	6,101	3,610	-218	-292	-29	-539

Scenario 2 ... *Continued*

Statistics of countries for which increases in female literacy rates lower only the required number of physicians compared to Scenario 1 (n=15)

	2008 Costs			Marginal Costs from 2008			Marginal savings compared to Scenario 1
	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria	Physicians
Mean	35,331	10,998	5,812	18,432	30,453	906	-12,836
S.D.	36,190	12,027	6,735	20,816	33,832	2,171	20,110
Min.	847	445	188	318	1,408	-1,818	-81,521
Max.	139,598	44,366	26,545	68,906	138,416	7,036	-44

Scenario 3: Not feasible

Scenario 4: Not feasible

Scenario 5

Statistics of countries under weak effectiveness of political stability (n=12)

	2008 Costs			Marginal Costs			
	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria	
Mean	25,861	6,113	4,955	13,701	59,307	846	73,854
S.D.	23,806	6,476	7,118	10,782	63,343	2,105	69,037
Min.	4,204	344	534	1,251	820	-2,702	5,999
Max.	95,036	23,183	26,545	30,722	226,329	5,496	254,350

Scenario 6

Statistics of countries under strong effectiveness of political stability (Costs compared to Scenario 5)

	2008 Costs			Marginal Costs from 2008			Marginal savings compared to weakly effective political stability		
	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria	Immunization	Physicians	Malaria
Mean	25,861	6,113	4,955	9,090	8,323	428	-4,611	-50,984	-418
S.D.	23,806	6,476	7,118	9,611	20,955	1,376	6,670	47,054	1,206
Min.	4,204	344	534	1,033	85	-1,818	-19,060	-151,921	-2,927
Max.	95,036	23,183	26,545	30,722	74,408	3,611	0	0	1,447

Table 3.10: Regression of 2013 maternal mortality rate on independent variables from 2008

Maternal Mortality	Coefficient
Physicians	-9.229*
	(3.896)
HIV	-0.522*
	(0.205)
HIV*GHE	0.010*
	(0.004)
Malaria	-0.223
	(0.248)
Family planning	-1.361†
	(0.711)
Water	(-5.189)
	(3.704)
Female literacy	-0.390
	(1.457)
GHE	(-5.998)
	(9.994)
GHE squared	(-0.015)
	0.106
Political stability	-3.729†
	(2.049)
Constant	2,828**
	(622)

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1% n= 29

Table 3.11: Scenarios 1 for MDG5: Effectiveness measured at point estimates of coefficients (costs are expressed in thousands of dollars)

Country	**MMR 2008**	**MMR target**	**2008 coverage**			**Coverage from optimization**			**2008 costs**			**Marginal Costs from optimization**		
			Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**
Angola	610	250	8	124.8	833	8.0	124.8	977	24,481	22,863	313	6,022	5,624	151
% Δ 2008						*(0.0%)*	*(0.0%)*	*(17.3%)*				*(24.6%)*	*(24.6%)*	*(48.2%)*
Benin	410	198	6	116.7	891	16.7	116.7	980	3,155	10,474	260	7,498	2,225	89
% Δ 2008						*(178.5%)*	*(0.0%)*	*(10.0%)*				*(237.7%)*	*(21.2%)*	*(34.4%)*
Botswana	190	21	40	2,386	950	58.9	2385.6	980	24,192	46,131	9	13,685	2,926	0.378
% Δ 2008						*(47.2%)*	*(0.0%)*	*(3.2%)*				*(56.6%)*	*(6.3%)*	*(4.0%)*
Burkina Faso	560	193	6	177.6	877	17.1	177.6	980	4,622	26,029	139	11,513	5,780	52
% Δ 2008						*(185.7%)*	*(0.0%)*	*(11.7%)*				*(249.1%)*	*(22.2%)*	*(37.3%)*
CAR	850	220	8	62.4	895	41.8	62.4	980	2,683	2,613	17	13,417	386	4
% Δ 2008						*(422.9%)*	*(0.0%)*	*(9.5%)*				*(500.1%)*	*(14.8%)*	*(25.5%)*
Comoros	340	133	15	55.3	943	30.5	55.3	980	445	359	16	603	57	4
% Δ 2008						*(103.1%)*	*(0.0%)*	*(3.9%)*				*(135.4%)*	*(15.9%)*	*(24.9%)*
Congo	580	115	10	179.0	883	23.1	179.0	980	1,684	6,941	4	2,996	1,423	1
% Δ 2008						*(130.6%)*	*(0.0%)*	*(11.0%)*				*(177.9%)*	*(20.5%)*	*(34.4%)*

LEGEND: Phys: physician density per 100,000; HIV: HIV funding per 100; in parentheses: percentage difference from 2008.

Country	MMR 2008	MMR target	2008 coverage			Coverage from optimization			2008 costs			Marginal Costs from optimization		
			Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**
Côte d'Ivoire	470	173	14	272.0	875	44.9	272.0	980	26,053	49,665	358	71,382	8,256	121
% Δ 2008						*(220.7%)*	*(0.0%)*	*(12.0%)*				*(274.0%)*	*(16.6%)*	*(33.7%)*
Ethiopia	470	248	5	326.6	932	26.8	326.6	980	13,941	269,806	1,812	75,577	53,297	636
% Δ 2008						*(436.2%)*	*(0.0%)*	*(5.2%)*				*(542.1%)*	*(19.8%)*	*(35.1%)*
Gambia	400	188	5	217.8	925	16.3	217.8	980	344	3,438	15	1,056	854	5
% Δ 2008						*(226.0%)*	*(0.0%)*	*(5.9%)*				*(306.9%)*	*(24.8%)*	*(33.0%)*
Ghana	350	158	11	195.6	931	24.0	195.6	980	21,019	45,206	347	32,522	7,578	56
% Δ 2008						*(118.2%)*	*(0.0%)*	*(5.3%)*				*(154.7%)*	*(16.8%)*	*(16.1%)*
Guinea Bissau	1000	300	5	144.8	892	35.7	144.8	980	431	2,196	8,817	3,197	392	2,393
% Δ 2008						*(614.2%)*	*(0.0%)*	*(9.9%)*				*(741.8%)*	*(17.9%)*	*(27.1%)*
Malawi	510	228	5	1143.7	884	11.8	1143.7	980	6,588	161,701	221	12,403	36,261	78
% Δ 2008						*(135.5%)*	*(0.0%)*	*(10.9%)*				*(188.3%)*	*(22.4%)*	*(35.3%)*
Mali	830	300	7	259.6	817	14.7	259.6	980	7,043	34,111	342	11,208	8,101	167
% Δ 2008						*(109.4%)*	*(0.0%)*	*(20.0%)*				*(159.1%)*	*(23.7%)*	*(48.7%)*

Country	MMR 2008	MMR target	2008 coverage			Coverage from optimization			2008 costs			Marginal Costs from optimization		
			Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**
Mauritania	550	195	13	58.1	922	29.7	58.1	980	3,076	1,990	240	5,306	382	60
% Δ 2008						*(128.6%)*	*(0.0%)*	*(6.3%)*				*(172.5%)*	*(19.2%)*	*(25.2%)*
Mozambique	550	250	5	709.5	856	13.6	709.5	980	7,204	161,510	429	16,111	30,931	169
% Δ 2008						*(171.6%)*	*(0.0%)*	*(14.5%)*				*(223.6%)*	*(19.2%)*	*(39.4%)*
Namibia	180	45	30	4284.0	930	30.0	4,284	958	30,885	90,427	51	4,120	12,063	6
% Δ 2008						*(0.0%)*	*(0.0%)*	*(3.0%)*				*(13.3%)*	*(13.3%)*	*(12.5%)*
Niger	820	350	5	48.7	796	9.6	48.7	980	2,667	7,176	181	4,014	2,206	124
% Δ 2008						*(91.6%)*	*(0.0%)*	*(23.1%)*				*(150.5%)*	*(30.7%)*	*(68.5%)*
Nigeria	840	275	40	164.7	883	58.2	164.7	980	303,173	249,076	1,014	231,804	53,231	333
% Δ 2008						*(45.4%)*	*(0.0%)*	*(11.0%)*				*(76.5%)*	*(21.4%)*	*(32.8%)*
Rwanda	540	275	5	1133.1	962	10.5	1,133	980	5,764	115,839	933	8,948	24,985	404
% Δ 2008						*(109.9%)*	*(0.0%)*	*(1.9%)*				*(155.2%)*	*(21.6%)*	*(43.3%)*
Senegal	410	188	6	153.3	897	15.1	153.3	980	6,363	18,768	301	13,254	4,184	79
% Δ 2008						*(152.1%)*	*(0.0%)*	*(9.3%)*				*(208.3%)*	*(22.3%)*	*(26.4%)*
Sudan	750	208	30	45.5	940	56.8	45.5	980	44,366	15,501	14	53,326	2,538	68
% Δ 2008						*(89.2%)*	*(0.0%)*	*(4.3%)*				*(120.2%)*	*(16.4%)*	*(499.4%)*

Country	MMR 2008	MMR target	2008 coverage			Coverage from optimization			2008 costs			Marginal Costs from optimization		
			Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**
Tanzania	790	220	5	531.9	870	12.0	531.9	980	29,135	225,270	566	57,523	52,853	193
% Δ 2008						*(140.9%)*	*(0.0%)*	*(12.6%)*				*(197.4%)*	*(23.5%)*	*(34.0%)*
Togo	350	163	5	213.6	937	39.4	213.6	980	2,003	12,790	3	16,908	2,528	1
% Δ 2008						*(688.4%)*	*(0.0%)*	*(4.6%)*				*(844.3%)*	*(19.8%)*	*(18.3%)*
Uganda	430	168	12	802.2	855	23.8	802.2	980	23,183	254,922	453	35,016	67,082	207
% Δ 2008						*(98.7%)*	*(0.0%)*	*(14.6%)*				*(151.0%)*	*(26.3%)*	*(45.8%)*
Zambia	470	98	6	1241.7	855	18.6	1241.7	980	7,746	154,671	321	22,165	38,034	148
% Δ 2008						*(209.9%)*	*(0.0%)*	*(14.6%)*				*(286.1%)*	*(24.6%)*	*(46.0%)*

Table 3.12: Scenarios 5 and 6 for MDG5: Weak and strong effectiveness of political stability (costs expressed in thousands of constant 2011 dollars)

Country	Political stability	MMR 2008	MMR target	2008 coverage			Coverage (optimized)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Phys.	HIV	Family planning	Phys.	HIV	Family planning	Phys.	HIV	Family planning	Phys.	HIV	Family planning	
Angola	Weak	610	250	8	124.8	833	31.9	124.8	980	24,481	22,863	313	96,967	5,624	152	
							(298.1%)	*(0.0%)*	*(17.6%)*				*(396.1%)*	*(24.6%)*	*(48.6%)*	
	Strong*		223				8	124.8	833				6,022	5,624	82	-91,014
							(0.0%)	*(0.0%)*	*(0.0%)*				*(24.6%)*	*(24.6%)*	*(26.3%)*	
Benin	Weak	410	198	6	116.7	891	50.6	116.7	980	3,155	10,474	260	29,096	2,225	89	
							(743.2%)	*(0.0%)*	*(10.0%)*				*(922.4%)*	*(21.2%)*	*(34.4%)*	
	Strong*		105				6.0	116.7	891				670	2,226	58	-28,457
							(0.0%)	*(0.0%)*	*(0.0%)*				*(21.2%)*	*(21.3%)*	*(22.2%)*	
Botswana	Weak	190	21	40	2385.6	950		Not feasible		24,192	46,131	9				
	Strong							Not realistic								
Burkina Faso	Weak	560	193	6	177.6	877	43.7	177.6	980	4,622	26,029	139	36,522	5,780	52	
							(628.4%)	*(0.0%)*	*(11.7%)*				*(790.2%)*	*(22.2%)*	*(37.3%)*	
	Strong*		*190*				6	177.6	877				1,026	5,780	32	-35,515
							(0.0%)	*(0.0%)*	*(0.0%)*				*(22.20%)*	*(22.21%)*	*(22.83%)*	
CAR	Weak	850	220	8	62.4	895	53.8	62.4	980	2,683	2,613	17	18,010	386	4.29	
							(572.1%)	*(0.0%)*	*(9.5%)*				*(671.3%)*	*(14.8%)*	*(25.5%)*	
	Strong						29.9	62.4	980				8,823	386	4.29	-9,186
							(273.7%)	*(0.0%)*	*(9.5%)*				*(328.9%)*	*(14.8%)*	*(25.5%)*	

LEGEND: Phys: physician density per 100,000; HIV: HIV funding per 100; in parentheses: % difference from 2008.
Strong*: mortality rates are lower than target.

Country	Political stability	MMR 2008	MMR target	2008 coverage			Coverage (optimized)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	
Comoros	Weak	340	133	15	55.3	943	47.4 *(216.1%)*	55.3 *(0.0%)*	980 *(3.9%)*	445	359	16	1,185 *(266.3%)*	57 *(15.9%)*	3.89 *(24.9%)*	
	Strong						15 *(0.0%)*	55.35 *(0.0%)*	970.0 *(2.9%)*				71 *(15.9%)*	57 *(15.9%)*	3.69 *(23.7%)*	-1,114
Congo	Weak	580	115	10	179.0	883	44.6 *(346.2%)*	179.0 *(0.0%)*	980 *(11.0%)*	1,684	6,941	4	7,371 *(437.7%)*	1,423 *(20.5%)*	1.34 *(34.4%)*	
	Strong						10.0 *(0.0%)*	179.0 *(0.0%)*	922 *(4.5%)*				345 *(20.5%)*	1,423 *(20.5%)*	1.03 *(26.5%)*	-7,026
Côte d'Ivoire	Weak	470	173	14	272.0	875	59.5 *(325.2%)*	272 *(0.0%)*	980 *(12.0%)*	26,053	49,665	358	103,133 *(395.9%)*	8,256 *(16.6%)*	121 *(33.7%)*	
	Strong						30.3 *(116.2%)*	272 *(0.0%)*	980 *(12.0%)*				39,631 *(152.1%)*	8,256 *(16.6%)*	121 *(33.7%)*	-63,502
Ethiopia	Weak	470	248	5	326.6	932	38.7 *(674.9%)*	327 *(0.0%)*	980.0 *(5.2%)*	13,941	269,806	1,812	115,429 *(828.0%)*	53,297 *(19.8%)*	636 *(35.1%)*	
							14.87 *(197.5%)*	326.6 *(0.0%)*	980.0 *(5.2%)*				35,725 *(256.3%)*	53,297 *(19.8%)*	636 *(35.1%)*	-79,704
Gambia	Weak	400	188	5	217.8	925	42.9 *(757.3%)*	217.8 *(0.0%)*	980 *(5.9%)*	344	3,438	15	3,338 *(970.3%)*	854 *(24.8%)*	4.92 *(33.0%)*	
	Strong*		121				5 *(0.0%)*	217.85 *(0.0%)*	925.0 *(0.0%)*				85 *(24.8%)*	854 *(24.8%)*	3.81 *(25.5%)*	-3,254

Strong*: mortality rates are lower than target

Country	Political stability	MMR 2008	MMR target	2008 coverage			Coverage (optimized)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	
Ghana	Weak	350	158	11	195.6	931	50.6	195.6	980	21,019	45,206	347	91,795	7,578	56	
							(359.7%)	*(0.0%)*	*(5.3%)*				*(436.7%)*	*(16.8%)*	*(16.1%)*	
	Strong*		99				11	195.61	931.0				3,524	7,578	36	-88,291
							(0.0%)	*(0.0%)*	*(0.0%)*				*(16.8%)*	*(16.8%)*	*(10.3%)*	
Guinea Bissau	Weak	1000	300	5	144.8	892	55.0	144.8	980	431	2,196	8,817	5,153	392	2.39	
							(999.2%)	*(0.0%)*	*(9.9%)*				*(1,196%)*	*(17.9%)*	*(0.0%)*	
	Strong						16.5	144.8	980				1,241	392	2.39	-3,912
							(229.2%)	*(0.0%)*	*(9.9%)*				*(288.0%)*	*(17.9%)*	*(0.0%)*	
Malawi	Weak	510	228	5	1143.7	884	38.3	1143.7	980	6,588	161,701	221	55,254	36,261	78	
							(666.8%)	*(0.0%)*	*(10.9%)*				*(838.7%)*	*(22.4%)*	*(35.3%)*	
	Strong*		176				5.0	1143.7	884				1,477	36,261	49	-53,806
							(0.0%)	*(0.0%)*	*(0.0%)*				*(22.4%)*	*(22.4%)*	*(22.1%)*	
Mali	Weak	830	300	7	259.6	817	41.2	259.6	980	7,043	34,111	342	44,285	8,101	167	
							(488.9%)	*(0.0%)*	*(20.0%)*				*(628.8%)*	*(23.7%)*	*(48.7%)*	
	Strong						7	260	852				1,673	8,101	100	-42,679
							(0.0%)	*(0.0%)*	*(4.3%)*				*(23.7%)*	*(23.7%)*	*(29.3%)*	
Mauritania	Weak	550	195	13	58.1	922	46.7	58.1	980	3,076	1,990	240	10,084	382	60	
							(258.9%)	*(0.0%)*	*(6.3%)*				*(327.8%)*	*(19.2%)*	*(25.2%)*	
	Strong						13.00	58.1	978.5				591	382	60	-9,494
							(0.0%)	*(0.0%)*	*(6.1%)*				*(19.2%)*	*(19.2%)*	*(25.0%)*	

Strong*: mortality rates are lower than target

Country	Political stability	MMR 2008	MMR target	2008 coverage			Coverage (optimized)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Phys.	HIV	Family planning	Phys.	HIV	Family planning	Phys.	HIV	Family planning	Phys.	HIV	Family planning	
Mozambique	Weak	550	250	5	709.5	856	47.6	710	980	7,204	161,510	429	74,436	30,931	169	
							(851.1%)	*(0.0%)*	*(14.5%)*				*(1,033%)*	*(19.2%)*	*(39.4%)*	
	Strong*		186				5	709.5	856				1,380	30,931	93	-73,133
							(0.0%)	*(0.0%)*	*(0.0%)*				*(19.2%)*	*(19.2%)*	*(21.8%)*	
Namibia	Weak	180	45	30	4284.0	930	65.2	4,284	980	30,885	90,427	51	45,244	12,063	7.64	
							(117.5%)	*(0.0%)*	*(5.4%)*				*(146.5%)*	*(13.3%)*	*(15.1%)*	
	Strong							Not realistic								
Niger	Weak	820	350	5	48.7	796	26.5	48.7	980	2,667	7,176	181	15,829	2,206	124	
							(430.4%)	*(0.0%)*	*(23.1%)*				*(593.4%)*	*(30.7%)*	*(68.5%)*	
	Strong						5.0	48.7	896				820	2,206	98	-15,035
							(0.0%)	*(0.0%)*	*(12.6%)*				*(30.7%)*	*(30.7%)*	*(54.0%)*	
Nigeria	Weak	840	275	40	164.7	883	70.1	164.7	980	303,173	249,076	1,014	341,598	53,231	333	
							(75.2%)	*(0.0%)*	*(11.0%)*				*(112.7%)*	*(21.4%)*	*(32.8%)*	
	Strong						46.2	164.7	980				122,010	53,231	333	-219,587
							(15.5%)	*(0.0%)*	*(11.0%)*				*(40.2%)*	*(21.4%)*	*(32.8%)*	
Rwanda	Weak	540	275	5	1133.1	962	32.1	1,133	980	5,764	115,839	933	39,164	24,985	404	
							(541.2%)	*(0.0%)*	*(1.9%)*				*(679.4%)*	*(21.6%)*	*(43.3%)*	
	Strong*		151				5.0	1,133	962				1,243	24,985	380	-37,945
							(0.0%)	*(0.0%)*	*(0.0%)*				*(21.6%)*	*(21.6%)*	*(40.7%)*	
Senegal	Weak	410	188	6	153.3	897	39.4	153.3	980	6,363	18,768	301	44,710	4,184	79	
							(556.4%)	*(0.0%)*	*(9.3%)*				*(702.7%)*	*(22.3%)*	*(26.4%)*	
	Strong*		161				6.0	153.3	897				1,419	4,184	47	-43,324
							(0.0%)	*(0.0%)*	*(0.0%)*				*(22.3%)*	*(22.3%)*	*(15.7%)*	

Strong*: mortality rates are lower than target

Country	Political stability	MMR 2008	MMR target	2008 coverage			Coverage (optimized)			2008 costs			Marginal Costs (optimized)			Marginal savings due to stability
				Phys.	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	**Phys.**	**HIV**	**Family planning**	
Sudan	Weak	750	208	30	45.5	940	61.8	45.5	980	44,366	15,501	14	61,940	2,538	68	
							(105.9%)	*(0.0%)*	*(4.3%)*				*(139.6%)*	*(16.4%)*	*(499.4%)*	
	Strong						52	46	980				44,713	2,538	68	-17,227
							(72.5%)	*(0.0%)*	*(4.3%)*				*(100.8%)*	*(16.4%)*	*(499.4%)*	
Tanzania	Weak	790	220	5	531.9	870	40.9	531.9	980	29,135	225,270	566	265,254	52,853	193	
							(718.4%)	*(0.0%)*	*(12.6%)*				*(910.4%)*	*(23.5%)*	*(34.0%)*	
	Strong*		168				5	531.9	870				6,836	52,853	108	-258,503
							(0.0%)	*(0.0%)*	*(0.0%)*				*(23.5%)*	*(23.5%)*	*(19.0%)*	
Togo	Weak	350	163	5	213.6	937	66.0	213.6	980	2,003	12,790	3	29,651	2,528	0.62	
							(1,220%)	*(0.0%)*	*(4.6%)*				*(1,481%)*	*(19.8%)*	*(18.3%)*	
							12.9	213.6	980				4,165	2,528	0.62	-25,486
							(157.1%)	*(0.0%)*	*(4.6%)*				*(208.0%)*	*(19.8%)*	*(18.3%)*	
Uganda	Weak	430	168	12	802.2	855	45.4	802.2	980	23,183	254,922	453	87,630	67,082	207	
							(278.4%)	*(0.0%)*	*(14.6%)*				*(378.0%)*	*(26.3%)*	*(45.8%)*	
	Strong						12.0	802.2	914				6,101	67,082	163	-81,574
							(0.0%)	*(0.0%)*	*(6.9%)*				*(26.3%)*	*(26.3%)*	*(36.0%)*	
Zambia	Weak	470	98	6	1241.7	855	57.1	1241.7	980	7,746	154,671	321	84,094	38,034	148	
							(851.6%)	*(0.0%)*	*(14.6%)*				*(1,086%)*	*(24.6%)*	*(46.0%)*	
	Strong*		29				6	1241.7	855				1,905	38,034	88	-82,249
							(0.0%)	*(0.0%)*	*(0.0%)*				*(24.6%)*	*(24.6%)*	*(27.4%)*	

Strong*: mortality rates are lower than target

Table 3.13: Summary statistics of costs for attaining MDG5 target per scenario (in thousands of 2011 USD)

Scenario 1

Statistics of countries which require changes in physician density and coverage of malaria prevention (n=24)

	2008 Costs			Marginal Costs		
	Physicians	HIV	Family planning	Physicians	HIV	Family planning
Mean	22,787	78,174	700	30,060	16,937	225
S.D.	60,809	93,934	1,777	48,222	21,571	485
Min.	344	359	3	603	57	0
Max.	303,173	269,806	8,817	231,804	67,082	2,393

Scenario 2: Not feasible

Scenario 3: Not feasible

Scenario 4: Not feasible

Scenario 5

Statistics of countries under weak effectiveness of political stability (n=25)

	2008 Costs			Marginal Costs		
	Physicians	HIV	Family planning	Physicians	HIV	Family planning
Mean	23,122	77,734	687	68,287	16,850	126
S.D.	59,551	92,449	1,741	79,271	21,072	148
Min.	344	359	3	1,185	57	1
Max.	303,173	269,806	8,817	341,598	67,082	636

Scenario 6

Statistics of countries under strong effectiveness of political stability (n=13) (Costs compared to Scenario 5)

	2008 Costs			Marginal Costs from 2008			Marginal savings compared to weakly effective political stability		
	Physicians	HIV	Family planning	Physicians	HIV	Family planning	Physicians	HIV	Family planning
Mean	33,135	69,780	1,021	20,454	15,375	122	-44,261	0	-11
S.D.	82,210	108,270	2,399	34,679	24,588	180	59,869	0	22
Min.	431	359	3	71	57	1	-219,587	0	-66
Max.	303,173	269,806	8,817	122,010	67,082	636	-1,114	0	0

Table 3.14: Main findings from scenarios exercise

	Scenario 1		**Scenario 2**		**Scenario 5**		**Scenario 6**	
	MDG 4	MDG5	MDG 4	MDG5	MDG 4	MDG5	MDG 4	MDG5
# of countries achieving the goal with 2008 levels of interventions	1/27	0/26	2/27	n/a	0/27	0/26	4/27	10/26
# of countries unable to achieve mortality targets	3/27	0/26	1/27	n/a	15/27	1/26	0/27	0/26
# of countries achieving the goal with increased levels of interventions	23/27	26/26	24/27	n/a	12/27	25/26	23/27	14/26
Principal messages	Increase in physician density drive the achievement of MDGs		There exist an important trade off between female literacy rates and physician density	n/a	This scenario is more costly than the three others		Cheapest environment in which to implement policies (Feasibility not tested)	
					Under weak effectiveness of political stability, a lot fewer countries can reach MDG4			

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Appendices

Appendix A

MDG

Goal 1: Eradicate extreme poverty and hunger

Goal 2: Achieve universal primary education

Goal 3: Promote gender equality and empower women

Goal 4: Reduce child mortality
(Reduce by 2/3, between 1990 and 2015, the under 5 mortality rate)

Goal 5: Improve maternal health
(Reduce by 3/4, between 1990 and 2015, the maternal mortality rate; Achieve, by 2015, universal access to reproductive health)

Goal 6: Combat HIV/AIDS, malaria and other diseases
(Have halted by 2015 and begun to reverse the spread of HIV/AIDS; Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it; Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases

Goal 7: Ensure environmental sustainability

Goal 8: Develop a global partnership for development

Appendix B

Robustness checks for MDG4; low income group

Tobit regression of DEA efficiency scores on contextual factors including natural log of GNI

Explanatory variable	Coefficient
SSA	-0.743+
	(0.397)
ln(GNI)	0.301**
	(0.092)
PEH	-0.018***
	(0.004)
Stability	-0.666*
	(0.283)
Elections	-0.133
	(0.100)
Rule of law	-1.606*
	(0.573)
Share of income spent on food	-0.021**
	(0.006)
Literacy	0.003
	(0.003)
MMR	-0.001***
	(0.000)
Child labor	-0.013***
	(0.003)
Ethnic diversity	-0.051***
	(0.009)
Constant	3.747**
	(1.110)

*n=29; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Tobit regression of DEA efficiency scores on contextual factors including percentage of urban population

Explanatory variable	Coefficient
SSA	-0.638
	(0.389)
GNI	0.001
	(0.000)
PEH	-0.017***
	(0.004)
Stability	-0.678+
	(0.334)
Elections	-0.148
	(0.160)
Rule of law	-1.442*
	(0.559)
Share of income spent on food	-0.021**
	(0.006)
Literacy	0.005
	(0.003)
MMR	-0.001***
	(0.000)
Child labour	-0.009***
	(0.003)
Ethnic diversity	-0.042***
	(0.011)
Urban population	-0.001
	(0.004)
Constant	4.858***
	(0.999)

*n=29; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Appendix C

Robustness checks for MDG4; lower-middle income group

Tobit regression of DEA efficiency scores on contextual factors including natural log of GNI

Explanatory variables	Coefficients
SSA	-0.074
	(0.406)
ln(GNI)	0.606
	(0.398)
PEH	0.000
	(0.002)
Stability	-3.001***
	(0.714)
Elections	-0.149
	(0.185)
Rule of law	6.933***
	(1.527)
Share of income spent on food	0.058***
	(0.014)
Literacy	0.003
	(0.004)
MMR	-0.001+
	(0.001)
Ethnic diversity	-0.073+
	(0.042)
Constant	-6.579+
	(3.496)

*n=36; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Tobit regression of DEA efficiency scores on contextual factors including percentage of urban population

Explanatory variables	Coefficients
SSA	-0.078
	(0.346)
GNI	0.0004*
	(0.0002)
PEH	-0.002
	(0.002)
Stability	-3.126***
	(0.681)
Elections	-0.153
	(0.204)
Rule of law	7.200***
	(1.441)
Share of income spent on food	0.065***
	(0.009)
Literacy	0.003
	(0.003)
MMR	-0.002*
	(0.001)
Ethnic diversity	-0.077*
	(0.034)
Urban population	0.004
	(0.009)
Constant	-3.234***
	(0.717)

*n=36; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Appendix D

Robustness checks for MDG5; low income group

Tobit regression of DEA efficiency scores on contextual factors the including natural log of GNI

Explanatory variable	Coefficient
SSA	-0.519*
	(0.214)
ln(GNI)	-0.227
	(0.188)
PEH	-0.003
	(0.003)
Stability	0.195
	(0.412)
Elections	-0.252
	(0.146)
Control of corruption	0.854+
	(0.398)
Share of income spent on food	-0.010
	(0.006)
Literacy	-0.002
	(0.003)
Ethnic diversity	-0.003+
	(0.001)
Constant	3.280**
	(1.068)

*n=26; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Tobit regression of DEA efficiency scores on contextual factors including percentage of urban population

Explanatory variables	Coefficients
SSA	-0.522*
	(0.201)
GNI	-0.001
	(0.000)
PEH	-0.003
	(0.003)
Stability	0.344
	(0.411)
Elections	-0.233
	(0.166)
Control of corruption	0.845*
	(0.350)
Share of income spent on food	-0.010
	(0.006)
Literacy	-0.002
	(0.003)
Ethnic diversity	-0.003+
	(0.001)
Urban population	-0.003
	(0.004)
Constant	2.227***
	(0.430)

*n=26; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Appendix E

Robustness checks for MDG5; lower-middle income group

Tobit regression of DEA efficiency scores on contextual factors including natural log of GNI

Explanatory variable	Coefficient
SSA	-0.579
	(0.173)**
ln(GNI)	0.490**
	(0.160)
PEH	0.0001
	(0.001)
Stability	0.137
	(0.355)
Elections	-0.221*
	(0.103)
Control of corruption	2.312**
	(0.600)
Share of income spent on food	0.057**
	(0.014)
Literacy	-0.010
	(0.007)
Ethnic diversity	0.000
	(0.000)
Constant	-5.020*
	(1.623)

*n=29; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Tobit regression of DEA efficiency scores on contextual factors including percentage of urban population

Explanatory variable	Coefficient
SSA	-0.559**
	(0.188)
GNI	0.0002**
	(0.00007)
PEH	0.000
	(0.001)
Stability	0.067
	(0.349)
Elections	-0.207+
	(0.104)
Control of corruption	2.206***
	(0.612)
Share of income spent on food	0.056***
	(0.014)
Literacy	-0.008
	(0.007)
Ethnic diversity	0.0005
	(0.001)
Urban population	0.001
	(0.004)
Constant	-1.847
	(-1.151)

*n=29; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Appendix F

Robustness checks for MDG5; upper-middle income group

Tobit regression of DEA efficiency scores on contextual factors including natural log of GNI

Explanatory variable	Coefficient
TAC	-0.251 (0.171)
ln(GNI)	1.120* (0.400)
PEH	-0.001+ (0.001)
Stability	-1.538*** (0.396)
Elections	0.072 (0.260)
Control of corruption	1.248** (0.416)
Share of income spent on food	0.009 (0.008)
Literacy	-0.023 (0.018)
Ethnic diversity	-0.002+ (0.001)
Constant	-5.837 (3.044)+

*n=27; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Tobit regression of DEA efficiency scores on contextual factors including percentage of urban population

Explanatory variable	Coefficient
TAC	-0.202
	(0.175)
GNI	0.000*
	(0.000)
PEH	-0.001+
	(0.001)
Stability	-1.676**
	(0.406)
Elections	0.079
	(0.255)
Control of corruption	1.343*
	(0.468)
Share of income spent on food	0.008
	(0.008)
Literacy	-0.021
	(0.016)
Ethnic diversity	-0.003*
	(0.001)
Urban population	-0.004
	(0.005)
Constant	2.677
	(1.651)

*n=27; significance level: + 0.10; * 0.05; ** 0.01; *** 0.001*

Appendix G

Papers on neonatal, infant and child mortality, at country-level

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	**Statistically non-significant variables**
Sepúlveda, J., Bustreo, F., Tapia, R., Rivera, J., Lozano, R., Oláiz, G., Partida, V., García-García, L. and Valdespino, J.L. _ Improvement of child survival in Mexico: the diagonal approach _ Lancet 2006; 368: 2017–27	Analyze the effects of proximal factors and contextual variables on child mortality	• OLS of <u>child mortality</u> on: stunting, underweight ; female education, measle vaccination of children that are less than 5 years old, household conditions (proportion of homes with sewage systems and a dirt floor) and underweight • MLE stepwise procedure to select best OLS • correlation of variables with child mortality	underweight female education MCV coverage	stunting husehold conditions *(only best OLS is shown)*
Andargie , G., Berhane, Y., Worku , A., Kebede, Y. _ Predictors of perinatal mortality in rural population of Northwest Ethiopia: a prospective longitudinal study _ BMC Public Health 2013, 13:168	Estimate the perinatal mortality rate in Amhara Regional state of rural Ethipia and identify causal factors	Logistic regression of <u>perinatal mortality</u> on CATEGORICAL variables: Marital status of mother Educational status of mother Father's educational status Mother's /Father's occupation, Sex of infants Type of birth out comes Birth interval for the index child History of abortion Previous still births Ever use of family planning Neonatal tetanus	Educational status of mothers: illiterate (vs secondary or higher) Mother's occupation: own business (vs others) Sex of infant: female Type of birth outcomes: multiple (vs single) Birth interval for the index child: >24 months (vs more than 2 months and less than 24) Previous still births: yes Neonatal tetanus (all higher odds than the reference group)	Marital status of mothers Educational status of mother: primary/informal Educational status of father Mother's occupation: farmer, housewife Father's occupation History of abortion Ever used family planning
Zimba, E., Kinney,M.V., Kachale, F., Waltensperger, K.Z., Blencowe, H., Colbourn, T. George, J., Joshua, M., Chanza, H., Nyasulu, D., Mlava, G., Gamache, N., Kazembe, A. and Lawn, J.E., Mwansambo, C., _ Newborn survival in Malawi: a decade of change and future implications _ Health Policy and Planning 2012;27:iii88–iii103	Identify determinants of neonatal survival	OLS of <u>neonatal mortality</u> rate on GNI per capita female literacy HIV prevalence total fertility rates skilled birth attendance LiST: coverage data from surveys used for prediction of NMR	Female literacy HIV prevalence *All variables have 20 data points but female literacy has only 3 and SBA 4.*	GNI per capita total fertility rates skilled birth attendance
Anyamele, O.D. _ Urban and rural differences across countries in child mortality in SSA _ Journal of Health Care for the Poor and Underserved 2009 (Vol.20):4, pp. 90-98	Comparative analysis of urban and rurual determinants of child mortality	logistic regression of <u>child mortality</u> on: wealth, literacy, urban residence country-specific regressions based on household data (11 countries)	literacy: significant in 8 countries wealth: significant in 7 countries; in one (Mali) in increase probability of U5 mortality urban residence: significant in all 11 countries	literacy: Chad, Ethiopia, Niger wealth: Cameroon, Ethiopia, Niger, Rwanda

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Nakamura, H., Ikeda, N., Stickley, A., Mori, R., Shibuya. K. _ Achieving MDG 4 in Sub-Saharan Africa: What Has Contributed to the Accelerated Child Mortality Decline in Ghana? _ PLoS March 2011 Volume 6 Issue 3	Asses the relation between child mortality trends in Ghana and key determinants of declines of child mortality	log-linear hazard function of child mortality on Type of residence Region, Religion, Ethnic, Economic status Mother's educational achievement Mother's age at birth (years) Mother's marital status ORS, Bed net, ANC 4 visits or more Child's sex, Multiplicity in birth, Birth order	Mother's education: Primary Mother's age at birth (years): 13-16 Bed net Multiplicity in birth Birth order Breastfeeding duration	Type of residence Region, Religion, Ethnic, Economic status Mother's education: No education Mother's marital status, ORS ANC 4 visits or more, Child's sex Mother's age at birth (years): 17-48
Fuchs, R.; Pamuk, E.; Lutz, W. _ Education or wealth: which matters more for reducing child mortality in developing countries? _ Vienna Yearbook of Population Research 2010 (Vol.8), pp. 175-199	Determine which has a greater impact on child mortality reduction in developing countries: maternal education or material resources; information required in order to promote the right child health policies.	logistic regression of infant death on: above median education above median wealth urban residence OR a model with extended variables: education category: primary, secondary, tertiary wealth quintiles with and without inclusion of urban residence *country-specific regressions based on household data (27 countries)*	18/27 countries: above median education decreases the likelihood of infant death 4/27 countries: above median wealth decreases the likelihood of infant death 6/27 countries: urban residence is significant; it reduces likelihood of infant mortality in 5 of the 6 countries *(extended models show similar results)*	9/27 countries: above median education is not significant 23/27 countries: above median wealth is not significant 21/27 countries: urban residence is not significant *(extended models show similar results)*
Iram, U.; Butt, M.S. _ Socioeconomic determinants of child mortality in Pakistan: Evidence form sequential probit model _ International Journal of Social Economics 2008 (Vol. 35):1/2, pp63-76	Identification and quantification of variables which may affect child mortality at different ages	Sequential probit model of NMR, IMR and CMR on child's gender, household income mother's: age at childbirth, age at marriage, years of schooling, self-employed binary variables: breasfeeding, postnatal care, neonatal tetanus, child birth at home, piped water at home, sanitation facilities, electricity, independent house, urban residence	increasesprobability of neonatal mortality: child's gender: female, maternal age, self employed mothers, home birth decreases probability of neonatal mortality: maternal: education, age at marriage, breastfeeding, neonatal tetanus vaccination, at home: sanitation facilities, electricty, income increases probability of infant mortality: mother's: age at marriage, self employed, at home sanitation facilities decreases probability of infant mortality: maternal education, breastfeeding, neonatal tetanus vaccination, birth at home, income, electricity at home, independent home increases probability of child mortality: self-employed, lack of sanitation facilities decreases probability of child mortality: neonatal tetanus vaccination	neonatal mortality: postnatal care, neonatal tetanus vaccination infant mortality: child's gender: female, maternal age, postnatal care, home birth, sanitation facilities child mortality: child's gender: female, maternal age, maternal education, mother's age at marriage, postnatal care, home birth, income, electricity at home, piped water at home, independent home, urban location

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Hossain,M.B.; Philips,J.F.; Pence, B. _ The effect of women's status on infant and child mortality in four rural areas of Bangladesh _ Journal of Biosocial Science 2007 (Vol.39) pp. 355-366	Examine the effect of constraints on women's status on neonata and child mortality in Bangladesh	Proportional hazard regression of: <u>neonatal, infant or child mortality</u> on CATEGORICAL variabels for: child's gender birth order mother's education father's education economic status women's status score	<u>neonatal:</u> birth order (risk of mortality decreases with birth order) womens's status score: index of *purdah* <u>infant:</u> birth order father's education women's status score: autonomy, authority <u>child:</u> child's gender Birth order: 4+ only father's education economic status women's status scores: authority	<u>neonatal:</u> child's gender,mother's education, father's education, economic status, women's status scores: autonomy, authority <u>infant:</u> child's gender, birth order: 4+, mother's education, economic status women's status scores: index of *purdah* <u>child:</u> birth order,mother's education, women's status: autonomy, index of *purdah*
Mondal, N.I.; Hossain, K.; Ali, K. _ Factors influencing infant and child mortality: a case study of Rajshahi district, Bangladesh _ Journal of Human Ecology 2009 (vol. 26):1 pp.31-39	Identify determinants of neonatal, infant and child mortality	logistic regression: <u>neonatal, infant and child mortality</u> on CATEGORICAL variables: residence mother's/father's education mother's/father's occupation sanitation facility television child's gender mother's age at birth birth order birth interval immunization treatment place place of delivery breastfeeding Family planning	<u>neonatal:</u> mother's/father's education mother's/father's occupation sanitation facility, mother's age at birth birth interval, immunization treatment place, place of delivery breastfeeding <u>infant:</u> father's occupation, mother's age at birth, immunization, breastfeeding <u>child:</u> residence, mother's/father's education sanitation facility, television child's gender, mother's age at birth birth order, birth interval immunization, treatment place place of delivery, breastfeeding	<u>neonatal:</u> residence television child's gender birth order Family planning <u>infant:</u> residence mother's/father's education mother's occupation sanitation facility television, child's gender birth order, birth interval treatment place, place of delivery Family planning <u>child:</u> mother's/father's occupation Family planning
Agha, A.; Ajmal, F., Iqbal, A., White, F. _ Father's support and literacy- factors associated with child mortality in Gambat, Sindh-Pakistan _ Journal of Pakistan Medical (Vol.60):2 pp 81-85	Identify causes of U5MR in Gambat, Pakistan	logistic regression of <u>child mortality</u> on mother's age, education & ability to visit facility alone; father's occupation, education & support during child rearing; number of families; house construction	father's education father's support during child rearing	mother's age, education & ability to visit facility alone; father's occupation; number of families; house construction

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
D'Souza,R.M. _ Role of health-seeking behaviour in child mortality in the slums of Karachi, Pakistan _ Journal of Biosocial Science 2003 (35) pp. 131-144	Identify health seeking behaviors which affect the probability of dying of children under five years of age	Conditional logistic regression of <u>child mortality</u> (case-control study) on: took child to traditional healer Type of first healer time until changed healer treatment explained by healer mother's education (in 1/2 models)	took child to traditional healer First healer (base: MBBS doctor): hospital, doctor (unqualified) Type of first healer time until changed healer mother's education	First healer (base: MBBS doctor): nurse, homeopath treatment explained by healer
Gayen,K.; Raeside, R. _ Communicative actions, women's degree of social connectedness and child mortality in rural Bangladesh _ Child: care, health and development 2010 (Vol.36): 6 pp. 827–834	Assess the effect of communication and social network variables on under-five mortality.	Poisson regression of <u>child mortality</u> (number or proportion of dead children): number of children, mother's age, mother's age at marriage, wife's/husband's education, microcredit affiliation, female autonomy score, SES, religion, professional deliver help, contraception, access to information, out degree centrality, bonacich power	number of children, mother's age, wife's education, microcredit affiliation, professional deliver help, contraception, out degree centrality, bonacich power	mother's age at marriage, husband's education, female autonomy score, SES, religion, access to information
Muhuri, P.K. _ Estimating Seasonality Effects on Child Mortality in Matlab, Bangladesh _ Demography, 1996 (Vol. 33): 1 pp. 98-110	Test the effect of seasonality on child mortality given other determinants of U5MR	Logistic regression of <u>child mortality</u> on: season dummies, age dummies, gender and family composition variables, maternal education, ownership of household items, dwelling space per capita, and the Matlab treatment area, maternal schooling; interactions terms: child's gender, family composition, selected months	diarrhea-related death: month: March older brother older sister, no schooling x treatment area non-diarrhea-related death all months (excpet April, September) female child, older brother, older sister Matlab treatment area No schooling x Sep./Oct. Treatment area x Sep./Oct.	diarrhea-related death: month: all except March, age, gender, older brother, Female x POB2, Female x POS, owning physical capital, mother's education Matlab treatment area, No schooling x Sep./Oct., Treatment area x Sep./Oct. non-diarrhea-related death: month: April, September, age, older brother, Female x POB2, Female x POS, owning physical capital, mother's schooling, No schooling x treatment area
Yaqoob M, Cnattingius S, Jalil F, Zaman S, Iselius L, Gustavson K-H. _ Risk factors for mortality in young children living under various socio-economic conditions in Lahore, Pakistan: with particular reference to inbreeding _ Clinical Genetics 1998 (Vol.54): 426-434	Investigate the role of cosanguinity and other variables on child mortality in Pakistan	Logistic regression of <u>infant mortality</u> on: maternal age; parity; inbreeding; elder siblings' death (including stillbirths); birth weight birth length	Consanguinity birth weight	maternal age; parity; elder siblings' death (including stillbirths); birth length

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Bhutta, Z.A., Nizami,S.Q., Thobani, S. and Issani, Z. _ Risk Factors for Mortality Among Hospitalized Children with Persistent Diarrhoea in Pakistan _ Journal of Tropical Pediatrics 1997 (Vol. 43) pp.330-336	Identify factors contributing to child mortality of hospitalized children suffering from persistent diarrhoea.	univariate and logistic regression of child mortality on: Age, Weight-for-age z-score, Admission serum albumin, Duration of diarrhoea, Severity of dehydration at admission, Stool frequency at admission, Febrile at admission, Sepsis at admission, Presence of oral candidiasis	Weight-for-age z-score, Sepsis at admission	Age, Admission serum albumin, Duration of diarrhoea, Severity of dehydration at admission,Stool frequency at admission, Febrile at admission, Presence of oral candidiasis
Muhuri, P.K.; Preston, S.H. _ Effects of Family Composition on Mortality Differentials by Sex Among Children in Matlab, Bangladesh _ Population and Development Review 1991 (Vol. 17): 3 pp. 415-434	Investigate the effect of gender of older sibblings, given other factors, on child mortality in Matlab, Bangladesh	Logistic regression of child mortality on: age, gender of siblings, mother's education, place of birth, ownership of physical capital, birth order and interaction terms (6 models)	age, family composition and interaction terms; mother's schooling, place of birth, ownership of physical capital	birth order
Binka, F.N., Maude, G.H., Gyapong, M., Ross, D.A. And Smith. P.G. _ Risk Factors for Child Mortality in Northern Ghana: A Case-Control Study _ International Journal of Epidemiology 1995 (vol.24):1 pp. 127-135	Examine potential determinants of high neonatal and child mortality in Northern Ghana	Logistic regression of neonatal and child mortality on: violence: Father beats carer no SBA Previous birth interval wet season water source feeding of colostrum type of roof dry season water source	neonatal: type of roof child >1years of age: violence: Father beats carer Previous birth interval wet season water source child: no SBA violence: Father beats carer Previous birth interval wet season water source	no SBA type of roof feeding of colostrum dry season water source
Benefo, K. and Schultz, T.P. _ Fertility and Child Mortality in Cote d'Ivoire and Ghana _ World Bank Econ Rev 1996 (Vol. 10):1 pp.123-158.	Examining the relationship between individual, household, and community characteristics and child mortality.	OLS of child mortality or number of births on: mother's/father's: schooling, age, height; household assets; residence; ethnicity; religion; access to water/ sanitation facilities, community health: problems malaria, measles, diarrhea; distance to health facilities or market; public health expenditure; immunization; prices of basic commodities	mother's/father's height Household assets per adult Krou/Ga-Adangbe language religion: christian ; price of maize or fish; community health: problems malaria, measles, diarrhea; distance to health clinic or market	mother's/father's: schooling, age; residence; language: other than Krou/Ga-Adangbe; religion: no christian; public health expenditure; immunization; prices of basic commodities other than maize and fish; access to water/ sanitation facilities
Taha, T.E., Dadabhai, S.S., Sun, J., Rahman, M.H. and Kumwenda, N. _ Child Mortality Levels and Trends by HIV Status in Blantyre, Malawi: 1989–2009 _ J Acquir Immune Defic Syndr 2012 (Vol.61): 2 pp.226-234	Identify factors which contributed to child mortality of infants born to HIV infected women in Malawi during different time periods	Multivariate Cox regression of child mortality of infants born to HIV infected mothers on: gender, birth weight, birth year, age, mother's age, mother's education, electricity, parity	HIV infected children: birth weight, age, electricity HIV uninfected children: birth weight, age, birth year	HIV infected children: gender, birth year, mother's age, parity HIV uninfected children: gender, mother's age, electricity, parity

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Landes, M., Van Lettow, M., Chan, A.K., Mayuni, I., Schouten, E.J. and Bedell, R.A. _ Mortality and health outcomes of HIV-exposed and unexposed children in a PMTCT cohort in Malawi. _ PLoS One. (2012) (Vol.7):10 e47337	Identify potential causes of child mortality of HIV exposed children.	Logistic regression of child mortality on: Marital status; socio-economic status; BMI; maternal self-reported health; HIV testing; maternal sd-NVP receipt/use; infant sd-NVP use; exclusive breastfeeding; HIV exposure; Maternal death; Birthweight; previous child death	HIV exposure; maternal death; birthweight; previous child death	marital status, socio-economic status, BMI, maternal self-reported health, HIV testing, maternal sd-NVP receipt/use, infant sd-NVP use, exclusive breastfeeding;
Rico,E., Fenn, B., Abramsky, Watts, T. _ Associations between maternal experiences of intimate partner violence and child nutrition and mortality: findings from Demographic and Health Surveys in Egypt, Honduras, Kenya, Malawi and Rwanda _ Journal of Epidemiology and Community Health 2011 (vol.65) pp. 360-367	Highlight the relationship between intimate partner violence and child mortality and stunting	Logistic regression of child mortality on: intimate partner violence adjustment variables: maternal: age, education, number of children, household wealth ranking, place of residence (Egypt, Honduras, Kenya, Malawi, Rwanda)	IPV (general term) for Kenya only IPV by type for Kenya (except "sexual only") *OR of adjustment variables were not reported*	IPV for all countries excpet Kenya
Jahn, A., Floyd, S., McGrath, N., Crampin, A.C., Kachiwanda, L., Mwinuka, V., Zaba, B., Fine, P.E.M., Glynn, J.R. _ Child Mortality in Rural Malawi: HIV Closes the Survival Gap between the Socio-Economic Strata _ PloS June 2010 (Vol. 5): 6	Investigate whether socio-economic factors affect child mortality differently when death is AIDS related versus when it is not.	Poisson regression of infant, child or teen mortality on: Age, sex and area of residence AND Mother's education, Father's education OR Household assets Dwelling class household source of income	AIDS mortality: household source of income: small trading, other	for non-AIDS mortality and all causes: none of the factors were significant for AIDS mortality: all causes but small trading and other main sources of income
Ombok, M., Adazu, K., Odhiambo, F., Bayoh, N., Kiriinya, R., Slutsker, L., Hamel, M.J., Williamson, J., Hightower, A., Laserson, K.L. and Feikin, D.R. _ Geospatial distribution and determinants of child mortality in rural western Kenya 2002–2005 _ Tropical Medicine and International Health 2010 (Vol.15): 4 pp 423–433	Study the role of geospatial risk factors on child mortality	Poisson regression of infant or child mortality on: Distance to stream ; Distance to public transport road; Distance to health facility; Distance to market; Elevation; Study area; Population density; Age; Education; Household size; Maternal age; Socio-economic status	Infant mortality: distance to stream ; distance to public transport road; age; household size; Child mortality: distance to market; Eelevation; study area; population density; age; education; household size; maternal age;	Infant mortality: distance to health facility; distance to market; elevation; study area; population density; age; education; maternal age; socio-economic status Child mortality: distance to stream ; distance to public transport road; distance to health facility; socio-economic status

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Omariba,D.W.R., Beaujot, R. and Rajulton, F. _ Determinants of infant and child mortality in Kenya: an analysis controlling for frailty effects _ Population Research and Policy Review 2007 (Vol. 26) pp.299–321	determine whether accounting for the frailty effect leads to identification of different determinants of child mortality	Frailty hazard model of <u>infant and child mortality</u> on: maternal education, migration status, household socioeconomic status, year of child's birth, ethnicity, marital status, type of marriage, religion, survival status of the preceding sibling, preceding birth interval, maternal age at birth of child, source of water and type of toilet facility	infant mortality: mainly biodemographic factors child mortality: socioeconomic, socioculturaland hygienic factors	infant mortality: mainly socioeconomic, socioculturaland hygienic factors child mortality: biodemographic factors
Eisele, T.P., Lindblade, K.A., Wannemuehler, K.A., Gimnig, J.E., Odhiambo, F., Hawley, W.A., Ter Kuile, F.O., Phillips-Howard, P., Rosen, D.H., Nahlen, B.L., Vulule, J.M. and Slutsker, L. _ Effect Of Sustained Insecticide-Treated Bed Net Use On All-Cause Child Mortality in An Area of Intense Perennial Malaria Transmission in Western Kenya _ The American Journal of Tropical Medicine and Hygiene 2005 (73):1 pp. 149–156 Test the effect of prolongued ITN usage on child mortality in Kenya		logistic regression of <u>child mortality</u> on : ITN usage (0-4 year periods) adjusted for age, sex, rainfall, underlying changes in child mortality in the area	ITN were significiant in all models	*results for adjustment variables were not shown*
Feng,X.L.,Theodoratou, E., Liu, L., Chan, K.Y., Hipgrave, D., Scherpbier, R., Brixi, H., Guo, S., Chunmei, W., Chopra, M., Black, R.E., Campbell, H., Rudan, I.,Guo, Y. _ Social, economic, political and health system and program determinants of child mortality reduction in China between 1990-2006 _ Journal of Global Health June 2012 (Vol. 2): 1 e. 010405		Random effect linear regression of <u>child mortality</u> on: health system and policy factor, health programmes and interventions factor, economic factor, social factor, political factor *(constructs made by factor analysis on 35 indicators)*	no-lags, 1-yr lag, 2 yr lag: health system and policy factor, health programmes and interventions factor, social factor, political factor 3yr-lag:: all significant	no-lags, 1-yr lag, 2 yr lag: economic factor
Godson, M.C. _ Environmental Determinants of Child Mortality in Nigeria _ Journal of Sustainable Development 2012 (Vol. 5): 1 pp. 65-75	Investigate the role of environmental factrors, in the presence of immunization, on child mortality	Principal component analysis of sanitation, safe water, electricity, maternal education, employment, infant immunization, average person per household, type of cooking fuel, housing type, type of flooring, method of solid waste disposal, type of roofing material, type of refuse disposal facilities, economic status, monthly household income simultaneous regression model of <u>child mortality</u> on components	factors for: immunization, household dwelling infrastructure, low polluting fuel	Maternal education Household Income Unemployment/mud house Unhealthy refuse disposal practice Refuse disposal Rich household Other factors Proximity to dump site Unsafe water

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Chowdhury, Q.H., Islam, R. and Hossain, K. _ Socio-economic determinants of neonatal, post neonatal, infant and child mortality _ International Journal of Sociology and Anthropology Vol. 2(6), pp. 118-125, June 2010	Identify socio-economic factors which affect child mortality in Bangladesh	Logistic regression of <u>neonatal and child mortality</u> on: mother's/father's education mother's/father's occupation monthly income of household types of latrine electricity	neonatal: nothing is significant postneonatal: mother's education mother's occupation child: mother's/father's education mother's occupation types of latrine electricity	neonatal: mother's/father's education; mother's/father's occupation; monthly income of household; types of latrine electricity postneonatal: father's education; father's occupation; monthly income of household; types of latrine; electricity child: father's occupation monthly income of household
Kembo , J. , Van Ginneken , J.K. _ Determinants of infant and child mortality in Zimbabwe: Results of multivariate hazard analysis _ Demographic Research 2009 (Vol. 21):1 3, pp.367-384	Identify socio-economic determinants of child mortality in Zimbabwe	Hazard function of <u>infant mortality</u>: Birth order and preceding birth; maternal age; gender of child; type of birth; residence; maternal/paternal education; wealth; piped water; toilet types	Birth order and preceeding birth: 6+ and short; type of birth;	maternal age; gender of child; residence; maternal/paternal education; wealth; piped water; toilet types
Gordon, R.M. _ Socio-economic Determinants of Infant and Child Mortality in Haiti _ Journal of Eastern Caribbean Studies 2009 (Vol. 34): 1 pp. 1-19	Identify determinancts of infant and child mortality in Haiti	Logistic regression of <u>child mortality</u> on: Education Income Age Type of Residence Piped Water	Education Income Age Piped Water	Type of Residence
Mekonnen, Y., Tensou, B., Telake, D.S., Degefie, T. and Bekele, A. _ Neonatal mortality in Ethiopia: trends and determinants _ BMC Public Health 2013, 13:483	Examine the determinants of neonatal mortality in Ethiopia	Cox hazard model of <u>neonatal mortality</u> on: year of birth, residence, region, mother's education, marital status, Household wealth index score, gender, season of birth, size at birth, birth order, Preceding birth interval, Age of mother at birth, tetanus injection, place of delivery, mode of delivery	region, mother's education, gender, season of birth, Preceding birth interval, Age of mother at birth, tetanus injection	year of birth, residence, marital status, Household wealth index score, size at birth, birth order, place of delivery, mode of delivery
Kamal, S.M.M _ Maternal Education as a Determinant of Neonatal Mortality in Bangladesh _ Journal of Health Management 2012 (Vol.14):3 pp.269–281	Investigate the effect of maternal education and other variables on neonatal mortality in Bangladesh.	logistic regression of <u>neonatal mortality</u> on: Maternal education; Place of residence; Religion; Region; Wealth index; Maternal age; Birth order; gender; Drinking water; Toilet facility; ANC; SBA; Delivery setting	Maternal education; Religion; Maternal age; Birth order; ANC;	Place of residence; Region; Wealth index; gender; Drinking water; Toilet facility; SBA; Delivery setting

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Zaninil, R.R., Moraes, A.B.; Giuglianil,E.R.J.; Riboldil, J. _ Contextual determinants of neonatal mortality using two analysis methods, Rio Grande do Sul, Brazil _ Revista de Saúde Pública 2011 (vol.45):1	Investigating the effect of methodology chosen on the significance of potential determinants of neonatal mortality in Brazil.	Logistic regression (normal and multilevel) of <u>neonatal mortality</u> on: gender, ethnicity, birth weight, 1-minute Apgar score, 5-minute Apgar score, Birth defects, Simplifi ed SGA, Place of birth, Type of delivery, Type of pregnancy, Gestational age, Prenatal visits, parity, Previous fetal loss, Mother's age, Maternal education, Marital status, Mother's occupation	birth weight, 1-minute Apgar score, 5-minute Apgar score, Birth defects, Type of delivery, Gestational age, Previous fetal loss *Hierarchical effect model shows similar results*	gender, ethnicity, Simplified SGA, Place of birth, Type of pregnancy, Prenatal visits, parity, Mother's age, Maternal education, Marital status, Mother's occupation
Titaley, C.R., Dibley, M.J., Agho, K., Roberts, C.L. and Hall, J. _ Determinants of neonatal mortality in Indonesia _ BMC Public Health 2008 (vol.8): 232	Investigate the impact of proximal and distal factors on neonatal mortality in Indonesia	Multilevel logistic regression of neonatal mortality on: Region, SBA, Parental occupation, Household wealth index, Maternal age at child birth, gender, Birth size,Birth rank and birth interval, Delivery complications, Postnatal care	Region, SBA, Parental occupation, gender, Birth size,Birth rank and birth interval, Delivery complications, Postnatal care	regions: NTB/NTT, Kalimantan SBA: <25%, 25% – 49% Household wealth index, Maternal age at child birth, birth size: Larger than average Birth rank and interval:1st birth rank; ≥ 4th birth rank, birth interval >2 yrs
Kumar, C., Singh, P.K. and Rai, R.K., _ Under-Five Mortality in High Focus States in India: A District Level Geospatial Analysis _ PloS May 2012 (Vol. 7): 5 e37515	Identify determinants of child mortality in India via various methodologies.	OLS and spatial model of <u>child mortality</u> on: Urbanization; Population Density; Female Literacy; HHs having BPL cards; Coverage Gap Index; CHC with LBWM; Newborn Care provided in PHC; Average Annual Temperature; Rainfall	OLS: Urbanization; HHs having BPL cards; Coverage Gap Index; Average Annual temperature, rainfall spatial error model: Urbanization; Female Literacy; HHs having BPL cards; Coverage Gap Index; Newborn Care provided in PHC;	OLS: Population Density; Female Literacy; CHC with LBWM; Newborn Care provided in PHC; spatial error model: Population Density; CHC with LBWM; Average Annual Temperature; Rainfall

Appendix H

Papers on maternal mortality, at country-level

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Asamoah, B., K. Moussa, M. Stafstrom, and G. Musinguzi _ Distribution of causes of maternal mortality among di erent socio-demographic groups in Ghana; a descriptive study _ BMC Public Health 2011 vol 11 (1): 159	Test if causes of maternal mortality vary across socio-demographic groups	Logistic Regression of causes (haemorrhage, abortion, other NID, mscellaneous) of MMR on categorical variables fo age, education, residence and marital status	**All variables** are significant for at least on cause of maternal mortality. Socio-demographic factors have different impacts across the various maternal mortality causes	
Chowdhury, M.E.; Botlero, R.; Koblinsky, M.; Saha, S.K.; Dieltiens, G.; Ronsmans, C. _ Determinants of reduction in maternal mortality in Matlab, Bangladesh: a 30-year cohort study _ Lancet 2007; 370: 1320–28	Contribute to the limited research done on the effectiveness of actions taken to reduce maternal mortality by analyzing the effect of SBA on mortality trends in Bangladesh over the past 30 years.	logistic regression of MMR on annual trends, SBA regions (ICDDR, B) vs other (government), mother's education, asset quintiles, religion, maternal age, pregnancy order	annual trend 1990-2005, **SBA region** (ICDDR,B), mother with more than 5 years of eduction, maternal age (more than 30), first child	Annual trend 1976-1989, mother with 4 or less years of formal education, asset quintiles, religion, maternal age (< 19), pregnancy order (4th or higher)
Du, Q.; Nass, O.; Bergsjo, P.; Kumar, B.N. _ Determinants for High Maternal Mortality in Multiethnic Populations in Western China _ Health Care for Women International 2009 (Vol. 30):957–970	Investigation of determinants of maternal mortality and identify the links between the various contributing factors	Stepwise regression of MMR on population density, % of minority groups, % of women in reproductive age, Annual net income per capita,Farmer annual income per capita, % of health expenditure to total financial expenditure, Average number of village doctors, % of villages with no doctor, Skilled maternal and child health personnel per 1,000 population, % of female village doctors, % of village doctors qualified to deliver, % of registered birth attendants, Hospital delivery rate, Antenatal care, Postnatal visit rate	Average number of village doctors, proportion of villages without doctors, percent of minority groups	Stepwise regression of MMR on population density, % of women in reproductive age, Annual net income per capita, Farmer annual income per capita, % of health expenditure to total financial expenditure, **Skilled maternal and child health personnel** per 1,000 population, % of female village doctors, **% of village doctors qualified to deliver, % of registered birth attendants**, **Hospital delivery** rate, **Antenatal care**, **Postnatal** visit rate

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant variables
Fournier, P., A. Dumont, C. Tourigny, G. Dunkley, and S. Dramé _ Improved access to comprehensive emergency obstetric care and its e ect on institutional maternal mortality in rural Mali. _ Bulletin of the World Health Organization. 2009 Vol. 87(1): 30–38.	Evaluation of the effect of obstetric referral system on maternal moratlity	Logistic regression of maternal mortality on before, during and after implementation of comprehensive obstetric intervention , adjusted for age, previous C- section, district accessibility, Caesarean delivery and transfusion	**obstetric referal** leads to a 50 percent decrease in probability of mortality between the year beofre the intervention was implemented and 2 years after the implementation.	
Gupta, S.D.; Khanna, A.; Gupta, R.; Sharma, N.K.; Sharma, N.D. _ Maternal Mortality Ratio and Predictors of Maternal Deaths in Selected Desert Districts in Rajasthan: A Community-Based Survey and Case Control Study _ Women's Health Issues 2010 (Vol. 20): 80–85	Identification of risk factors of maternal mortality	Logistic Regression of MMR on mother's age, gravida (1), no schooling, below poverty line, no ANC, complications during pregnancy, complications during delivery, home delivery (vs institutional)	mother age, gravida (1), below poverty line, no **ANC**, complications during pregnancy, home delivery (vs **institutional**)	no schooling, complications during delivery
Hussein, J., J. Bell, M. Dar Iang, N. Mesko, J. Amery, and W. Graham _ An appraisal of the maternal mortality decline in Nepal. _ PLoS ONE 2011. Vol 6. (5), 1–10.	Identification of factors which could explain the changes in maternal mortality ratio and maternal mortality rate reported over time in Nepal	OLS regression of changes of maternal mortality ratio or rate one changes in clean, institutional deliveries, change in met need of emergency obstetric care, change in anemic status, change in birth preparation, birth order, wealth, maternal age, HDI, GDP, gender empowerement and general fertility	**All variables** are significant when the dependent variable is maternal mortality rate;	GDP is not significant in the regression of maternal mortality ratio
Koblinsky, M., I. Anwar, M. Mridha, M. Chowdhury, and R. Botlero _ Reducing maternal mortality and improving maternal health: Bangladesh and MDG 5. _ Journal of Health, Population and Nutrition 2009. Vol. 26(3).	Identify actions which have the potential of reducing maternal mortality	Analysis of time trends between maternal mortality (or survival) and -skilled birth attendants, -ANC -quality emergency obstetric care -family planning -education of women	**All these variables** are correlated with decreases in maternal mortality over time (in both rural or urban areas)	

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	**Statistically non-significant variables**
Moran, A., G. Sangli, R. Dineen, B. Rawlins, M. Yaméogo, and B. Banza _ Birth-preparedness for maternal health: findings from Koupéla district, Burkina Faso. _ Journal of Health, Population and Nutrition (2006) Vol. 24:(4), 489–97	Investigate the impact of preparaeness on usage of skill birth attendants (using the assumption that SBA leads to decrease maternal mortality)	logistic regression of SBA usage on socio-demographic factors and on 4 measures of birth preparadness (Knowledge of at least five danger signs, plan for SBA, plan for transport emergency and plan for saving money for emergency)	**antenatal care** parity distance from health center plan for **SBA** plan for transport emergency plan for saving money for emergency	education knowledge of at least five danger signs
You, F., K. Huo, R. Wang, D. Xu, J. Deng, Y. Wei, F. Shi, H. Liu, G. Cheng, Z. Zhang, P. Yang, T. Sun, X. Wang, B. Jacobsson, and C. Zhu _ Maternal mortality in henan province, china: Changes between 1996 and 2009. _ PLoS ONE . 2012. Vol 7 (10): 1-7	Investigate trends in maternal mortality ratio across time	logistic regression of MMR for various mortality causes and controled for education, georaphics, income, health care quality	Marked decline in maternal mortality over time, especially in rural areas Main cause of maternal death: hemorrhage (43.8%), and hypertension MMR higher in rural areas when income is lower income, education is lower and health care is poorer	
Illah, E., G. Mbaruku, H. Masanja, and K. Kahn. _ Causes and risk factors for maternal mortality in rural Tanzania - Case of Rufiji health and demographic surveillance site (HDSS) _ African Journal of Reproductive Health 2013 Vol. 17(3): 119–130.	Identify causes and risk factors of maternal mortality in rural Tanzania	Build SES index via PCA Cox regression of maternal mortality on socioeconomic status, education, occupation, marital status, SES index	maternal age, maritas status	SES, education, occupation

Appendix I

Papers on neonatal, infant and child mortality, cross-country

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant
Akachi, Y., Atun, R. _ Effect of Investment in Malaria Control on Child Mortality in Sub-Saharan Africa in 2002–2008 _ PLOS One 2011 Vol. 6 (6)	Assess the impact on child mortality of international financing for malaria control in SSA.	Fixed effect, random effect and feasible generalised least squares regressions on U5MR on various interventions	**malaria control** measures are always significant	**ORT, PMTCT, ART for children, immunization and clean water** are significant in some regressions not in others
Boschi-Pinto, C., R. Bahl, and J. Martines _ Limited progress in increasing coverage of neonatal and child-health interventions in Africa and Asia. _ Journal of Health, Population and Nutrition 2009 Vol. 27(6): 755–62.	Identification of interventions which lead to decrease in child mortality	OLS of neonatal or child mortality on SBA, breastfeeding, vaccination, ORT, ARI	early initiation of **breastfeeding, oral rehydration therapy** for diarrhea and care-seeking for **ARI**	SBA; exclusive breastfeeding
Fay,M. and Leipziger,D. and Wodon,Q.and Yepes,T. _ Achieving Child-Health-Related Millennium Development Goals: The Role of Infrastructure _ World Development 2005 Vol. 33 (8) , pp. 1267–1284	Identify factors which lead to better child-health outcomes	Fixed effect regression of infant and child mortality on infractrure index, health index, GDP, literacy, ethnic diversity and asset holding	health principal component index (**immunization, ANC SBA**), malnutrition, GDP, female literacy, urbanisation are always singificant Infrastructure index is signifcant in the child mortality study only	Infrastructure index is not signifcant in the infant mortality study signficance of asset holding, ethnic diversity and Gini inquality index vary across regressions
Fayissa, B. _ The Determinants of Infant and Child Mortality in Developing Countries: The Case of Sub-Sahara Africa _ The Review of Black Political Economy 2001 (Vol. 29):2 pp 83-98	Identify factors which affect child mortality while accounting for potential endogeneity effect	OLS and Two-stage regression of infant and child mortality on: crude birth rate; public health expenditures; reductions in the debt burdens; years of education of women;rural residence malnourished TSLS of child mortality: crude birth rate; public health expenditures; years of education of women; rural residence; reductions in the debt burdens	infant: public health expenditures; reductions in the debt burdens; rural residence child:crude birth rate; public health expenditures; reductions in the debt burdens; years of education of women; TSLS of child mortality: crude birth rate; public health expenditures; years of education of women; rural residence; reductions in the debt burdens	infant: crude birth rate; years of education of women; child: rural residence; malnourished TSLS: all were significant

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant
Hojman, D.E. _ Economic and other determinants of infant and child mortality in small developing countries: the case of Central America and the Caribbean _ Applied Economics, 1996 (Vol.28) 281290	Investigate the role of determinants of child or infant mortality in a cross sectional study (countries: Central America and Caribbean)	OLS of child mortality on: malnutrition water inflation public expenditure on health care x crude birth rate total external debt as a share of GNP	**malnutrition** **water** total external debt as a share of GNP	inflation public expenditure on health care x crude birth rate
Lawn, J.E. and Kinney, M.V. and Black, R.E. and Pitt, C. and Cousens, S. and Kerber, K. and Corbett, E. and Moran, A.C.and Morrissey, C.S. and Oestergaard, M.Z. _ Newborn survival: a multi-country analysis of a decade of change. _ Health Policy and Planning 2012 Vol.27	Identification of factors which impact neonatal survival in various geographical regions	Elastic net algorithm of the average annual rate of change (AARC) of <u>neonatal</u> mortality on the AARC of GNi per capita, general fertility, female literacy, THE, DPT3, SBA, government effectiveness, teen fertility, baseline NMR level, political stability, HIV prevalence, PAB	All but PAB are significant in developed countries **teen fertility** and **PAB** are significant for SSA SBA, general and teen fertility are significant for other regions	for SSA: AARC of GNi per capita, general fertility, female literacy, THE, DPT3, SBA, government effectiveness, baseline NMR level, political stability, HIV prevalence
Muldoon, K.A., Galway, L.P., Nakajima, M., Kanters, S., Hogg, R.S., Bendavid, E. And Mills, E.J. _ Health system determinants of infant, child and maternal mortality: A cross-sectional study of UN member countries _ Globalization and Health 2011 (Vol. 7): 42	Examine the link between health systems indicators and mortality rates	Mixed effect logistic regression of <u>infant child</u> and <u>maternal mortality</u> on: Nursing/midwife density Physician density; access to water and sanitation; % Of births attended by skilled staff; Measles immunization; Total health expenditure; Out-of-pocket expenditure on health; Government health expenditure; Private share of total health expenditure Corruption index ; Fertility rate; Urban population value; Population growth value; Female labour force participation	Infant or child mortality: **Physician** density; access to **water** and sanitation; Out-of-pocket expenditure on health; Corruption index Maternal mortality: % Of population with sustainable access to **water** and sanitation Total health expenditure per person Corruption index Fertility rate	<u>Infant/child</u>: **Nursing/midwife density;** **% Of births attended by skilled staff;** **Measles immunization;** Total health expenditure; Government health expenditure; Private share of total health expenditure; **Fertility rate**; Urban population value; Population growth value; Female LFP <u>Maternal:</u> Nursing/midwife density **Physician density;** % Of **births attended by skilled staf**f; Measles **immunization**; Out-of-pocket expenditure on health; Government health expenditure; Private share of total health expenditure; Urban population value; Population growth value; Female LFP

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant
Sattler, C.; Shandra, J.M. _ Do health nongovernmental organizations improve child mortality? _ International Journal of Sociology 2012 (Vol.42): 2 pp.28-46	Test whether NGOs decrease child mortality in SSA	OLS regression of child mortality on: health NGO, IMF structural adjustment recipient, multilateral debt service ratio, multinational corporate investment, international trade, access to improved water source, access to improved sanitation facility, GDP, domestic investment, secondary school enrollment, female secondary school enrollment, democracy, public health expenditure, malnutrition prevalence, total fertility rate, HIV prevalence	health NGO, multilateral debt service ratio, multinational corporate investment, international trade, access to improved water source, access to improved sanitation facility, GDP, public health expenditure, malnutrition prevalence, HIV prevalence	IMF structural adjustment recipient, domestic investment, secondary school enrollment, female secondary school enrollment, democracy, total fertility rate
Shandra, C.L., Shandra, J.M. and London,B. _ The International Monetary Fund, Structural Adjustment, and Infant Mortality: A Cross-National Analysis of Sub-Saharan Africa _ Journal of Poverty 2012, (Vol.16) 194–219	Investigate the potential adverse effect of IMF structural adjustemnt on infant health in SSA.	Two-way fixed effect OLS of infant mortality in 32 SSA countries on: amount received from IMF structural adjustment; access to improved water and sanitation; caloric intake; GDP ; democracy; public health expenditures; female secondary school enrollment; debt service ratio; immunization rate; HIV prevalence; corporate investment; international trade; domestic investment	HIV prevalence; water and sanitation; female secondary school enrollment; debt service ratio; corporate investment; international trade; GDP	amount received from IMF structural adjustment; caloric intake; GDP ; democracy; public health expenditures; immunization rate; domestic investment
Wang, L. _ Determinants of child mortality in LDCs: Empirical findings from demographic and health surveys _ Health Policy 2003 Vol. 65: 277 -299	Investigate trends in child mortality and identify its determinants	OLS and WLS of infant or child mortality on Five-year moving average of GDP per capita, Five-year moving average of share of rural population, Index for possession of durable goods for all households, Share of health expenditure to GDP, Percent of household population with female age 6 and over having primary education, Percent of household population with female age 6 and over having secondary education, Proportion of women who have knowledge of ORT, Proportion of children who were breastfed for 2 /3 months,vaccination, water, sanitation, electricity • National, urban, rural analysis	as child mortality declines, inequality gap increases significance vary by geographic classification urban: assets, electricity and share of health expenditure to GDP are significant; national: pit. oilets, water, breastfeeding 2 3 months, Percent of household population with female age 6 and over having secondary education,Percent of household population with female age 6 and over having primary education,	significance vary by geographic classification : rural: nothing is significant; urban: vaccination, water national: water, ORT (for U5MR only)

Appendix J

Papers on maternal mortality, cross-country

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant
Ahmed, S., Q. Li, L. Liu, and A. Tsui _ Maternal deaths averted by contraceptive use: an analysis of 172 countries. _ The Lancet 2012 Vol. 380(9837),: 111–25.	Perform a counterfactual analysis of unmet family planning on maternal mortality	Logistic regression of maternal deaths on GDP, general fertility rate, SBA, contraceptive prevalence rate, dummy variables for regions or country	**contraceptives**	
Conde-Agudelo, A., J. Belizán, and C. Lammers _ Maternal-perinatal morbidity and mortality associated with adolescent pregnancy in Latin America: Cross-sectional study. _ American Journal of Obstetrics and Gynecology 2005 Vol.192(2): 342–9.	Test whether teen pregnacies are a cause of adverse pregnancy outcomes	Multivariate Cox Regression Hazard of maternal mortality on teen pregnancy adjusted for parity, mother's education, marital status, cigarette smoking, interpregnancy interval, prepregnancy, BMI, weight gain due to pregnancy, miscarriage history, LBW, perinatal death, and chronic hypertension, gestational age at first attendance for antenatal care, number of antenatal visits, geographic area, hospital type, and year of delivery.	**teen pregnancy**	
DerSarkissian, M.; Thompson, C.A.; Arah, O.A. _ Time series analysis of maternal mortality in Africa from 1990 to 2005 _ Journal of Epidemiology and Community Health 2013: 1-7	Assess the role of sociodemographic and other factors on maternal mortality rates in Africa	negative binomial and mixed Poisson regression models of MMR on HIV prevalence, GDP, fertility rate, female to male primary school enrolement, NMR, sanitation facilities (contemporaneous and/or explanatory varibales)	all contemporaneous independent variables: all variables were significant contemporaneous and lagged variables: all were significant except female to male primary school enrolment	**contemporaneous and lagged variables:** **primary school enrolment**
Gil-Gonzàlez, D., M. Carrasco-Portieno, and M. Ruiz _ Knowledge gaps in scientific literature on maternal mortality: a systematic review _ Bulletin of the World Health Organization. 2006 Vol. 84: 903 – 909	Identify knowledge gaps that should be included in studies on maternal mortality	Systematic review of determinants of maternal mortality	There is ainsufficient information on the role play by cultural and political factors	

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant
Karlsen, S., L. Say, J. Souza, C. Hogue, D. Calles, A. Gülmezoglu, and R. Raine _ The relationship between maternal education and mortality among women giving birth in health care institutions: Analysis of the cross sectional WHO Global Survey on Maternal and Perinatal Health _ BMC Public Health 2011 Vol. 11 (1): 1–10.	Assess how maternal education impacts maternal mortality given a set of potentially influencial factors	Logistic regression of maternal morality on categories of maternal education, maternal age, marital status, previous births, and institutional and country characteristics	age marital status previous births education	**Institutional capacity**
Liotta, G., S. Mancinelli, K. Nielsen-Saines, E. Gennaro, P. Scarcella, N. Magid, P. Germano, H. Jere, G. Guidotti, E. Buonomo, F. Ciccacci, L. Palombi, and M. Marazzi _ Reduction of Maternal Mortality with Highly Active Antiretroviral Therapy in a Large Cohort of HIV-Infected Pregnant Women in Malawi and Mozambique _ PLOS One August 2013 Vol. 8(8): e71653	Assess the impact of HAART, along side other factors, on maternal mortality	Cox regression of maternal mortality on CD4 count, ANC HAART, viral load, BMI, hemoglobin	**antenatal HAART** CD4 cell count hemoglobin BMI	viral load
Montoya, A., C. Calvert, and V. Filippi _ Explaining differences in maternal mortality levels in sub-Saharan African hospitals: a systematic review and meta-analysis _ International Health 2014 Advance online publication	Identify reasons for variation of MMR in hospital settings	Systematic review of hospital-based studies on maternal mortality prevalence	**SBA** and type of hospital account for 44% of the variation in mortality ratio across hospitals	

Author Title Journal	Objective	Methods	Results and comments	
			Statistically significant variables	Statistically non-significant
Muldoon, K.A., Galway, L.P., Nakajima, M., Kanters, S., Hogg, R.S., Bendavid, E. And Mills, E.J. _ Health system determinants of infant, child and maternal mortality: A cross-sectional study of UN member countries _ Globalization and Health 2011 (Vol. 7): 42	Examine the link between health systems indicators and mortality rates	Mixed effect logistic regression of infant child and maternal mortality on: Nursing/midwife density Physician density; access to water and sanitation; % Of births attended by skilled staff; Measles immunization; Total health expenditure; Out-of-pocket expenditure on health; Government health expenditure; Private share of total health expenditure Corruption index ; Fertility rate; Urban population value; Population growth value; Female labour force participation	Infant or child mortality: **Physician** density; access to **water** and sanitation; Out-of-pocket expenditure on health; Corruption index Maternal mortality: % Of population with sustainable access to **water** and sanitation Total health expenditure per person Corruption index Fertility rate	Infant/child: **Nursing/midwife density; % Of births attended by skilled staff; Measles immunization;** Total health expenditure; Government health expenditure; Private share of total health expenditure; **Fertility rate**; Urban population value; Population growth value; Female LFP Maternal: Nursing/midwife density **Physician density;** % Of **births attended by skilled sta**ff; Measles **immunization**; Out-of-pocket expenditure on health; Government health expenditure; Private share of total health expenditure; Urban population value; Population growth value; Female LFP
Souza, J., A. Gülmezoglu, J. Vogel, G. Carroli, P. Lumbiganon and al. _ Moving beyond essential interventions for reduction of maternal mortality (the WHO multicountry survey on maternal and newborn health): a cross-sectional study _ The Lancet 2013 Vol.381 (9879): 1747– 55.	Assess how maternal health interventions and the maternal severity index (MSI) influence maternal mortality rates	Logistic regression of MMR on key maternal interventions and MSI		maternal mortality ratio was 2-3 timeshigher than expected for the noted severity in spite of the high coverage of **maternal key inerventions:** prophylactic uterotonic, therapeutic uterotonic, magnesium sulphate, prophylactic antibiotic, and parenteral antibiotic
Sudhir, A. and T. Bärnighausen _ Human resources and health outcomes: cross-country econometric study _ The Lancet 364(9445), 1603–9.	Provide information on the unclear link between resources for health and mortality	OLS of infant, child or maternal mortality on GNI per capita, income poverty, female literacy, doctor density nurse density	GNI nurse density doctor density	female literacy

Appendix K

Finite mixture model calculation

$$f(y_i) = \sum_{k=1}^{K} \lambda_k \ f_k(y_i, \theta_k)$$

$$0 < \lambda_k < 1; \sum_{k=1}^{K} \lambda_k = 1$$

i: observations (countries) i ϵ[1,2,...,n]
k: sub-group: k ϵ[1,2,...,K]
λ_k: endogenously determined weight
θ_k: set of parameters (mean, variance...)

The log-likelihood function is:

$$l(\theta) = \sum_{i=1}^{n} ln\left(\sum_{k=1}^{K} \lambda_k \ f_k(y_i, \theta_k)\right)$$

F.O.C.:

$$\frac{\partial l(\theta)}{\partial \theta_j} = \sum_{i=1}^{n}\left(\frac{1}{\sum_{k=1}^{K} \lambda_k \ f(y_i, \theta_k)} \lambda_j \frac{\partial f(y_i, \theta_j)}{\partial \theta_j}\right) = 0$$

$$\frac{\partial l(\theta)}{\partial \theta_j} = \sum_{i=1}^{n}\left(\frac{1}{\sum_{k=1}^{K} \lambda_k \ f(y_i, \theta_k)} \lambda_j \frac{f(y_i, \theta_j)}{f(y_i, \theta_j)} \frac{\partial f(y_i, \theta_j)}{\partial \theta_j}\right) = 0$$

$$\frac{\partial l(\theta)}{\partial \theta_j} = \sum_{i=1}^{n}\left(\frac{\lambda_j \ f(y_i, \theta_j)}{\sum_{k=1}^{K} \lambda_k \ f(y_i, \theta_k)} \frac{\partial ln \ f(y_i, \theta_j)}{\partial \theta_j}\right) = 0$$

$$\frac{\partial l(\theta)}{\partial \theta_j} = \sum_{i=1}^{n}\left(w_{ij} \ \frac{\partial ln \ f(y_i, \theta_j)}{\partial \theta_j}\right) = 0$$

Appendix L

Example of calculation of costs

I) Effective cost of immunization

If in 2008:
the total EPI cost: $ 12, 500,000
under-five population: 1,495,400
Immunization coverage: 60%

The effective unit cost of immunization:

$$\frac{total\ EPI\ cost}{0.60 * population\ in\ 2008} = \frac{\$12,500,000}{0.60 * 1,495,400} = \$13.93 \tag{L.1}$$

Accounting for population growth between 2008 and 2009:

If in 2009 population grows and is 1,525,100 then 60% coverage of immunization costs:

$$C_{60\%} = (1 + percentagechangeinpopulationsize) * annualcostreportedfor2008$$

$$= \left(1 + \frac{1,525,000 - 1,495,400}{1,495,400}\right) * \$12,500,000 = \$12,747,430$$

II) Cost of malaria prevention

Unit cost of a bed net in 2008 inclusive of associated campaign cost: $11.25 (2011 USD)
Under-5 population in 2008: 1,495,400
Under-5 coverage of malaria nets: 40%

- Cost of malaria prevention per child in 2008 (ω_{MAL}; in 2011 USD)

$$\omega_{MAL} = \frac{Cost\ of\ supplying\ a\ net\ in\ 2008}{number\ of\ children\ sleeping\ under\ the\ same\ net}$$

$$= \frac{\$11.25}{2} = \$5.61\ (2011\ USD)$$

- Cost of malaria prevention in 2008 (2011 USD)

$$Cost_{MAL} = U5\ coverage\ of\ malaria\ nets * U5 population * \omega_{MAL}$$

$$= (\frac{40}{100}) * 1,495,400 * \$5.61$$

$$= \$3,355,678$$

III) Cost of family planning

ODA disbursement on family planning: \$1,490,000 Population of 15-39 years of age : 4,882,000 Number of women aged 15-19, out of 1,000 that are not pregnant: 796
Female population of 15-19 years of age:729,000
Unit cost of family planning: ω_{FP}

$$\omega_{FP} = \frac{ODA\ disbursement\ on\ family\ planning}{Population\ of\ 15-39\ years\ of\ age}$$

$$= \frac{\$1,490,000}{4,882,000} = \$0.31$$

Total cost of *successful* family planning: $Cost_{FP}$

$$Cost_{FP} = \omega_{FP} * \frac{\# of\, not\, pregnant\, women 15-19\, (out\, of\, 1{,}000)}{1000} * Female\, population\, of\, 15-19$$

$$= \$0.31 * \frac{796}{1000} * 729{,}000 = \$179{,}888$$