Multilevel effects of education and economic resources on infant mortality in developing countries

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INTRODUCTION

The literature linking socioeconomic status and health has been accumulating for over a century (Antonovsky 1967). For much of this time, the focus has been on an individual's social status or societal position - as reflected either by their education, occupation, income or wealth - acting as a fundamental determinant of health by influencing many different intermediate factors (Adler, Boyce et al. 1994; Link and Phelan 1995). This focus on socioeconomic status as a unified concept may well have been due, in large part, to the recognition that the indicators or components of social status were not only correlated with each other, but generally demonstrated similar associations with health outcomes (Antonovsky 1967; Liberatos, Link et al. 1988; Bollen, Glanville et al. 2001)

More recently, however, some analysts have come to stress the multidimensional nature of socioeconomic status and have attempted to disentangle the relative health impacts of its various components. The justifications for examining the separate health effects of different socioeconomic indicators are several: different indicators may operate through different pathways to influence health, and may therefore have a larger or smaller influence depending on the health outcome under consideration (Winkleby, Jatulis et al. 1992; Davey Smith, Hart et al. 1998; Braveman, Cubbin et al. 2005; Geyer, Hemström et al. 2006). But perhaps most important has been the recognition that determining the relative importance of human resources (such as education) versus economic resources (as reflected by income or assets) has important policy implications, particularly with respect to developing countries (Fuchs, Pamuk et al. 2010).

In fact, the need to assess the contribution of increased education, as opposed to more general indicators of economic development, was recognized early within the context of assessing strategies aimed at improving child health in developing countries. The pioneering work of John Caldwell did much to emphasize the unique effects of maternal education on infant mortality (Caldwell 1979; Caldwell and Caldwell 1985). Since these early efforts, research on child health in developing countries has provided an impressive body of evidence supporting the strong, independent positive effect of greater maternal education on child health after adjustment for household economic resources (Hobcraft, McDonald et al. 1984; Mensch, Lentzner et al. 1985; Cleland and van Ginneken 1988; Bicego and Boerma 1993; Heaton, Forste et al. 2005), although the deterministic character of this relationship has often been questioned (Wolfe and Behrman 1987; Hobcraft 1993; Desai and Alva 1998).

Increasingly, however, researchers have come to acknowledge that decisions regarding the allocation of investments depend not only upon the relative effects of increasing either education of wealth assessed at the level of individuals or households, but also depend upon the larger, contextual effects of increasing human versus material resources. That is, does increased education or material well-being within a community or country convey health benefits to those less educated and less materially well-off?

Comparative research has repeated shown that both the strength of the maternal education and child health relationship is contextually dependent, varying across regions and countries (Hobcraft 1993; Boyle, Racine et al. 2006), and across regions and communities within countries (Terra de Souza, Cufino et al. 1999; Kravdal 2004). Historically, studies that wished to examine community level effects of education, economic resources and other factors did so by examining within-country community variation in indicators of child health using ecological analyses, generally finding that child health outcomes were often associated not only with indicators of economic development, such as electricity and sanitation, but also with the overall level of educational attainment. In recent years, some studies have taken advantage of the hierarchical structure of surveys conducted in developing countries to examine the question of whether a higher level of education among women in a community conveys an additional child health advantage in addition to any effect of mother's education at the individual level. The reasons to expect such an added effect are numerous, including an 'imitative effect' where less educated women learn from and model the health behaviors of the broader community as well as a positive effect on women's autonomy more generally (Kravdal 2004).

At even larger levels of population aggregation, the assessment of the effects of human and material resources has been distinctly one-sided. There is no question that the overall level of economic development is an important determinant of variation in child health across countries. Comparative country analyses have consistently found economic resources, as measured by per capita GDP or GNI, to be the strongest determinant of infant and child mortality (Schell, others) among the factors included for analysis. However to date only a few studies have examined the role of education on cross-national variation in child health, and those that have usually used the level of adult - or women's - literacy as the measure of educational attainment. These studies have generally indicated a strong education effect, net of GDP or GNI and other variables included in the models (Schell, others).

We know of no studies, however, that have taken all of these levels into account simultaneously. It is therefore difficult to determine if the relative impacts of education and material resources at each higher level of aggregation is merely a reflection of the combined individual effects, or if there is an additional benefit bestowed by attaining community and population levels of education or wealth such that even households with less wealth and less education benefit. It is generally assumed that an increase in average per capita income implies general improvements in health-related infrastructure and services through tax-generated revenues. But the mechanisms through which increases in average educational attainment might operate to improve overall health are not as intuitive. One might well hypothesize, though, that a higher average education level might improve child health through such avenues as technological advances affecting health and, perhaps more importantly, in supporting country-level policies that enhance human capital.

This paper is an attempt to assess the relative effects of education and material resources on infant mortality in developing countries by considering the impact of individual, community and country levels of education and wealth on the likelihood of infant death. We employ multi-level logistic models in order to capture this hierarchical structure, assessing both explained and random variation across countries, across communities within countries, and across individuals within communities.

DATA

The primary sources of data for this study are the Demographic and Health Surveys (DHS) conducted in developing countries since 2003. The DHS program strives to collect data that are comparable across countries by employing a basic standard questionnaire which has been modified and improved in each phase of the program. This core questionnaire covers background characteristics of women aged 15-49, their reproductive histories, knowledge and use of contraceptive methods, breastfeeding, child health and nutrition, husband's background, as well as information on characteristics of the household. [further details can be found in the Guide to DHS Statistics (Rutstein and Rojas 2003)]. This study uses data from DHS surveys from developing countries in Africa, Asia, and Latin America defined by the World Bank as "low-" or "lower-middle" income countries in 2005 (World Development Indicators database, World Bank), excluding the transitioning countries of the former Soviet Union. We include the most recent survey for each country beginning with 2003. Some country surveys meeting this criterion were excluded because they did not contain comparable data for the variables used in this analysis[1].

The DHS surveys report full birth histories of women aged 15-49. For each woman in the sample we selected only the most recent birth occurring no more than 5 years prior to the interview date. For women whose most recent birth occurred within the 12 months immediately prior to the interview, we selected the previous live birth (if any and if it occurred no more than 5 years prior to the interview date). Limitation to only the most recent birth prevented clustering at the level of the individual mother and placed the relevant birth closer in time to the other variables being measured.

DHS collects information on education of individuals within the household, including highest level of schooling completed. We examined the effect of education of both the mother and household head using 5 levels of educational attainment: no formal education, incomplete primary, completed primary, incomplete secondary, and completed secondary or more. To assess the effect of community-level education, we calculated the mean years of completed schooling for all reproductive aged (15-49) women, based on weighted samples. We then divided the distribution of mean years of attained education for all clusters into approximate tertiles: 0-<4 years (referent), 4-<8 years, and 8 or more years. At the country level, we examined the impact of the proportion of the entire working-age population (ages 15 – 65) that had completed secondary school as a continuous variable, transformed by taking the natural logarithm in order to correct for skewness in distribution. We included both sexes at the country level because the presumed modeling or imitative effect whereby less educated mothers model the behavior of their more educated counterparts would be less important at the national level than at the community level. On the other hand, a higher proportion of both men and women with at least a secondary school credential would provide not only a general indication of social and economic

[1] Guyana was dropped because of missing information on fertility preferences and an overall small sample of births (4,923). Turkey is classified as an 'upper-middle' economy.

development, but would also be an indicator of the availability of a more highly skilled work force. A higher proportion of highly skilled workers could, at least theoretically, provide both skilled health professionals and highly trained teachers, which could in turn improve the quality of both the health care and education available for the country a whole.

An important requirement for inclusion in our analytic dataset was that the DHS surveys contain the wealth index, a standardized measure of economic status for households within a specific country. The Wealth Index was developed in the late 1990s and was designed to measure economic resources available to households in countries where traditional income and consumption measures are inadequate or inappropriate (Rutstein and Johnson 2004). Education and occupation are deliberately excluded from the calculation of the Wealth Index because they might interfere with the purely economic variables and potentially offset their effects. Instead, the DHS collects information on assets and services available within the household, e.g. Type of flooring, water supply, electricity, radio, refrigerator, domestic servants, etc. These goods are associated with a regionally-specific underlying wealth scale: where, for example, having a TV and a refrigerator increases the household's wealth score and having a surface source of drinking water decreases household wealth. Using principal components analysis, each indicator variable is assigned a weight used to calculate the overall wealth score. The resulting wealth index is then standardized within a country to generate a relative score for each household; it is therefore a measure of relative, rather than absolute, economic resources within each country. Since 2003, most DHS surveys have included a wealth quintile indicator for each household with the quintiles formed from the distribution of the household population (in contrast to the distribution of households). To assess the effect of relative household wealth on the likelihood of infant death, we used the household's wealth quintile as a categorical variable with the lowest quintile as the referent. We assessed relative wealth at the community level by calculating a weighted mean wealth quintile score for all households within the cluster, and divided the distribution of mean scores across clusters into approximate tertiles: 0-1.99 (referent), 2.0 – 3.49, and 3.5 or higher.

To assess the effect of material resources and overall economic development at the national level, we used per capita gross national income expressed in standard US dollars (pc$GNI). In order to more adequately reflect the environment experienced by the mothers in our study population, we averaged each country's pc$GNI for the 5 years preceding the DHS survey using the estimates contained in the World Development Indicators database. GNI constitutes the World Bank's official estimate of the size of a national economy by taking into account all production in the domestic economy and plus the net flows of income from abroad. These estimates are converted to current U.S. dollars using the Atlas method which smoothes exchange rate fluctuations by using a three year moving average, price-adjusted conversion factor (World Bank 2010). National per capita income was included in our models as a continuous variable, transformed by taking the natural logarithm.

Because previous studies in developing countries have generally shown infant mortality to be higher in rural areas, and because the construction of the wealth index does not differ between urban and rural households, we additionally included a rural residence indicator in the analysis. The definition of rural and urban within the DHS corresponds to the standard definition used by each country for reporting official population estimates. Similarly, we assessed global regional differences in the effects of education and economic resources by including indicator variables indicating countries located in sub-Saharan Africa (referent), North Africa or the Middle East, Asia, or Latin America.

We also attempted to judge the responsiveness of the education and economic resource variables to inclusion of two types of variables that present possible mediating mechanisms through which background social factors might operate. We examined the extent to which these background factors operated through changing the reproductive behavior of women by including indicator variables for a short interval since the previous birth (<2 years), mother's age <20 or 35+ years, and high parity (total number of children ever born >4). We also included an indicator of having a skilled attendant at the relevant birth to assess the extent to which greater education or economic resources might increase the likelihood of infant survival by increasing access to and use of medical services for delivery. We categorized DHS birth attendance into a binomial variable, regrouping all health professionals (doctor, nurse, midwife, etc.) assisting in the delivery of the child into the category 'skilled attendance'. Any other birth attendants (including traditional birth attendants) were coded as not having received skilled assistance while giving birth.

METHODS

Within each country, the DHS survey employs a hierarchical sample design using area-based sampling frames to select clusters - the primary sampling units - and then households within clusters, in order to obtain a nationally representative probability sample of individuals. Clusters are generally single-stage, equal probability samples of segments of equal size. In rural areas, a cluster generally spans one village or settlement and the random sample of households within each cluster usually yields 30 to 40 women of reproductive age, whereas an urban community is a part of a town or city with usually 20 to 25 women interviewed. The DHS generally define households in accordance with each country's census definition, which tend to conform to the United Nations' recommendation that a household be defined "…based on the arrangements made by persons, individually or in groups, for providing themselves with food or other essentials for living"(United Nations 2004). In most countries, the samples are self-weighting and previous comparative studies using many DHS surveys have found that inclusion of sample weights have had little impact on point estimates (Boyle, Racine et al. 2006).

We make use of the hierarchical structure of the DHS sample by employing multilevel logistic regression models to assess the impact of education and economic resources at the individual, community and country levels on the likelihood of infant death. Multilevel modeling explicitly acknowledges the correlation among mothers within the same community, and communities within the same country. Although some households contain more than one woman of reproductive age, only 5% of women in our sample resided in a household with more than one mother included in the sample, and there was insufficient within-household variation to model separately. The combined DHS dataset consists of 268,515 births to individual mothers (level 1) grouped within 31,506 community clusters (level 2) within 43 countries (level 3).

We first modeled the unadjusted effects of each background variable used in the analysis by including only the variable under consideration as a fixed effect in a multi-level model that included unexplained variation at each of the 3 levels. We then model the adjusted education effects at each level, followed by a model that includes only economic resource effects at each level. Our primary outcome model mutually adjusts for both education and economic resource effects at all levels to assess the relative robustness of these correlated social factors. We then separately include rural/urban residence, region, and the intervening reproductive risk factors and skilled delivery variables in the primary outcome model. All models use a logit link function to obtain estimates of fixed and random effects and are estimated MLwiN software, version 2.22. Fixed coefficients are converted to odds ratios, and the random intercept coefficients at the community and country level converted to median odds ratios for interpretive ease. Predicted mean probabilities were generated using the simulation procedures in MLwiN.

RESULTS

Table 1 shows the countries, associated survey years, number of clusters and sample births included in the analysis. It also shows the infant mortality rate, proportion of working aged adults with completed secondary education, and the average per capita GNI (in standard dollars) for each country. Despite limiting our analysis to low and lower-middle income countries, there is a large amount of heterogeneity with respect to overall level of development, educational attainment, and infant mortality. Per capita GNI ranges from a low of $120 per year in the Democratic Republic of the Congo to a high of $3272 in Namibia. The proportion of all working aged adults with a completed secondary education varies from just over 1% in Niger to over half in the Philippines. Prospects for infant survival were also quite varied across these countries, ranging from a high of 129 infant deaths per 1000 live sample births in Chad, to a low of 14 per thousand in Jordan.

Results obtained from the primary multi-level models are shown in Table 2. The first column shows the bivariate relationship between each explanatory variable and the likelihood of infant death adjusting only for unexplained variation at the individual, community and country levels. Consistent with most previous research, we observe strong effects for all variables included in the analysis. Relative to mothers with no education, the likelihood of infant death decreases by 10 percent for those with only some primary school, by 28% with primary school completion, by over a third for those with some secondary schooling and by 57% for mothers who have completed secondary school. The unadjusted effect of education for heads of household was somewhat less than that for mothers, with the greatest reduction occurring at the highest education level. The decrease in the likelihood of infant death with increasing wealth quintile followed a pattern very similar to that for education of head of household; the odds of infant death in the top wealth quintile was only 60% of that in the lowest quintile.

These relationships between education, household wealth and the likelihood of infant death were also apparent when aggregated at the community level. Mothers residing in communities where schooling of reproductive aged women averaged between 4 and 8 years had a risk of infant death 27% lower than those in communities where the average educational attainment was less than 4 years, while mothers in communities with even higher levels of average educational attainment had just over half the risk. Increasing the mean wealth quintile score of the community of residence also brought about a decline in the risk of infant death, but the bivariate effect was slightly less than for increasing average education levels for reproductive aged women. At the country level, increasing the proportion of the working aged population and increasing per capita GNI had very large and virtually identical effects on reducing the odds of infant death.

The locational variables included in additional models – rural residence and region – had the associations with infant mortality expected from previous studies. The likelihood of infant death was higher by a third within communities defined as rural versus those defined as urban. The risk of infant death was also higher in sub-Saharan Africa (the reference category) compared to Asia (although this difference was not statistically significant), Latin America, and especially the countries within our sample from North Africa and the Middle East.

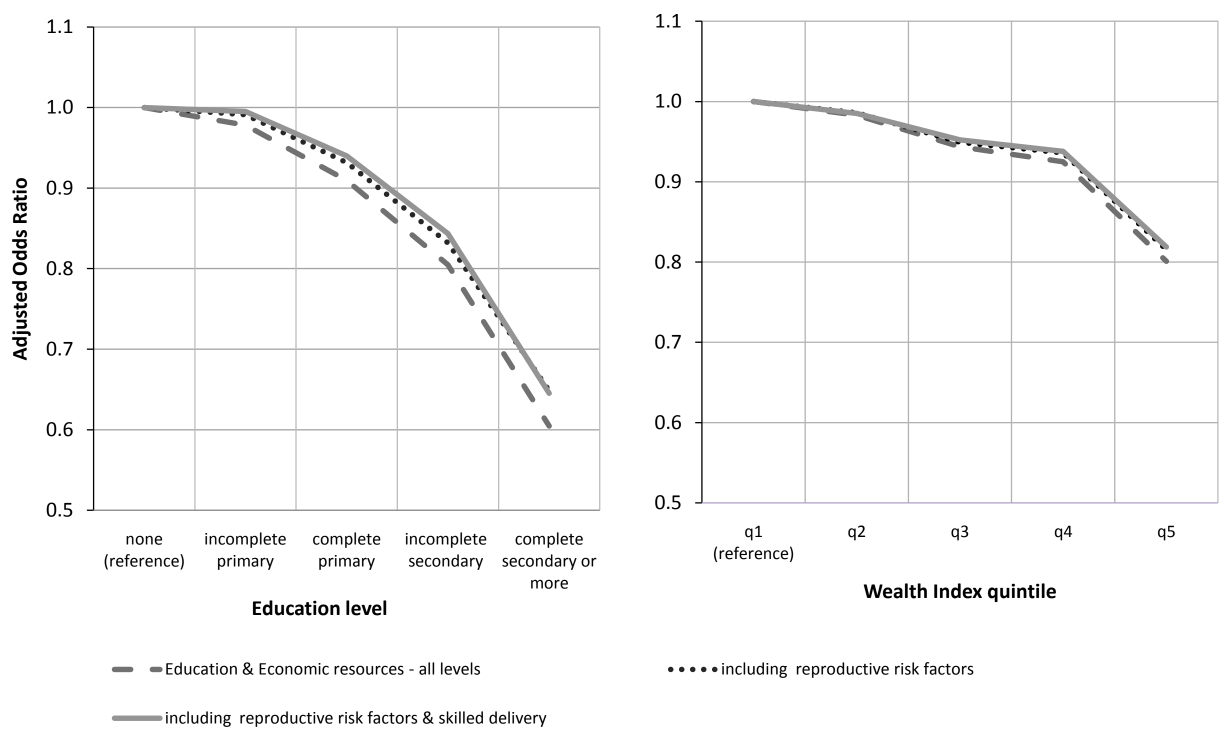
The potential mediating variables we were able to examine, those related to reproductive behavior and the presence of a skilled attendant at the delivery, all had the expected associations. A birth interval of less than 2 years increased the odds of infant death by over 50 percent, mother's age at birth of less than 20 or 35 or older increased the odds by nearly a third, and a birth order of 4 or higher was associated with 17 percent increase. Having a skilled attendant at delivery, on the other hand, reduced the odds of infant death by 24 percent.

Model 1 (Table 2) shows the results of mutually adjusting the education effects at the individual, community and country levels. The effect of increasing education at each level is, as expected, reduced by adjusting for the education effects at other levels. However, except for the increase between no education and only some primary schooling for both the mother and household head, an increase in education continues to exert a substantial and statistically significant effect on reducing the likelihood of infant death at all levels. Model 2 shows that including economic resource indicators at all levels reduces the unadjusted effects of increasing relative wealth at both the individual and community level, especially for higher levels of wealth. Still, these higher wealth levels at both the individual and community levels continue to have the expected effect of reducing infant mortality risk. The large effect of national level pc$GNI is not affected by the inclusion of the wealth indicators for mothers and communities of residence, because the wealth index measures household wealth relative to others households within the same country, whereas the pc$GNI measures economic resources on an absolute scale reflecting the different living standards across countries.

The primary purpose of this analysis was to examine the independent effects of education and economic resources when measured at the individual, community and country levels, as reflected in the results in Model 3. Simultaneous adjustment for education and wealth reduces the effect of each at every level. However, the effect of mother's education at the individual level, and the average education level of reproductive aged women at the community level, are less affected than the effect of household head's education and the wealth effects at both the individual and community levels. In the mutually adjusted model, increasing mother's education to completed primary or more, household head's education to some secondary or more, and household wealth in the two highest quintiles still significantly reduces the likelihood of infant death. Residing in a community with higher average levels of education among reproductive aged women continues to exert an independent effect reducing infant mortality, but increasing the average wealth index within the community no longer exerts a large or significant effect of the likelihood of infant death. Mutual adjustment for education and economic resources reduces the effect of both the proportion of working aged adults with completed secondary education and pc$GNI at the country level, resulting in still relatively large, significant and nearly identical coefficients.

An interesting additional result is obtained when rural residence is included in the adjusting for education and economic resources at all levels in that the 33 percent increase in infant mortality risk associated with residing in a rural area observed in the bivariate analysis (1st column) is eliminated (model 4). This indicates that the excess risk associated with rural residence is due to rural populations being less educated with fewer economic resources than their urban counterparts. In contrast, including a regional indicator in the basic model demonstrates that much of the regional disparity in infant mortality is related to regional differences in pc$GNI and in the proportion of the working aged population with completed secondary education, as indicated by the odds ratios associated with these variables no longer significantly differing from 1. But other factors associated with regions also exert an independent influence on infant mortality; the greatest reduction in the unexplained country-level variation in the odds of infant death, as indicated by the median odds ratio, is seen in this model.

Figure 1:



The effect of including the proposed mediating variables associated with changes in reproductive behavior - short birth interval, young or older age at birth, and fourth or higher order birth - on the odds ratios for infant death associated with mother's education and household wealth quintile are shown in Figure 1. Including these reproductive behavior variables in the model adjusted for education and economic resources at all levels slightly reduced the effect of mother's education, but had an even more modest impact on the effect of wealth. Including an indicator variable for having a skilled attendant at delivery produced only a minor and insignificant additional change in the odds ratios associated with maternal education, and no change in the odds ratios associated with household wealth.

The population mean probabilities of infant death predicted by model 3 for selected combinations of the fixed effect parameters are shown in Table 3. For a birth occurring in the most disadvantaged conditions, that is, in a family in the lowest wealth quartile where both the mother and household head have no schooling and reside in a community with the lowest average values for household wealth and where women of reproductive age are the least educated, in a country near the bottom of the distributions of both pc$GNI ($150) and proportion of the working aged population with completed secondary education (.02), the mean probability death in infancy is nearly 13 percent (equivalent to an infant mortality rate of 127 per 1000 live births). An increase in the pc$GNI from $150 to $525 (the median of the distribution of these low and lower-middle income countries) reduces the probability of death by 18 percent and an increase from $150 to $1230 (the 75th percentile value) results in a 28 percent reduction. A similar reduction of is achieved by increasing the proportion of working aged adults from .02 to .10 (median) and from .02 to .24 (the 75th percentile) – 21 percent and 31 percent respectively. However, if the increase in the proportion with completed secondary education from .02 to .10 at the national level results in a larger number of communities where women of reproductive age have attain an average of between 4 and 8 completed years of education, the probability of death for infants in poor and uneducated households is reduced by 29 percent, the same reduction achieved by increasing pc$GNI to $1230. If there is no change in education at any level, an increase in the household's relative wealth from q1 to q3 results in a 6 percent reduction in mean probability of infant death, but a 23 percent reduction if accompanied by an increase in the pc$GNI from $150 to $525. Alternatively, for a poor household, completion of primary school for both the mother and household head lowers the probability of infant death, on average, by 10 percent, if accompanied by an increase in the proportion secondary at the country level from .02 to .10 percent it is lowered 30 percent, and if the average education of women in the community is increased to over 4 years, then the reduction is at least 37 percent.

Figure 2:

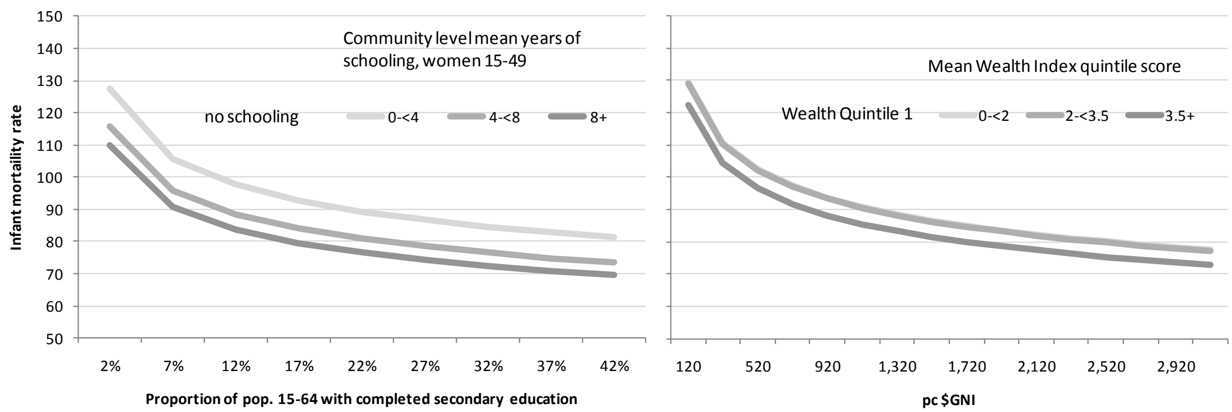


Figure 2 shows community level effects of both education on the left panel, and impacts of the mean Wealth Index quintile score on the right panel. For a birth occurring in the lowest educated and poorest household, keeping country level education characteristics constant, community mean years of schooling can lower chances of infant death from 129 per thousand live births to 109 in countries with only 2 per cent of women with completed secondary education. The mean community level Wealth Index Quintile Score only affects the survival of infants of uneducated mothers in uneducated, poor households within the wealthiest subset of communities. The magnitude of change is higher for community level education than increases in mean wealth.

DISCUSSION

In this study we have attempted to model the relative effects on health of the two primary aspects of development, education and economic resources, in a more comprehensive way than has been done to date. Using multi-level models to examine infant mortality, we assessed the independent effects of these two social determinants as they are manifested within the family, communities and countries. Obtaining this broad picture of the relative effects of education compared to material resources is important for informing policy choices aimed at a sustained improvement in survival and health of children in the least developed parts of the world.

The assessment of the role of material resources in a cross-national comparative framework has benefited from the creation of wealth index measures within the DHS. While the composition, scoring and scaling of assets is specific to each country, the measurement intention - to assess the relative economic position of households - and the construction of the wealth quintiles is the same across surveys (Rutstein and Johnson, 2004). An advantage of multilevel analysis is that the inclusion of per capita GNI as an indicator of overall living standards at the country level makes the relative wealth measures at the household and community levels more meaningful. The importance of the absolute, as opposed to relative, standard of living is indicated by the robustness of the country per capita GNI in the model that also includes the household wealth quintile and the average wealth quintile in the community. While the effect of assets on the likelihood of infant death is reduced at the individual and community levels, the effect of pc$GNI at the country level remains unaltered. In contrast, the model including only education effects at all levels reduces the unadjusted fixed effect of education at each level, yet education continues to exert a considerable negative effect on the risk of infant death at the household, community and country levels.

The primary purpose of this analysis, however, was to examine the extent to which these multi-level effects of educational attainment and economic resources are changed when both factors are considered at all three levels. Compared to the model including only the education effects at all levels, the adjustment for economic resources reduces the effect of mother's education only slightly and by a similar amount at all education levels. The reduction in the effect of household head's education is also relatively small, with a slight flattening of the gradient. But adjusting for education reduces the effect of household relative wealth to a greater extent at each higher quintile, resulting in a flattening of the household wealth effect on the likelihood of infant death. Thus, these results indicate that, averaged across these 43 low and lower-middle income countries, being born to a mother that has only completed primary school produces the same reduction in infant mortality risk as being born into a household in the 60th – 80th percentile range of the household wealth distribution.

Most previous research has also shown a reduced, but still substantial effect of maternal education on infant mortality adjusting for the education level of other members of the household, usually that of the father, and household income or assets (Hobcraft, McDonald et al. 1984; Mensch, Lentzner et al. 1985; Cleland and van Ginneken 1988; Bicego and Boerma 1993; Heaton, Forste et al. 2005). The literature is less clear on the role and relative strength of the mechanisms through which maternal education operates to reduce the risk of infant death (Heaton, Forste et al. 2005). The role of played by increased education in delaying and truncating age at child-bearing and increasing the length of the interval between births is well-documented (Hobcraft 1985; Cleland and Rodriguez 1988), and in addition to lowering fertility, each of these factors would be expected to reduce the likelihood of infant death. In the bivariate analyses, we found that mother's age at birth of less than 20 or 35 or older, a birth interval of less than 2 years, and a birth order of 4 or higher each significantly increased the likelihood of dying within the first year. Despite this, adding these reproductive behavior factors to the model had only a small effect on the coefficients for maternal education, but even less on the coefficients for the wealth quintiles. In indicating that maternal education may be effecting infant mortality only slightly by changing reproductive behavior – and lowering fertility - these results are, in fact, comparable to those in Cleland and VanGinneken's 1988 review of survey data from developing countries (Cleland and van Ginneken 1988) and stronger than those found in the 1993 analysis of DHS surveys done by Bicego and Boerma (Bicego and Boerma 1993).

Similarly, previous research has shown a strong relationship between maternal education and the utilization of health services related to childbirth, such as antenatal care and delivery with skilled personnel in attendance (Cleland and van Ginneken 1988; Bicego and Boerma 1993; Gabrysch and Campbell 2009). In addition, studies examining the role of differences in health services use on the relationship between maternal education and infant mortality within a single country have often shown a strong mediating effect for hospital or other skilled delivery (Panis and Lillard 1994; Raghupathy 1996;

Song and Burgard 2008). We found no evidence, however, that either maternal education or household wealth operated to reduce the likelihood of infant death through increased use of skilled delivery for the birth. This may be due to combining data for countries where the definition of skilled attendant at delivery varies considerably in terms of effectiveness in increasing infant survival (Hatt, Stanton et al. 2009) and perhaps due in part to problematic pregnancies being more likely to obtain skilled delivery in areas where such services are scarce and costly (Gabrysch and Campbell 2009).

Our results also indicate that residing in a community where women of reproductive age have attained, on average, 4 or more years of completed schooling independently reduces the risk of infant death. In contrast, there was little indication that an increase in the average wealth quintile score among households in the community had any effect on the likelihood of infant death. This result is consistent with that found by Kravdal in his study of education and child mortality in India (Kravdal 2004). Inclusion of additional variables in Kravdal's study gave some suggestion that increased community-level education among women operates to a certain extent through the same pathways as individual level education of the mother, increased autonomy and use of health services. Our study was limited in its ability to assess potential mechanisms for the community level effect of women's education; combining data from many countries severely restricted the number of comparable variables available for clusters.

However, inclusion of many surveys from a broad geographical representation of low and lower-middle income countries permitted the assessment of country-level educational attainment on infant mortality in a multi-level context, something that, to our knowledge, had not been done. In his 2006 study of anthropometric indicators of child health (weight and height for age) using multilevel methods, Boyle and colleagues assessed the effects of both maternal education and household wealth along with GDP per capita in 42 developing countries (Boyle, Racine et al. 2006). He found strong effects for all three variables, with pcGDP having the largest effect, followed by mother's education and then by household wealth quintile. He also observed that the strength of the association between mother's education and child nutrition varied across countries, but that it was consistently stronger than the association with household income. These results are consistent with the study by Fuchs and colleagues that found a stronger and more consistent decline in infant mortality risk with increasing maternal education than with increasing wealth quintile (Fuchs, Pamuk et al. 2010). But neither study considered the effect of education or wealth within communities or educational attainment at the country level.

We expected the finding of a strong effect for per capita GNI robust to the inclusion of the relative wealth measures at the community and individual level. Country level GNI indicates the average absolute standard of living for the population and is thus a more valid measure of overall development, whereas the relative wealth quintiles reflect the distribution of material resources. The finding that the proportion of the working aged population with completed secondary education exerts an effect equal to that of pcGNI lowering the risk of infant mortality was less expected. It is especially important in that the effect persists in the models that adjust not only for per capita GNI, but for the absolute effects of education at the individual and community levels.

Previous research examining the role of secondary education with respect to health at the country level has been limited. In their seminal work linking women's education to both fertility and infant mortality, Subbarao and Raney found the effect of increasing female secondary enrollment rates was much more important in than increasing pcGDP or the number of physicians per capita in reducing infant mortality (Subbarao and Raney 1995). Similarly, a recent study of global trends in child mortality concluded that over 50 percent of the decline between 1970 and 2009 could be attributed to gains in the mean years of education by women (Gakidou, Cowling et al. 2010). Previous research examining trends for specific countries has usually found that increases in women's schooling contribute significantly to infant mortality decline, but that this effect is often dependent on the time period and on other factors, such as the expansion of maternal and child health services (DaVanzo and Habicht 1986; Pena, Liljestrand et al. 1999; Hertel-Fernandez, Giusi et al. 2007).

Our analysis also indicates a substantial role for factors other than economic resources and education in determining the likelihood of infant death; considerable variation remains at the community and country levels after adjustment for education and economic resource at all levels. Regional and country-specific differences in HIV-AIDS, other endemic diseases, along with cultural and environmental factors surely contribute to this unexplained variation. However, it is worth noting that, within countries, the rural disadvantage with respect to infant mortality is entirely eliminated by adjusting for the different education and economic composition of rural versus urban areas. It should also be acknowledged that any single measure of educational attainment or economic well-being - at any level - is unlikely to capture all of the relevant aspects of these indicators. In particular, differences in income distribution and the quality of formal education are likely to account for at least some of the variation left unexplained by the model.

Despite the limitations inherent in a study of this kind, this analysis has pointed to the benefit of examining the full effects of potential policy choices. This study not only contributes to the growing body of literature indicating the preeminent role of increasing education, especially for women, in generating improved survival for infants, but provides a more complete understanding of how increases in education operate at the individual, community and country levels. We have been able to show that increases in the average levels of schooling for reproductive aged women improve the survival chances of infants born to uneducated women within their communities. We also show that increasing the proportion of the working aged population with a completed secondary education benefits the less educated to an extent equal to raising overall living standards as reflected by increases in per capita income.

Understanding of these contextual impacts of education is important for generating effective policy. Policies that simply focus on expanding primary education for women, while extremely beneficial to the individual woman and her future children, are unlikely to capture all of the potential benefits that could accrue if educational expansion is more broadly conceived, that is, increasing women's education across all communities and increasing secondary school completion for both sexes.

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Table 1: Survey year, number of sample clusters, number of sample births, and selected characteristics for 43 developing countries

Country	Survey year	Number of sample clusters	Sample births	pc $GNI[1]	Proportion of adults aged 15-64 with completed secondary education	Infant mortality rate
Bangladesh	2007	361	4269	430	0.137	37.8
Burkina Faso	2003	400	6695	250	0.024	108.8
Benin	2006	750	9466	474	0.041	62.2
Bolivia	2008	984	5615	1232	0.357	39.6
Congo, DR	2007	300	4901	120	0.138	84.4
Congo	2005	225	2950	820	0.097	67.9
Cameroon	2004	461	4685	660	0.060	88.7
Colombia	2005	3307	9824	2420	0.375	17.9
Dominican Republic	2007	1412	7015	3048	0.279	28.9
Egypt	2008	1235	6815	1398	0.468	15.7
Ethiopia	2005	534	5933	134	0.042	75.6
Ghana	2008	407	1864	524	0.178	51.3
Guinea	2005	295	3961	390	0.036	93.3
Honduras	2005/06	1038	7324	1300	0.144	19.3
Haiti	2005/06	339	3647	416	0.061	56.4
India	2005/06	3831	32612	638	0.145	48.5
Indonesia	2007	1694	12982	1268	0.283	28.8
Jordan	2007	926	5996	2498	0.420	14.0
Kenya	2008/09	397	3581	650	0.244	49.9
Cambodia	2005	557	5353	358	0.046	53.9
Liberia	2004	298	3498	130	0.134	63.5
Lesotho	2004	401	2478	546	0.088	80.6
Morocco	2003/04	480	4187	1460	0.087	28.3
Madagascar	2008/09	594	7327	343	0.049	42.8
Mali	2006	407	6812	374	0.020	112.5
Malawi	2004	521	6505	168	0.088	73.1
Mozambique	2003	603	6127	232	0.015	98.3
Nigeria	2008	886	16019	822	0.297	96.2
Niger	2006	342	5296	220	0.011	103.1
Namibia	2006/07	495	3354	3272	0.197	52.9
Nepal	2006	260	3772	270	0.127	34.3
Peru	2004-08	1824	12045	2612	0.521	17.6
Philippines	2008	764	4150	1458	0.550	23.4
Pakistan	2006/07	961	5134	714	0.242	64.5
Rwanda	2005	462	4892	222	0.030	83.8
Sierra Leone	2008	352	3319	260	0.067	89.5
Senegal	2005	376	6270	620	0.035	67.0
Swaziland	2006	271	1809	1742	0.199	91.5
Chad	2004	196	3166	218	0.021	129.1
Tanzania	2004	475	5093	296	0.027	71.4
Uganda	2006	368	4523	282	0.063	72.6
Zambia	2007	319	3721	520	0.136	70.5
Zimbabwe	2005/06	398	3530	635	0.063	58.4

Table 2: Estimated odds ratios (and 95% confidence intervals) for the probability of infant death among the most recent births to women aged 15-49, 43 developing countries

Level	Unadjusted		Model 1: Education adjusted		Model 2: Economic resource adjusted		Model 3: Mutually adjusted		Model 4: including rural residence		Model 5: including region		Model 6: including reproductive variables	
Births	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Mother's education														
none (reference)	**1.00**		**1.00**				**1.00**		**1.00**		**1.00**		**1**	
incomplete primary	**0.90**	0.86 - 0.94	**0.96**	0.92 - 1.02			**0.98**	0.93 - 1.03	**0.98**	0.93 - 1.03	**0.98**	0.93 - 1.03	**0.99**	0.94 - 1.04
complete primary	**0.78**	0.73 - 0.84	**0.89**	0.83 - 0.96			**0.91**	0.85 - 0.98	**0.91**	0.85 - 0.98	**0.91**	0.84 - 0.97	**0.93**	0.87 - 1.00
incomplete secondary	**0.64**	0.61 - 0.68	**0.78**	0.73 - 0.83			**0.80**	0.75 - 0.86	**0.80**	0.75 - 0.86	**0.80**	0.75 - 0.86	**0.83**	0.78 - 0.89
complete secondary or more	**0.43**	0.40 - 0.47	**0.57**	0.52 - 0.63			**0.60**	0.55 - 0.67	**0.60**	0.55 - 0.67	**0.61**	0.55 - 0.67	**0.65**	0.59 - 0.72
Education of household head														
none (reference)	**1.00**	**1.00**	**1.00**				**1.00**		**1.00**		**1.00**			
incomplete primary	**0.92**	0.88 - 0.97	**0.97**	0.92 - 1.02			**0.98**	0.93 - 1.03	**0.98**	0.93 - 1.03	**0.98**	0.93 - 1.02	**0.98**	0.93 - 1.03
complete primary	**0.84**	0.79 - 0.89	**0.93**	0.87 - 0.99			**0.95**	0.89 - 1.01	**0.95**	0.89 - 1.01	**0.95**	0.89 - 1.01	**0.95**	0.89 - 1.02
incomplete secondary	**0.74**	0.70 - 0.79	**0.88**	0.83 - 0.94			**0.91**	0.86 - 0.97	**0.91**	0.86 - 0.97	**0.91**	0.86 - 0.97	**0.92**	0.87 - 0.98
complete secondary or more	**0.58**	0.55 - 0.62	**0.83**	0.77 - 0.90			**0.88**	0.82 - 0.95	**0.88**	0.82 - 0.95	**0.88**	0.82 - 0.95	**0.89**	0.82 - 0.96
Quintile of wealth index														
q1 (reference)	**1.00**				**1.00**		**1.00**		**1.00**		**1.00**		**1**	
q2	**0.94**	0.90 - 0.99			**0.96**	0.91 - 1.01	**0.98**	0.94 - 1.03	**0.98**	0.94 - 1.03	**0.98**	0.94 - 1.03	**0.99**	0.94 - 1.04
q3	**0.85**	0.81 - 0.90			**0.89**	0.85 - 0.95	**0.94**	0.89 - 1.00	**0.94**	0.89 - 1.00	**0.94**	0.89 - 1.00	**0.95**	0.90 - 1.00
q4	**0.76**	0.72 - 0.80			**0.84**	0.79 - 0.90	**0.92**	0.87 - 0.99	**0.92**	0.87 - 0.99	**0.92**	0.87 - 0.99	**0.94**	0.88 - 1.00
q5	**0.56**	0.53 - 0.60			**0.65**	0.60 - 0.70	**0.80**	0.73 - 0.87	**0.80**	0.73 - 0.87	**0.80**	0.74 - 0.87	**0.82**	0.75 - 0.89
Communities														
Mean years of completed education among women 15-49														
0-<4 (reference)	**1.00**		**1.00**				**1.00**		**1.00**		**1.00**		**1.00**	
4-<8	**0.73**	0.70 - 0.77	**0.84**	0.80 - 0.89			**0.89**	0.85 - 0.94	**0.89**	0.85 - 0.94	**0.89**	0.84 - 0.94	**0.90**	0.85 - 0.95
8 or more	**0.52**	0.48 - 0.55	**0.75**	0.69 - 0.81			**0.84**	0.77 - 0.92	**0.84**	0.77 - 0.92	**0.84**	0.77 - 0.91	**0.85**	0.78 - 0.93
Mean wealth index quintile score														
0-<2 (reference)	**1.00**				**1.00**		**1.00**		**1.00**		**1.00**		**1.00**	
2.0-<3.5	**0.89**	0.85 - 0.92			**0.95**	0.90 - 1.00	**1.00**	0.95 - 1.05	**1.00**	0.95 - 1.04	**1.00**	0.95 - 1.05	**1.00**	0.95 - 1.05
3.5 or higher	**0.64**	0.62 - 0.68			**0.84**	0.78 - 0.90	**0.93**	0.87 - 1.01	**0.93**	0.86 - 1.01	**0.94**	0.87 - 1.01	**0.94**	0.87 - 1.01
Countries														
Percent of the population (15-64) with completed secondary education or more (natural log)	**0.68**	0.60 - 0.76	**0.79**	0.70 - 0.88			**0.84**	0.72 - 0.98	**0.84**	0.72 - 0.98	**0.94**	0.85 - 1.04	**0.83**	0.71 - 0.97
per capita GNI in standard $ (natural log)	**0.65**	0.56 - 0.74			**0.64**	0.55 - 0.73	**0.83**	0.70 - 0.99	**0.83**	0.70 - 0.99	**0.98**	0.87 - 1.11	**0.83**	0.70 - 0.99
Locational indicators														
Urban/rural														
Urban	**1.00**								**1.00**					
Rural	**1.33**	1.28 - 1.39							**0.99**	0.94 - 1.05				
Region:														
Sub-Saharan Africa	**1.00**										**1.00**			
Latin America	**0.46**	0.30 - 0.70									**0.46**	0.35 - 0.59		
North Africa & Middle East	**0.31**	0.18 - 0.56									**0.32**	0.23 - 0.45		
Asia	**0.68**	0.44 - 1.07									**0.60**	0.48 - 0.75		
Intervening variables														
birth interval < 2 years	**1.55**	1.49 - 1.61											**1.53**	1.47 - 1.59
age of mother at birth <20 or 35+	**1.32**	1.28 - 1.37											**1.31**	1.26 - 1.35
birth order 4 or higher	**1.17**	1.13 - 1.21											**1.03**	1.00 - 1.07
skilled delivery	**0.76**	0.73 - 0.79												
Random effects:			MOR		MOR		MOR		MOR		MOR		**MOR**	
Level 4 (country):			**1.44**		**1.49**		**1.42**		**1.42**		**1.25**		**1.42**	
Level 3 (cluster):			**1.45**		**1.46**		**1.44**		**1.44**		**1.44**		**1.44**	

Table 3: Model-based predicted mean probabilities of infant death and confidence range for an uneducated woman in the lowest quintile of household wealth with other specified characteristics, 43 developing countries

	head's education = none, household wealth index = q1, community mean wealth index score =<2.0 and community mean years of education						head's education = none, household wealth index = q3, community mean wealth index score =<2.0 and community mean years of education						household head's education = completed primary, household wealth index = q1, community mean wealth index score community mean years of education					
	0 -<4			4 - <8			0 -<4			4 - <8			0 -<4			4 - <8		
country per capita GNI = $150, and	**mean**	**95% CI**		**mean**	**95% CI**		**mean**	**95% CI**		**mean**	**95% CI**		**mean**	**95% CI**		**mean**	**95% CI**	
country proportion with completed secondary education = .02	**0.127**	0.105	0.153	**0.116**	0.095	0.140	**0.119**	0.099	0.143	**0.109**	0.089	0.130	**0.114**	0.093	0.139	**0.103**	0.084	0.127
country proportion with completed secondary education = .1	**0.100**	0.078	0.125	**0.091**	0.070	0.113	**0.094**	0.074	0.118	**0.085**	0.067	0.108	**0.089**	0.070	0.113	**0.081**	0.063	0.102
country proportion with completed secondary education = .24	**0.088**	0.063	0.119	**0.080**	0.056	0.107	**0.082**	0.058	0.112	**0.075**	0.052	0.103	**0.078**	0.056	0.108	**0.071**	0.050	0.098
country per capita GNI = $525, and																		
country proportion with completed secondary education = .02	**0.104**	0.083	0.128	**0.094**	0.075	0.118	**0.098**	0.077	0.122	**0.088**	0.069	0.111	**0.093**	0.072	0.119	**0.084**	0.066	0.108
country proportion with completed secondary education = .1	**0.081**	0.072	0.090	**0.073**	0.065	0.082	**0.076**	0.067	0.085	**0.068**	0.060	0.077	**0.072**	0.063	0.082	**0.065**	0.057	0.074
country proportion with completed secondary education = .24	**0.071**	0.059	0.084	**0.064**	0.053	0.076	**0.066**	0.055	0.079	**0.060**	0.049	0.072	**0.063**	0.052	0.076	**0.057**	0.047	0.068
country per capita GNI = $1230, and																		
country proportion with completed secondary education = .02	**0.091**	0.066	0.124	**0.082**	0.059	0.113	**0.085**	0.060	0.118	**0.077**	0.054	0.107	**0.081**	0.056	0.113	**0.074**	0.051	0.103
country proportion with completed secondary education = .1	**0.070**	0.060	0.083	**0.063**	0.053	0.075	**0.065**	0.055	0.078	**0.059**	0.049	0.071	**0.062**	0.052	0.075	**0.056**	0.047	0.068
country proportion with completed secondary education = .24	**0.061**	0.052	0.071	**0.055**	0.047	0.064	**0.057**	0.048	0.066	**0.051**	0.043	0.060	**0.054**	0.046	0.064	**0.049**	0.041	0.057