Maternal Human Capital and Childhood Stunting In Nepal:
A Multi-Level Modeling Approach

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Abstract. *Childhood stunting among preschool-age children stands as a serious public health problem to be addressed in Nepal. Applying the multi-level modeling approach to nationally representative data, in the overall, we provide evidence that the negative influence of maternal own education to childhood stunting occurs especially for mother's higher level of education, but there exists substantial residential variations. Most interestingly, we provide new evidence of a strong negative community externality of maternal education on childhood stunting, even if mothers of children are uneducated. We also find mother's height is negatively related to childhood stunting, regardless of mother's educational attainment and place of residence, providing evidence of intergenerational transmission of maternal health.*

Introduction

Childhood stunting[1] is a serious public health problem in developing countries. Nutritional deprivation in childhood has been shown to have not only strong negative associations with the cognitive development of children and the productivity and economic development of nations but also a strong positive association with morbidity and mortality of people during childhood and adulthood (Martorell and Ho 1984; Senauer and Garcia 1991; WHO 2000; Case *et al.* 2002; Chang *et al.* 2002; MOH/N *et al.* 2002; United Nations 2002; Behrman and Rosenzweig 2004; de Onis *et al*. 2004). The seriousness of the childhood undernutrition problem is well acknowledged in the Millennium Development Goals (MDGs) both at global and national levels (United Nations 2002; United Nations Country Team of Nepal 2002). Nonetheless, disproportionately large proportions of preschool-age children -- age below five years – living in developing countries are still stunted. Half of these children live in South Asia including Nepal, and Nepal ranks the second worst among South Asian countries in prevalence of stunting (UNICEF 2006). In 2001, the prevalence of stunting in Nepal was estimated at 51% (MOH/N *et*

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[1] Stunting reflects the long-term growth faltering resulting from inadequate nutrition and/or recurrent illness. A child is classified as *stunted* if the height-for-age falls below minus 2 standard deviations from the median height-for-age of the National Center for Health Statistics (NCHS)/World Health organization (WHO) reference population.

al. 2002). A critical understanding of why such a large proportion of children are still stunted is important for effective policy action.

Recently, maternal human capital as a potential determinant of childhood undernutrition has attracted considerable research interest among sociologists, demographers, economists, and many others. According to human capital theory, education and health are two key endowments. While many claim that maternal education makes a significant positive contribution to child health (Strauss 1990; Thomas *et al.* 1991; Behrman and Rosenzweig 2002), others warn that the estimated relationship may be overestimated in the absence of important community context variables (e.g., Desai and Alva 1998). Additionally, past studies have failed to capture the full effects of maternal education, such as the community-externality (spillover) of maternal education. Evidence of positive spillover effects of community maternal education on reducing fertility and mortality has recently been documented (McNay *et al.* 2003; Moursund and Kravdal 2003; Kravdal 2004). Intergenerational transmission of maternal health, which can in part be attributed to spillover of genetic endowments, has received limited attention with a few exceptions (Strauss 1990; Thomas *et al.* 1991; Behrman and Rosenzweig 2002).

This study, using multi-level modeling applied to nationally-representative data from Nepal, examines the extent to which maternal education -- including the community maternal education -- and maternal health shape stunting outcomes of preschool-age children. An analysis is also extended to a restricted sample including only children from uneducated mothers to ascertain whether or not community-externality of maternal education is robust when children from educated mothers are excluded. Lastly, residential variation on the effect of maternal human capital is examined by analyzing rural and urban sub-samples.

Review of Literature

Maternal education as a potential determinant and mechanisms through which it influences child health have been widely studied by economists, demographers and other social scientists (Caldwell 1979; Grossman and Kaestner 1997; Handa 1999; Variyam *et al.* 1999; Pongou *et al.* 2006). According to household production theory, maternal education positively affects child health through greater allocative efficiency. More educated mothers are more able to acquire and process health information than less educated ones (Grossman and Kaestner 1997). Cowell (2006) provides three broad explanations of how education influences health behavior among adults. These include efficiency mechanism, unobserved heterogeneity, and future opportunity costs. The same explanations may also explain the link between maternal education and child health. In terms of efficiency mechanism, as mentioned by Grossman and Kaestner (1997), educated persons allocate their resources more efficiently to obtain better health. According to the unobserved heterogeneity explanation, education affects health because education proxies unobserved variables such as time preference. Finally, the future opportunity cost explanation posits that any utility improving future outcomes such as income can affect current behavior. The education of parents also indirectly affects the health production function of children through increased wages and income (Kassouf and Senauer 1996). Further, education improves mother's ability to access to resources for investment in child health and access to health services (Caldwell 1979) and break traditional taboos regarding dietary intake (Pongue *et al*. 2006).

Although past studies have documented a negative relationship between mother's education and long-term nutritional deprivation, these studies are limited to the mother's individual education. Above and beyond the mother's education, the education of others including the community-level education of mothers may play an important role. Other social scientists have put forth diffusion theory to explain the community externalities of maternal education that may affect individual fertility behavior and child mortality (e.g., Montgomery and Casterline 1996; Kravdal 2004). According to diffusion theory, the diffusion of innovative ideas takes place through social influence and social learning. Peer pressure and authority constitute the key elements of the social influence mechanism that is believed to affect the behavior of others. The social learning may occur due to interpersonal interactions and learning by observation.

There is no study, to the best of our knowledge, analyzing the effect of community-level education on child stunting. Kravdal (2004) has demonstrated the limitation of taking an individual-level perspective on education and argues that the individual-level perspective fails to encompass the full impact of education on child mortality in India. The inability to capture the full effect of education is likely to arise from the heterogeneity in community settings. The beneficial impact of education of mothers in the community above and beyond individual education on child health arises from peer or spillover effects. The community-effect of education on child health can have stronger effects in a developing country context, where only a small share of women has formal education and where social interaction among community members is strong.

Recently, the community-level effect of education has been examined on contraceptive use (McNay *et al.* 2003, Moursund and Kravdal 2003) and mortality (Kravdal 2004). Although maternal community-level effect of education has been ignored in the child health literature, the relevance of community-level unobserved factors is pointed out by Desai and Alva (1998). They show that even the incorporation of location of residence (rural/urban) variables weakens the effect of education on child nutrition; this effect is further weakened if a community-fixed effect is incorporated, demonstrating that the effect of education without considering community contexts is biased. However, their study does not take into account the potential effect of community-level education of mothers on child health. This study aims to fill this gap.

On the effect of the nutritional status of the mother on child health, Kebebe (2005) mentions that a nutrition spillover from mother to child can occur in part through sharing the genetic endowment or through behavioral effects. However, many studies on child health and its socioeconomic determinants ignore parent's health in the specification of models. The health economics literature considers that genetic endowment and behavior can substitute or complement the production of health (Ganz 2001). The fundamental role of genetic endowments on the production of child health is also recognized in other social science fields including economics (Haughton and Haughton 1997; Black *et al.* 2005; Kebede 2005).

In the economics literature, height is a commonly used measure to capture the intergenerational transmission of genetic endowments and unobserved family background characteristics (Strauss 1990; Kassouf and Senauer 1996; Burgard 2002; Kebede (2005). The estimated impact of education while ignoring parents' health is, therefore, argued to be overestimated (Behrman and Wolfe 1987). Kebede (2005) states that even the effect of income may be biased if unobserved heterogeneity originates from parent's health.

Kassouf and Senauer (1996), based on an analysis of data from the 1989 National Health and Nutritional Survey of Brazil for children aged 2-5 years, found that mother's and father's standardized height-for-age positively and significantly contributed to child height-for-age. Similarly, using 1996 Brazil Demographic and Health Survey (DHS) data for children aged 6 to 59 months, Burgard (2002) found that children of mothers who are 10 centimeters taller (height unstandardized) are 36% less likely to be stunted. Another study, based on five Sub-Saharan African counties, showed that height and weight-for-age of parents positively contributed to height-for-age of children aged 1 to 35 months, showing the intergenerational chain of poor nutrition (Madise *et al.* 1999). Fedorov and Sahn (2005), based on a longitudinal study based on the Russian Living Standard Measurement Survey (1992-2001), found similar effects for mother's and father's heights; however, Glick and Sahn (1998) found that the effect of mother's height was higher than father's in South Africa. A study of children below 6 years of age using the 1985 Living Standard Measurement Survey of Cote d'Ivoire showed that the effect of log of mother's standardized height was significant on height-for-age of children. A study using data from Vietnam showed that taller parents have taller children (Haughton and Haughton 1997). These studies generally do not account for unobserved heterogeneity at higher levels and important community characteristics including community education of mothers.

Data

The data for this study is from the 2001 Nepal Demographic and Health Survey (NDHS). The NDHS is a nationally-representative comprehensive survey of demographic and health indicators including maternal and child health (MOH/N *et al*. 2002). The sampling procedure consists of a two-stage stratified random sample of households. In the first stage, a systematic sampling with probability proportional to size was used to select 257 primary sampling units (PSUs) -- 42 in urban areas and 215 in rural areas. In the second stage, an average 34 households from each PSU were selected by using a systematic sampling procedure on the complete list of households within each PSU. Each PSU is comprised of a ward and sub-ward. Ward is the smallest political unit. In this study, PSU is used to represent community or cluster. The survey also collected geo-reference data for PSUs using the Global Positioning System (GPS), which made it possible to use altitude of place of residence in the models.

This study uses data from 6,125 children aged below five years (1 month to 59 months) nested in 4,250 households and 248 communities and their mothers aged 15-59 years inclusive. Anthropometric data on weight and height were collected from children and mothers. An average household has 1.5 children, ranging from 1 to 6 children. At the community- level, the average number of children is 26, ranging from 2 to 34. Slightly more than half (52%) of households have only one eligible child. As almost half of households have at least two eligible children and the number of households in the sample is fairly large, this study uses three-level multi-level models. The rationale for this model is discussed.

Conceptual Framework

The conceptual framework for this study is drawn from the nutrition model used by Behrman and Deolalikar (1988), which is based on the Becker's (1981) household economic model. It is assumed that a household aims to maximize the following joint utility function

$$U_j = U(H, C, l) \quad (1)$$

where U_j is the joint utility function of the j^{th} household with mother and father. The utility parents derive is dependent on the nutritional health status of a child (*H*), the consumption of goods and services from the market (*C*) and amount of leisure time (*l*). The household maximizes the joint utility function subject to the full-income constraint that includes budget and time constraints and the i^{th} child's health production function (H_i). The health of child is considered as a household-produced good. The health production function of an individual child is specified as

$$H_i = H(I_i, G_i, Ch_i; \phi, \theta, \psi_h, \psi_c) \quad (2)$$

where H_i represents the health outcome of the i^{th} child. The I_i is the child health input including dietary intake, child care time by parents, and the medical care provided when the child is sick; G_i is the child's health endowment, which is unobservable but is proxied by parent's health; Ch_i

is the child's observable characteristics including age, birth order, size at birth and sex; ϕ represents observable household characteristics including maternal education, mother's height, age, father's education, household wealth, ethnicity and household size; θ *is* community characteristics including access to health services, market price of consumption goods and services, micro-environmental conditions such as altitude, geographical location such as regions and community-level education of mothers; ψ_h is the unobserved household attributes such as quality of parenting, household public goods such as floor space and level of sanitation. These attributes are common to children within the household; whereas ψ_c represents community attributes such as sanitation condition, exposure to infection, and community location, which are common to children in households within the same community.

Equation 3 provides the budget constraint faced by the household, that is

$$pC + p'I^h = wL + M \qquad (3)$$

where p is the vector of prices of market goods and services and p' is the price of health inputs. The I^h represents amount of health inputs. The household income comprises of income from wage earnings (wL) at wage rate w and non-wage income (M). The time constraint facing the household in terms of wage labor (L) is

$$L = T - L^h - l \qquad (4)$$

Where the T represents the total time endowment of the household, which is allocated among wage labor (L), time to children including time for preparing food (L^h) and leisure (l). By combining equations 3 and 4, the full-income (F) constraint is

$$pC + p'I^h = w(T - L^h - l) + M = F \qquad (5)$$

Maximizing the household utility function (1) subject to the full-income constraint (5) and the health production function (2), the reduced-form equation for the health outcome of the i^{th} child can be obtained as

$$H_i = h(p, p', w, Ch, T, M, \phi, \theta, \psi) \qquad (6)$$

The estimation of the health production function using equation (1) demands many health inputs, which are generally not available in the data. Many empirical studies on child health, therefore, have considered reduced-form equations for the estimation (e.g., Rosenzweig and Schultz 1983; Senauer and Garcia 1991; Glewwe 1999). We also use reduced form equation (6) to model childhood stunting in Nepal. It is expected that an increase in education level of the mother decrease the stunting outcome of a child because of nurturing effects. Similarly, controlling the other factors, the maternal community-level education is expected to have a negative spillover effect on the stunting outcome of children. Mother's height is expected to be negatively related with children's stunting outcomes.

Accounting for Unobserved Heterogeneity

A discrete choice model such as logistic regression or probit is the frequently used statistical method to model childhood stunting, assuming that stunting outcomes of children in the sample are independent. But the assumption of independence is violated if there exists a clustering structure in child nutritional outcome, such as children being nested within household and households within community. Clustering of children's stunting status within the household can be expected because of characteristics common to them such as health inputs, quality of parental care and household pubic goods such as space, which can be expected to differ between households but be the same within the household. Similarly, households may be clustered within the community because of their shared characteristics, such as access to health innovations, exposure to infection, market and climatic conditions, which are common to households within a community but differ across communities. This shows that the child stunting outcome is likely to vary simultaneously at individual, household and community levels.

In the existence of clustering of child nutritional outcomes, the use of approaches such as logistic regression yield estimates that are less efficient than the generalized least squares estimates that are based on the true structure of the residual covariance matrix. Additionally, these approaches do not allow an avenue for exploring clustering structure (Goldstein 1991). Two approaches: fixed effects and random effects model are suggested to take into account the unobserved factors. However, given that stunting outcome is dichotomously measured the fixed effects estimators are likely to suffer from the incidental parameters problem (refer to, Wooldridge 2002). This may occur because fixed effects estimators rely on estimation of constants based on cluster observations, which are fixed and may be quite small. This leads to inconsistent estimates of constants as well as parameters. Also, the estimator is biased if cluster observations are small. On the other hand, in the random effects models the expected value of cluster heterogeneity, the idiosyncratic error term and covariance between cluster heterogeneity and idiosyncratic error are assumed to be zero.

Considering the dichotomously measured stunting variable and small number of cluster observations, a multi-level modeling approach with a random-intercept specification model is adopted, which is described in section it follows.

Empirical Model, Variables and Estimation

To account the unobserved heterogeneity at the household and community levels, we use the three-level random-intercept logistic regression model of following form (Raudenbush and Bryk 2002):

$$\log\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) = \beta_{000} + \sum_{p}^{P} \beta_{pjk} C_{ijk} + \sum_{q=1}^{Q_p} \beta_{0qk} H_{qjk} + \sum_{s=1}^{S_{pq}} \beta_{p0s} V_{sk} + \gamma_{0jk} + \mu_{00k} + \varepsilon_{ijk} \qquad (7)$$

where π_{ijk} represents the probability of the i^{th} child in the j^{th} household and k^{th} community being stunted. The log odds of the i^{th} child being stunted is predicted by the fixed effects components such as the p=1,…,P child-level characteristics (C_{ijk}), the q=1,…,Q_p household-level characteristics (H_{qjk}), and $s=1,\ldots,S_{pq}$ community-level characteristics (V_{sk}) and the random effects components explaining the variation between children within households (ε_{ijk}), that between households within communities (γ_{0jk}) and that between communities (μ_{00k}). β_{000} is the intercept for the community-level model after decomposing the child-level intercept with response to household characteristics and then decomposing the household level- intercept with response to community level characteristics. Random variables are assumed to be distributed normally with mean zero and variance as follows and are also assumed to be independent across levels (Goldstein 1991). That is, $\varepsilon_{ijk} \sim N(0, \sigma^2_c)$, $\gamma_{0jk} \sim N(0, \sigma^2_h)$, $\mu_{00k} \sim N(0, \sigma^2_v)$. The variances specified above are unknown and the aim of the proposed multi-level modeling is to estimate those variances or unobserved heterogeneity.

For the estimation of the above model, we follow the recently developed adaptive quadrature approach to maximum likelihood estimation of a discrete dependent variable with nested random effects (refer to, Rabe-Hesketh *et al.*2005). Based on the results of random components, intra-class correlations that measure the strength of correlation between children at household and community levels have been calculated (refer to, Rabe-Hesketh and Skrondal 2005).

The key independent variables of interest include mother's own education, the community means of mother's education and mother's health measured as height of mother. Based on years of schooling, mother's education is categorized into three categories: no education, primary level (<=grade 6) and higher than primary level (primary +). Children of mothers with no education are treated as the reference category, with two categories of dummy variables being created. The community mean education is measured as the mean level of education of mothers in the community they belong to, as measured in Kravdal (2004). Height of the mother, measured in centimeters, is specified as a continuous variable.

The child-specific variables included in the models are age, age-squared, birth order, size at birth, and sex of child. The age of the child measured in months and birth order are specified as continuous variables. Child's size at birth is specified dichotomously as '1' if mother's response to child size at birth was 'average or greater than average' and '0' if otherwise. It is often argued that the measured birth size may be highly correlated with nutritional outcomes such as stunting. The child size at birth variable is based on a subjective response and it is not clear whether the response represent the length or weight of the newly born child. Further, the Pearson correlation coefficient between stunting and size at child's birth is -0.11. Therefore, this variable is specified in the model and is expected to capture in part genetic endowments of parents and prenatal health. The sex of child is also specified as a dichotomous variable as '1' if child is girl or '0' if boy.

Breastfeeding is often considered as important child-specific variable (e.g., Madise *et al.* 1999). However, this variable is not used in the models for two important reasons. First, breast feeding in Nepal is almost universal; only 0.3% of children in the sample were reported as not being breast-fed by mothers. Further, while it could be argued that duration of time breast feeding since birth will influence stunting outcomes, child age is strongly correlated with breast feeding duration. Age of child (and age-squared) is controlled in the models, with age likely accounting for breast-feeding duration in its effect. This important relationship needs to be recognized.

The household-level covariates controlled in the models include education of father, age of mother, a household wealth index and ethnicity. The education of father is based on the survey response from the child's mother. Father's education is classified into four categories: no education (reference category), primary level, secondary and higher level, and 'do not know'. Age of mother is specified as a continuous variable. A household wealth index[2] is used as a proxy for household income. Inclusion of income is considered to create a serious endogeneity problem, while household wealth index is considered to be far less problematic (Smith *et al.* 2004). Instead of using household wealth index as a continuous variable, household wealth quintiles (five quintiles) are used to control for household's differential ability to invest in child health. The effect of household wealth quintiles are measured as opposed to a reference category, i.e., Quintile-I. Caste/ethnicity is relevant at it reflects household's socio-cultural background which is likely to affect childhood stunting. Ethnic backgrounds are categorized into five caste/ethnic groups: High-caste-Hindu (reference category), Low-caste-Hindu, Hill-Tibeto-Burmese, Terai-Tibeto-Burmese, and 'other' ethnic group. In general, High-caste-Hindus are socio-economically better off compared with other caste/ethnic groups. Household's experience of child mortality is often used to capture the vulnerability of households in raising healthy child (e.g., Madise *et al.* 1999) and also to control for sample selectivity bias, as child health studies only include those currently living. The household experience of child mortality in the last five

[2] The household wealth index is constructed based on principal component analysis of household assets and amenities including water source, toilet facilities. In some studies, the water source and toilet facilities are specified as separate variables, however.

years is not included in the models estimated here because it is not clear whether or not child death was nutrition-related.

Altitude-- measured as the distance above mean sea level in meters according to GPS unit measurements-- is one of the key community-level variables included in the models to control micro-climatic local environment that affect child nutrition. Access to health services is critical in explaining child health. Because of the absence of variable measuring the access to health services for children in the community, we created community-level access to health services as the proportion of households in the community reporting the distance to health services to access medical help as a large problem. It is derived from the mother’s questionnaire whether distance to health services to receive medical help for her a large problem, a small problem or no problem. The response was recoded dichotomously as ‘1’ if response is a large problem and ‘0’ otherwise. We also control the extent of urbanization creating an urban variable as ‘1’ if community is designated as urban and ‘0’ if community is rural. Developmental regions are also included to capture variation in the extent of development, treating the Eastern region as reference and other regions such as the Central, Western, Mid-Western and Far-Western regions as dummy variables.

One of the concerns about estimating the effect of community-level maternal education is that this variable may also proxy the effect of community-level economic conditions and community-level environmental sanitary conditions. Therefore, to estimate the net effect of community-maternal education, a community economic status variable was created as community-level median value of the households’ wealth index. Similarly, a community-level sanitation deprivation index was created using principal component analysis of proportion of households in the community having poor toilet facilities, poor drinking water sources, use of traditional cooking fuels such as wood and cow dung, and traditional unfinished floor materials such as earth, mud and dung. A series of preliminary logistic regression models were estimated including these community-level variables. However, the results were not satisfactory, likely due to fairly high correlations between community-health access, community sanitary index and community wealth index, as might be expected. Therefore, instead of using all of these variables, only the community health access variable is used in the estimated models. It should be recognized that the estimated coefficient of community health access variable, in part, may capture the influence of community wealth condition and also community sanitary condition.

Results

Descriptive Results

Table 1 reports descriptive statistics for variables included in the models: for the whole sample, for children whose mothers are uneducated, and for the rural/urban residential models[3]. The table also reports one-way analysis of variance (ANOVA) results comparing the variable means between the rural and urban sub-samples. Only the summary statistics of dependent and key independent variables are briefly described here (for control variables refer to Table 1). Slightly more than half of preschool-age children in Nepal are found to be afflicted with long-term nutritional deprivation. Significant variation in the prevalence of stunting between rural and urban children is observed, with the average prevalence being higher in rural communities (52%) than in urban locations (38%). Among children of uneducated mothers, prevalence of stunting is higher (55%) than overall prevalence regardless of maternal education and place of residence, indicating that childhood stunting outcome is attributed to mother's education attainment. About

[3] Tables showing results from residential models (Rural and Urban Models) are not included in the paper to save the space. However, the results are discussed in the text. These tables are available from authors on request.

one-fourth of mothers of eligible children have formal schooling, and about half of these have attained higher than primary-level schooling. Also observed is significant variation in the breadth (percent of mothers educated) and the depth (average number of years of schooling) of maternal education by residence. In urban communities, more than half (55%) of mothers have some level of schooling as compared to one-fifth (21%) of mothers in rural communities. At the community-level, the mean level of education among mothers of preschool-age children in 2001 is 1.4 years. Again, there is a statistically significant difference in the community-level mean level of schooling between rural and urban mothers. The average height of a mother in the full sample is 150 cm, which does not vary by place of residence.

(Table 1 about here)

Unobserved Heterogeneity in Childhood Stunting

Except for the urban model, in all other models, the estimated coefficients for the household- and community-level variances were highly significant, indicating the existence of unobserved heterogeneity in child stunting at higher levels. Given that the random-intercept logistic and logistic regression models are quite different types, the usual likelihood ratio test cannot be performed to ascertain which model better performs. However, highly significant coefficients of random variables together with the larger log likelihood values suggest that the random-intercept logistic regression model out-performs the logistic regression model, except for the urban model. Hence, except for the urban model (logistic regression), for all other models the random-intercept logistic regression models were estimated, controlling child-, household- and community-level characteristics. The random effects results in the Tables 2 and 3 provide the extent to which the childhood stunting variance is shared by unobserved factors at household- and community-levels.

(Tables 2 and 3 about here)

The coefficients of both household- and community-level variances are statistically significant in all the models, providing evidence that the variance in child stunting in Nepal is attributed to unobserved heterogeneity at the household and community levels. The calculated intra-class correlations show that the share of household-level heterogeneity in the total variance of child stunting ranges from 18% to 19%, while that of community-level heterogeneity is 3%. The correlation coefficient value reflects the degree of inequality in stunting between similar children at the household and community levels. The extent of inequality between similar children is six times greater among households than that among communities. The results suggest that children of some households in the community have a higher risk of being stunted than children in other households.

Maternal Own Education and Child Stunting

For the overall model, results show that compared to children with uneducated mothers, those with of mother with primary-level education is statistically not different in stunting outcome. However, those of mothers with higher than primary-level education have 24% lower odds of being stunted. Note that the coefficient of higher than primary-level education is statistically significant only at 10% level (Table 2). Many past studies, however, have concluded that maternal education is a significant predictor of child long-term nutritional status. Most of those studies have failed to account for many important variables including household- and community-level heterogeneity and community context variables including community-level maternal education. Our results show that failure to account for those factors yields overestimated effects of maternal own education especially at lower level of schooling.

Interestingly, the residential models show quite different effects of maternal education on child nutrition in rural and urban communities. In the rural model, the coefficients for mother's primary-level and higher than primary-level education are less than one and significant in initial models. For instance, children with mothers who have primary level education have 22% lower odds of being stunted compared with those from uneducated mothers. Similarly, for mothers who have higher than primary-level education, the odds of children being underweight is 26% less than that of children with uneducated mothers. The inclusion of household- and community-level variables still retains the significance (at 10% level) of the coefficient for mother's primary education with a slight reduction in the value of the coefficient (odds ratio = 0.79) but the coefficient for mother's higher than primary-level education becomes insignificant. In the urban model, the coefficient for mother's higher than primary-level education is insignificant. But in contrast, the coefficient for mother's primary-level education exceeds one and is significant at 10% level. The results show that even mothers' lower levels of education are important in rural communities but this is not the case in urban communities. The lack of significance of coefficient for mother's secondary and higher than primary-level education may have been due to the mediating effect of community education of mother as well as other household-level factors such as wealth.

Community-Level Externality of Maternal Education

In the whole sample model (Table 2), the coefficient for community-level maternal education is negative and statistically highly significant in all three model specifications. According to the expanded model (Model-III), every unit increase in community-level maternal education reduces the likelihood of children being stunted in the community by 13%. This result provides evidence of a strong positive externality (spillover) of community-level maternal education on long-term nutritional health of children, even after controlling child-, household- and other community-level factors including community access to health services. Most interestingly, results show that even children from uneducated mothers positively benefit from the community externality of maternal education (Table 3), suggesting that improved nutritional technology and practices are 'spilled over' to uneducated mother through social interaction or/and social influence. The children from uneducated mothers are 12% less likely to be stunted for each unit increase in the community-level education of mothers. The residential models also show that children in both urban and rural places benefit nutritionally from community-level education of mothers. However, the benefits vary in their extent. Rural children from uneducated mothers have 11% lower odds of being stunted for every unit increase in community-level maternal education, controlling all other factors. It is almost twice as high if children are from uneducated mothers in urban communities. This difference may have been due to higher level of community-level maternal education in urban communities as compared to that in rural communities.

Based on the results from children of uneducated mother model, one might argue that the these results do not support the universal education proposed in Millennium Development Goals as there seems that it is not necessity to educate every mother in the society. This argument may not be valid for number of reasons. First, results provide a clear evidence that maternal own education is crucial for reducing childhood stunting in Nepal. Next, even the educated mothers seem to benefit from community-level maternal education as shown by whole model and residence models. Further, as shown by rural and urban model results, the negative spillover effect of community-level maternal education on childhood stunting seems to be stronger if community-level maternal education is higher. Lastly, from the holistic perspective results provide further evidence that children of educated children are far better off than those from uneducated mothers.

Intergenerational Transmission of Health

The results from the whole sample model show that the coefficients of mother's height are statistically highly significant across all three specifications and are robust (Table 2). Controlling all other factors, every centimeter increase in height of mother decreases the odds of children being stunted by 8%. The same level of effects (round up) is also evident even if the mothers are uneducated at all (Table 3) or the places they live, providing a strong evidence that the intergenerational transfer of mother's height to long term nutritional status of child is robust regardless of mother's education and the extent of urbanization of place of residence. This illustrates that the effect of mother's height on stunning of child to the greater extent captures the genetic transformation than the current health environment.

Other Factors Influencing Child Stunting

As reported in other studies, child age appears to be a strong determinant of child stunting in all models. The highly significant positive and negative signs of coefficients for the age and age-squared variables show that child age has a concave relationship with stunting outcome. The effect of child age may have also captured some influence of breast feeding practices which varies by age of the child. Birth order appears to be another significant determinant of child stunting except in the urban model. The odds of being stunted increases with birth order. The coefficient for size at birth is highly significant and robust, except in urban model. A child with size at birth perceived as equal or more than average in the community is 47-49% less likely to be stunted. It is not clear whether subjective response of size at birth measure the length or weight of the child; however it seems that the size at birth that reflects the genetic endowments of parents and also fetus health during pregnancy is very important factor shaping the child health in later life. Statistically, while there appears to be no sex differential in childhood stunting in overall and urban models, it appears to be case in rural communities and among children from uneducated mothers; girls have higher odds of being stunted than boys.

Despite the fact that both breadth and depth of education of father's is higher than the mother's, it is interesting that the father's education is not related to child stunting (Table 2). This appears to be true even if mothers are uneducated (Table 3). In the rural model, however, the effect of father's higher than primary-level education is negative and significant at 10% level, but is not significant in the urban model. Mother's age is found to have a significant negative relationship with child stunting in both the whole sample model and the rural model. The household wealth index quintiles stand out as another significant factor negatively shaping child stunting, except in urban model. As compared to household wealth Quintile-I, an increase in household wealth quintile lowers the odds of children being stunted. The ethnic background of children appears to be another important determinant of child stunting. Although High-caste-Hindus are socio-economically better off than any other ethnic group, the Hill-Tibeto-Burmese ethnic group children have lower odds of being stunted as compared to children from high-caste-Hindu children, except in urban areas. Similarly, in rural locations, children of the Terai-Tibeto-Burmese ethnic group appear to be less likely to be stunted than those of High-caste-Hindu. Besides social and economic factors, culturally-influenced food practices and genetic factors may have played an important role.

The altitude of current place of residence appears to be important factors shaping childhood stunting in Nepal, except in urban communities. Every unit (500 masl) increase in altitude is likely to increase childhood stunting by 20%-23%. Child stunting is observed to vary by development region. As opposed to children from the Eastern region, children in the rural areas and overall (whole sample) in the Central and Western regions of Nepal have higher odds of being stunted. The coefficients for the mid- and Far-Western regions are not statistically significant. Similarly, there appears to be no regional variation among urban children.

Conclusions

This study offers additional insights into our understanding of the key determinants of long-term child nutritional deprivation. Net of household-level and community-level factors, the variation in child stunting is significantly attributed to household-level and community-level heterogeneity. As can be expected, the share of household-level heterogeneity is substantially greater than that of community-level heterogeneity. The multi-level modeling approach adopted in this study is found to be an improvement over the simple logistic regression approach, as children are nested within households and households within communities, because of characteristics common to children at higher levels.

In the overall, the negative influence of maternal own education on child stunting is seen only with higher level of education, however, residential models show quite interesting results; in rural communities children benefit even from mothers' lower levels of education but this is not the case in urban communities. Results show that even when household-level and community-level factors are controlled, the negative influence of community-level maternal education stands out to be robust in explaining long-term child nutritional deprivation. This result is consistent regardless of urbanization of community, but varies in extent. Most interestingly, even children whose mothers are uneducated are found to benefit from education of other children's mothers in the community, providing evidence of negative externality (spillover effect) of community-level maternal education in shaping childhood stunting in Nepal.

Results also provide evidence that even when size at birth and other child-, household- and community-level variables are controlled, the child stunting outcome is negatively related to mother's height, regardless of mother's education and urbanization of community where child is raised. The notion that a taller mother tends to have a taller child relative to his/her age provides evidence of the intergenerational transmission of genetic endowment and in part the effect of post-natal environmental effects. It should be noted that the estimated coefficient for mother's height can be biased in the absence of father's height. The father's height was not included because this variable is not recorded by the survey for the fathers of all children.

Among other factors, child age and size at birth are important child-specific factors. Similarly, household wealth status and ethnic background are strong predictors of long-term childhood stunting. Development regions represent the key community variables showing significant variation in long-term child nutritional deprivation, within the Eastern region being better off than other regions especially Central and Western.

Our findings suggest that long-term nutritional deprivation among children in Nepal can be alleviated to a great extent through promotion of education of mothers and women while taking into consideration of geographical inequality in problems of stunting. The Central and Western regions as well the higher altitude places of Nepal should be the focal points for public health interventions.

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Table 1. Summary Statistics for Whole Sample, Children from Uneducated Mothers and for Rural/Urban Residence Models

Variable	Whole (n=6,152)		Uneducated Mothers (n=4,636)		Rural (n=5,571)		Urban (n=581)		F-Ratio[1]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Dependent Variable									
Stunting	0.508	0.500	0.549	0.498	0.521	0.500	0.379	0.485	***43.21
Independent Variables									
Mother's Education:									
Primary	0.122	0.328			0.118	0.322	0.165	0.372	***11.07
Higher than primary	0.124	0.330			0.097	0.296	0.386	0.487	***431.03
Community mean	1.441	1.686	0.941	1.149	1.185	1.426	3.895	1.991	***1744.78
Mother's height (cms)	150.382	5.335	150.127	5.370	150.347	5.345	150.714	5.228	2.48
Controls									
Level-I (Child-Level)									
Age	29.604	17.127	29.992	17.118	29.457	17.117	31.015	17.177	*4.36
Age-squared (*100)	11.697	10.520	11.925	10.550	11.606	10.487	12.565	10.805	*4.37
Birth order	3.240	2.143	3.604	2.225	3.303	2.150	2.639	1.971	***50.95
Size at birth >= average	0.775	0.418	0.760	0.427	0.774	0.418	0.780	0.415	0.09
Sex (girl =1)	0.504	0.500	0.495	0.500	0.504	0.500	0.497	0.500	0.1
Level-II (Household-Level)									
Father's Education:									
Primary	0.255	0.436	0.284	0.451	0.260	0.438	0.215	0.411	*5.46
Higher than primary	0.386	0.487	0.263	0.440	0.361	0.480	0.630	0.483	***164.79
Don't know	0.019	0.137	0.023	0.150	0.020	0.139	0.014	0.117	0.95
Mother's age	27.746	6.361	28.685	6.505	27.905	6.424	26.222	5.503	***37.05
Household size	7.184	3.379	7.261	3.369	7.220	3.416	6.849	2.983	*6.35
Wealth Index Quintiles									
Quintile-I	0.259	0.438	0.295	0.456	0.282	0.450	0.036	0.187	***170.51
Quintile-II	0.208	0.406	0.245	0.430	0.224	0.417	0.059	0.235	***88.3
Quintile-III	0.190	0.392	0.203	0.403	0.203	0.402	0.065	0.247	***65.14
Quintile-IV	0.190	0.392	0.187	0.390	0.196	0.397	0.126	0.332	***17.09
Quintile-V	0.154	0.361	0.070	0.255	0.095	0.294	0.714	0.452	***2069.7
Caste/Ethnicity									
Low-caste Hindu	0.147	0.354	0.166	0.372	0.145	0.352	0.169	0.375	2.42
Hill-Tibeto-Burmese	0.252	0.434	0.234	0.423	0.255	0.436	0.222	0.416	2.98
Terai-Tibeto-Burmese	0.119	0.324	0.143	0.350	0.125	0.331	0.067	0.250	***16.75
Other ethnic group	0.098	0.297	0.121	0.326	0.099	0.299	0.083	0.276	1.69
Level-III (Community-Level)									
Altitude (500 masl)	1.614	1.450	1.630	1.494	1.671	1.476	1.074	1.021	***90.52
Health access difficult	0.534	0.288	0.574	0.279	.564	.279	0.239	0.179	***756.34
Urban (yes=1)	0.094	0.292	0.056	0.231					
Developmental Regions:									
Central	0.275	0.446	0.284	0.451	0.267	0.442	0.353	0.478	***19.63
Western	0.165	0.372	0.142	0.349	0.173	0.378	0.098	0.298	***21.15
Mid-Western	0.139	0.346	0.152	0.359	0.143	0.351	0.102	0.302	**7.69
Far-Western	0.191	0.393	0.214	0.410	0.186	0.389	0.243	0.429	***11.11

*=P<0.05 **= P<0.01 ***=P<0.001 1=One-Way ANOVA for means by residence

Table 2. Maximum Likelihood Estimates for Three-Level Random-Intercept Logistic Regression Models for Childhood Stunting [Overall Model], Nepal, 2001

Parameters	Model-II			Model-III			Model-IV		
	Odds	Sig	z-stat	Odds	Sig	z-stat	Odds	Sig	z-stat
Fixed Effects									
Mother's Education:									
Primary	0.846		-1.57	0.892		-0.97	0.885		-1.04
Higher than primary	0.679	**	-2.99	0.77		-1.87	0.765		-1.92
Community mean	0.806	***	-7.04	0.852	***	-4.86	0.874	***	-3.73
Mother's height (cms)	0.917	***	-12.07	0.916	***	-12.01	0.917	***	-11.9
Age of child (months)	1.197	***	18.46	1.196	***	18.01	1.196	***	18.03
Age-squared	0.997	***	-15.23	0.998	***	-14.77	0.998	***	-14.78
Birth order	1.029		1.69	1.076	*	2.5	1.082	**	2.7
Size at birth >= average	0.512	***	-7.99	0.522	***	-7.65	0.531	***	-7.43
Sex (girl =1)	1.075		1.09	1.087		1.25	1.093		1.33
Father's Education:									
Primary				1.099		0.99	1.087		0.88
Higher than primary				0.864		-1.46	0.868		-1.41
Don't know				1.356		1.13	1.454		1.4
Mother's age				0.98	*	-2.04	0.977	*	-2.36
Household size				1.015		1.24	1.017		1.43
Wealth Index									
Quintile-II				0.656	***	-3.94	0.683	***	-3.58
Quintile-III				0.603	***	-4.32	0.644	***	-3.74
Quintile-IV				0.623	***	-4.03	0.655	***	-3.58
Quintile-V				0.516	***	-4.32	0.575	***	-3.47
Caste/Ethnicity:									
Low-caste Hindu				1.195		1.5	1.21		1.61
Hill-Tibeto-Burmese				0.794	*	-2.2	0.693	***	-3.3
Terai-Tibeto-Burmese				0.686	**	-2.64	0.826		-1.33
Other ethnic group				1.033		0.21	1.268		1.51
Altitude (500 masl)							1.203	***	4.95
Health access difficult							1.18		0.85
Urban (yes=1)							0.949		-0.3
Developmental Regions:									
Central							1.302	*	2.17
Western							1.394	*	2.36
Mid-Western							1.063		0.39
Far-Western							1.019		0.12
Random Effects									
Variance									
Household-level (σ^2_h)	0.814		(0.186)	0.827		(0.190)	0.814		(0.189)
Community-level (σ^2_v)	0.224		(0.048)	0.19		(0.047)	0.128		(0.039)
Intra-Class Correlation									
Household-level (ρ_h)	0.188			0.192			0.192		
Community-level (ρ_v)	0.055			0.046			0.031		
Log Likelihood	-3633.88			-3549.12			-3529.08		

*=p<0.05 **=p<0.01 ***=p<0.001 Note: Figures in parentheses are standard errors

Table 3. Maximum Likelihood Estimates for Three-Level Random-Intercept Logistic Regression Models for Childhood Stunting [Children of Uneducated Mother Model], Nepal, 2001

Parameters	**Model-II**			**Model-III**			**Model-IV**		
	Odds	Sig	z-stat	Odds	Sig	z-stat	Odds	Sig	z-stat
<u>Fixed Effects</u>									
Mother's Education									
Community mean	0.790	***	-5.520	0.846	***	-3.740	0.880	**	-2.600
Mother's height (cms)	0.915	***	-10.650	0.916	***	-10.520	0.918	***	-10.380
Age of child (months)	1.204	***	16.250	1.204	***	16.170	1.203	***	16.150
Age-squared	0.997	***	-13.660	0.998	***	-13.530	0.998	***	-13.510
Birth order	1.031		1.720	1.057		1.730	1.062		1.890
Size at birth >=average	0.503	***	-7.090	0.518	***	-6.800	0.527	***	-6.610
Sex (girl =1)	1.124		1.520	1.130		1.590	1.138		1.690
Father's Education									
Primary				1.081		0.770	1.063		0.610
Higher than primary				0.906		-0.900	0.908		-0.880
Don't know				1.437		1.280	1.543		1.540
Mother's age				0.984		-1.420	0.981		-1.700
Household size				1.012		0.880	1.015		1.100
Wealth Index									
Quintile-II				0.648	***	-3.780	0.678	***	-3.400
Quintile-III				0.579	***	-4.220	0.625	***	-3.610
Quintile-IV				0.552	***	-4.490	0.582	***	-4.070
Quintile-V				0.525	***	-3.260	0.561	**	-2.820
Caste/Ethnicity:									
Low-caste Hindu				1.177		1.240	1.194		1.350
Hill-Tibeto-Burmese				0.822		-1.540	0.707	*	-2.520
Terai-Tibeto-Burmese				0.635	**	-2.910	0.785		-1.530
Other ethnic group				0.972		-0.170	1.231		1.220
Altitude (500 masl)							1.230	***	4.750
Health access is difficult							1.103		0.430
Urban (yes=1)							0.952		-0.210
Developmental Regions									
Central							1.268		1.660
Western							1.326		1.650
Mid-Western							1.137		0.710
Far-Western							0.993		-0.040
<u>Random Effects</u>									
Variance									
Household-level (σ^2_h)	0.801		(0.215)	0.782		(0.213)	0.765		(0.212)
Community-level (σ^2_v)	0.279		(0.063)	0.215		(0.058)	0.150		0.048
Intra-Class Correlation									
Household-level (ρ_h)	0.183			0.182			0.182		
Community-level (ρ_v)	0.064			0.050			0.036		
Log Likelihood	-2717.5			-2689.0			-2672.5		

*=p<0.05 **=p<0.01 ***=p<0.001 Note: Figures in parentheses are standard errors