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Moving beyond the mother-child dyad: Women's education, child immunization, and the importance of context in rural India

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Abstract

The argument that maternal education is critical for child health is commonplace in academic and policy discourse, although significant facets of the relationship remain empirically and theoretically challenged. While individual-level analyses consistently suggest that maternal education enhances child health outcomes, another body of literature argues that the observed causality at the individual-level may, in fact, be spurious. This study contributes to the debate by examining the contextual effects of women's education on children's immunization in rural districts of India. Multilevel analyses of data from the 1994 Human Development Profile Index and the 1991 district-level Indian Census demonstrate that a positive and significant relationship exists between the proportion of literate females in a district and a child's complete immunization status within that district, above and beyond the child's own mother's education as well as district-level socioeconomic development and healthcare amenities. However, results also indicate that the effect of maternal education cannot be downplayed. Thus, increasing women's literacy at the community level, *in addition to* mother's access to higher education—such as matriculation and beyond—at the individual-level, emerge as effective developmental tools.

Keywords: Women's education; Child immunization; India; Multilevel modeling

Introduction: the debates surrounding causality

The argument that maternal education is critical for child health is commonplace in academic and policy discourse, although significant facets of the relationship remain empirically and theoretically challenged. On the one hand, several micro-level quantitative and qualitative studies as well as cross-national comparisons of the World Fertility Survey and the Demographic and Health Surveys consistently suggest that maternal education enhances child health outcomes such as nutrition, complete and timely immunization, or ORT usage (Caldwell, 1986). Such causal interpretations posit that education endows mothers with "instrumentality" or the ability to accrue information pertaining to health needs, access relevant healthcare services, and effectively interact with medical and allied personnel (Cleland, 1990).

An emerging body of literature, on the other hand, argues that the relationship between maternal education and child health is neither universal nor well established (Hobcraft, 1993). Although several scholars acknowledge the strong statistical correlation between these two variables at the individual-level, they question assumptions of causality (Palloni, 1981; Desai & Alva, 1998).

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According to Desai and Alva (1998), the influence of maternal education on child health (and the processes through which the relationship is manifested) is unclear because of inadequate socioeconomic controls at various levels. Because educated mothers tend to come from wealthy households that reside in affluent areas with good schools, well-developed medical infrastructure, and high levels of hygiene, their education may be a *proxy* for the socioeconomic status of the household *and* the community. Thus, the observed causality between both variables at the individual level may, in fact, be spurious (Desai & Alva, 1998).

While strongly convincing, both sets of arguments above ‘‘fail to capture the complex *interactions* between individual characteristics, household circumstances and community-level attributes’’ (Adams, Madhavan, & Simon, 2002, p. 166). That is, they tend to underestimate the larger ‘‘dispersion’’ effect of *other* women's education on the health outcomes of a child residing in the same geographical area, *above and beyond* the mother's own education (although Desai and Alva refer to the possibility of this ‘‘spillover’’ effect in their article's conclusion). Importantly, the clustered nature of health outcomes (due to neighborhood effects) or the nested nature of populations—i.e. areas as aggregates of households, and households as aggregates of children and various processes within them remains overlooked (Duncan, Jones, & Moon, 1996; Subramanian, 2004). So, one could argue that while increasing women's access to education may increase the *number* of women entering an educational category associated with reduced child mortality, even children of uneducated mothers may have better health due to the *externalities* generated by other women's education (Kravdal, 2004). Thus, the posited causality or spuriousness could be partially ascribed to the unmeasured social dimensions of education that are not captured in single-level or fixed effects models. Such *contextual causality* is especially relevant for studying preventive health behaviors such as infant immunization, the primary outcome of interest in this paper.

Using multilevel modeling, this study contributes to the ongoing debate by answering the question: does *other* women's education, independent of maternal education, improve a child's probability of getting completely immunized? Or, does the educational context *beyond* the mother-child dyad matter? I use stepwise models to support my hypotheses. Model 1 estimates the effect of district-level female literacy on a child's immunization status. In Model 2, district-level controls are introduced to investigate if the relationship observed in Model 1 remains consistent. Model 3 includes all the compositional (individual and household) as well as contextual (district) variables to evaluate: (1) the robustness of the contextual effect of female literacy by controlling for compositional factors, and (2) the extent to which compositional effects explain changes, if any, in the observed relationship between aggregate female literacy and child immunization in rural districts of India. I conclude the paper by discussing data limitations, relevant policy issues, and future avenues of research.

The Indian background

Classified as low income by the World Bank, with a GNP estimated at \$460 per capita, India ranks 127 among all countries on the human—and 103 on the gender-development index (UNDP, 2004). Approximately 72% of India's 1.07 billion residents live in rural areas, with agriculture contributing nearly one-fourth of the GDP and providing a source of livelihood to about two-thirds of all workers. Economic progress has been moderate, with the percentage of population living below the poverty line declining from 51.3% in 1977–1978 to 29.2% in 1996–1997 (Kurian, 2000). In 1991, the government adopted structural adjustment reforms to accelerate the process of making India internationally competitive. Critics of these reforms argue that decreases in employment and real wages, increases in prices of basic necessities, and cutbacks in government spending on social developmental goals such as improvements in health, education, and nutrition has resulted in widespread poverty, with negative ramifications on health, particularly among women and their children. Although national level trend analysis indicates improvements in various social and health indicators, they also tend to mask disparities between and within states on issues such as morbidity and mortality, education, HIV prevalence, and urbanization (Kurian, 2000).

India has a mixed system of health care: a majority of curative treatment is through private medical practitioners whereas the government provides a substantive share of the preventive and promotive care. In the 1940s, the government integrated immunization within maternal and child health services. Between 1969 and 1985, it adopted the WHO- and UNICEF-initiated Expanded Program on Immunization, followed by the Universal Immunization Program (UIP) in 1985–1986 and the Safe Motherhood Program in 1992 (Pande & Yazbeck, 2003). The UIP purportedly served *all* districts in the country by 1998–1999, and its objectives included immunizing at least 85% of all infants aged 12–23 months against six fatal but vaccine-preventable diseases (VPD). However, regional variations in health and vaccinations levels have emerged because of vertically structured health delivery systems that are based more on supply models and ‘‘territorial organization rather than on the burden of disease or on local ecology of disease’’ (Das, Das, & Coutinho, 2000, p. 626). Almost 50% of infants, particularly those residing in rural areas, face an elevated risk of illness and death due to incomplete or no immunization. Child mortality is almost twice as high, infant mortality is 56% higher, and under-five mortality is 64% higher in rural than in urban areas of India (IIPS, 2000). Girls, Muslims, and scheduled castes/tribes are significantly less likely to be fully immunized than boys, Hindus, and upper castes because of higher dropout rate for three-dose DPT and oral polio vaccines (Pande, 2003). In fact, by emphasizing quantitative fixed vaccination targets over public health education, the global partnership has circumvented national priorities; inept political management and instability at the state level has further aggravate the situation, leading to lack of direction, incentive, and leadership in immunization programs (Greenhough, 1995; Das & Dasgupta, 2000).

High morbidity and mortality due to VPD among under-five children (11.3% of the age structure) is further complicated by the predominantly rural, poor, and uneducated Indian population. Although the overall literacy rate in India has increased from 18% in 1951 (age 5+) to 65% in 2001 (age 7+), with the highest growth rate for women recorded between 1991 and 2001, regional, urban-rural, and gender differentials in education still persist. As of 2001, Kerala had the highest female literacy rate of 87.8% (90.9% overall), while Bihar occupied the lowest rung with 33.6% (47.5% overall). Across India, only 54.2% of women compared to 75.9% men, and 59.4% rural versus 80.3% urban residents, have basic reading and writing abilities (Government of India, 2002). Importantly, rural women (46.7%) are disproportionately disadvantaged compared to rural males (71.4%) and urban females (73.2%). Such disparities in a country that adopted the 1978 Alma Ata declaration of "Health For All," and where free and compulsory education for all children until they complete the age of 14 is a constitutional right, reinforces the need to study the contextual effect of female literacy on child immunization in rural areas and to further emphasize women's education as an appropriate developmental tool.

The importance of context

Huckfeldt (1986, p. 13) describes contextual effects as "instances in which individual behavior is affected by the presence of a social property in a population regardless of whether the individual possesses the property in question." Studies of contextuality are centered on the premise that shared membership of the family, neighborhood, or even the village, modifies or constrains individual behavior and attitudes. Or, that the resources, ideas, or behaviors generated by some individuals in a community influence society and social institutions, and thus, the behavior of others residing therein.

Within the context of this study, a large number of literate women in an area can influence child immunization through broad societal transformations as well as through increased institutional support and healthcare markets that may become available to uneducated mothers due to residential or employment proximity to educated mothers. Information diffusion through social networks and changes in parenting norms and expectations through social influence are other channels whereby externalities of female literacy are manifested in child health.[1]

Case studies in India demonstrate that a large number of literate women in a village may influence other women's capacity to seek and take advantage of state-provided healthcare by negotiating for better access to health information, services, skills, and technologies as well as continual support of responsive local-level medical personnel (Das et al., 2000). Female doctors, teachers, and political leaders in influential positions may manipulate extant social institutions, help foster growth in public services, and mobilize community resources to serve their own, and ultimately, other women's needs (Caldwell, 1986; Cleland, 1990). Higher-levels of women's education may also increase their visibility and participation, initiate changes in local attitudes regarding women's status, and contribute towards the community's overall development. Thus, in a positive "dispersion" effect, children of uneducated mothers residing in the same area as educated mothers may have better preventive health outcomes (Desai & Alva, 1998).

Through public health delivery systems and mass campaigns, major institutions such as the government (e.g. the Health Ministry) or the mass media (radio, television, and newspaper) endeavor to mobilize various social actors towards recognizing the efficacy of immunizations (Perez-Cuevas et al., 1999). The logic is that the creation of demand will automatically generate supply, leading to an environment conducive to *universal* child immunization (Das & Dasgupta, 2000). However, such efforts are successful only when the population *actively demands*, rather than passively accepts these messages (Nichter, 1995; Bonu, Rani, & Baker, 2003).

[1]Education is a consequence of several factors that may have an effect on child immunization itself. Rich, urbanized, or developed communities with political and religious attitudes that support women's education are more likely to establish educational institutions. The presence of schools, household wealth, parental attitudes towards the value of education, or the fact that other parents within the social network educate their children may influence one's decisions to send girls to school (Caldwell, 1986; Kravdal, 2004).

A study conducted in Salang village (India) revealed that despite a high cost-benefit ratio, households are often reluctant to vaccinate their children due to lack of education and poor knowledge of the sources of immunization services or the causal *linkage* between vaccinations and disease prevention (Das & Das, 2003). In such situations, trained female auxiliary nurse midwives and health workers act as powerful intermediaries between the technocratic health delivery system (which often assumes homogeneity of space) and the community, especially women (Singh & Bharadwaj, 2000). Local *anganwadi* workers (often educated beyond matriculation) in Gujarat and Kerala (India), facilitate women's utilization of health services by announcing immunization schedules, by encouraging (or cajoling) mothers to get their children immunized, and by making follow-up house visits (Das et al., 2000). Because of their "insider" position within the community, such recruits are more effective in house-to-house visits than nurses brought from outside. The underlying ideology is that institutionalizing local norms and expectations about health may affect parental behavior if the latter depends on the average level of behavior of other community members (Caldwell, 1986).

In addition to interactions with local health workers, networks with other knowledgeable women also contribute towards greater utilization of health services (Das et al., 2000). Women's participation in diverse organizations could initiate ideational and preventive behavioral change due to increased odds of having related discussions as well as the development of collective notions about child vaccinations. Ethnographic studies conducted in four sites across India revealed that the immediate kin group, neighbors, and older women in the community played an important role in providing therapeutic measles-related information to young mothers (Bisht & Coutinho, 2000). Similarly, immunization requires considerable commitment on the mother's part in knowing and remembering when to have the child immunized. Importantly, they need to be sufficiently *convinced* of the less tangible benefits of vaccinations to put up with the visibly distressing side effects (fever with DPT, an unpleasant boil with BCG (Das Gupta, 1990). In rural Punjab, women who were ambivalent about immunization often supplemented healthcare providers' instructions with the experiential knowledge of other women or employers, demonstrating that preventive healthcare can be effectively implemented thorough the social learning process (Bongaarts & Watkins, 1996; Streefland, Chowdhury, & Ramos-Jimenez, 1999).

Finally, the necessity to move *beyond* household boundaries for health-related information is widespread amongst young women residing in nuclear family units and who may not have direct access to the knowledge of other women, e.g. the isolationist Fulbe group living in resource-deprived areas of Mali (Adams et al., 2002). In contrast, probability of child death (e.g., among the Bamanan group in Mali) is lowered by the presence of female members residing *within* the extended household, highlighting the importance of externalities generated by someone else's knowledge and education (Adams et al., 2002). This raises an important point about the difference between *proximate literacy* and *illiteracy*: illiterate individuals residing in somewhat literate households may be slightly better off than illiterates residing in households where all are illiterate because the educational disadvantages experienced by the former are partially mitigated by direct access to the education of other household members (Borooah, 2004).

In conclusion, although lack of appropriate data makes it difficult to clarify or disentangle the specific links by which the contextual relationship between women's education and child immunization is maintained, such an effect is indeed theoretically plausible (Kravdal, 2004).

Hypotheses

Using multilevel stepwise models, I hypothesize that:

- *Hypothesis* 1: A significant and positive relationship exists between the average female literacy rate in a district and a child's probability of being completely immunized within that district.
- *Hypothesis* 2: The positive relationship between female literacy rate and a child's probability of being completely immunized is likely to persist and be significant even after controlling for individual-level characteristics such as maternal education and district-level characteristics such as wealth and healthcare amenities available.

In order to distinguish between contextual and compositional effects, relevant child- and district-level predictors and controls are included in the analysis.

Data and methods

Analytical multilevel strategy

Until recently, higher neighborhood-, community-, or even district-level effects were not incorporated in studies pertaining to maternal education and child health (Sastry, 1996). This may be due to problems in transporting these effects into individual-level models or choosing the appropriate units and levels of analysis. Even when such effects are included in single-level equations, the results can be misleading due to aggregation bias, misestimated standard errors, and heterogeneity of regression (Raudenbusch & Bryk, 2002). Hierarchical linear modeling (HLM), which permits simultaneous estimation of full micro- and macro-level models, helps correct these methodological problems. By using maximum likelihood statistical estimation, it provides relevant tools for modeling *within* and *between* social phenomena, thus allowing for the direct representation of the influence of higher-level factors on structural relations within areas. Finally, HLM adjusts for correlation errors among individuals within the same geographical region and uses the appropriate degrees of freedom for higher-level hypotheses, making it a useful technique to answer the questions posed here.

Because analyses in HLM cannot proceed with missing data in level 2 variables, values were either imputed through series means or dropped (for the dependent variable) from the analyses. Steps such as checking frequencies, distributions, and correlations were performed in SAS. Individual and district-level datasets were then read into HLM.

Data

Two levels of data are utilized. Level 1 (individual-level) data is from the 1994 cross-sectional Human Development Profile Index (HDPI) collected by the National Center for Applied Economic Research, New Delhi, India. Using a multi-stage sample design to minimize cost and time efforts and to facilitate operational feasibility, the survey interviewed individuals from 35,130 households residing in 195 districts nested in 16 states. In addition to a wealth of household-level information, extensive health details (immunization and anthropometric) of 32,459 children was also gathered. The sample size for the present analysis is 5623 infants between the ages of 12–24 months, with one child per household. Because father's education is included in the analyses as a control variable, only those children whose parents are currently living together are included.

Level 2 (district-level) data is from the 1991 Indian Census and provides information regarding employment, literacy rates, wealth, level of urbanization, and other demographic events for 412 rural and urban districts. In 1991, district population sizes varied from 28,000 to 9,926,000; a majority of the districts (56%) had populations of 2 million and less (McNay, Arokiasamy, & Cassen, 2003). Although Das and Dasgupta (2000) argue that disaggregating data below the state level increases error because of the data collection design, several authors have used district-level data meaningfully to study contraceptive use, fertility, female education, and development across India (Murthi, Guio, & Dreze, 1995; Dreze & Murthi, 2001; McNay et al. 2003). Although it would be ideal to use a geographical area that is small enough to encompass the immediate "context" of an individual woman, data collection problems and the enormity of the Indian landscape render it problematic, if not impossible. 195 rural districts are included in this analysis because of the restriction posed by the rural-based HDPI survey. Unique state–district identifier codes were created to merge individual and district-level data so that children are "nested" within districts. Tables 1 and 2 encapsulate descriptive statistics of the dependent and independent variables at both levels.

Table 1
Individual-level descriptive statistics

Variable	Mean	Standard deviation	Range
Immunization status (dependent)	1.70	0.84	1.00–3.00
Maternal education: none	0.72	0.45	0.00–1.00
Maternal education: primary	0.08	0.27	0.00–1.00
Maternal education: secondary	0.08	0.27	0.00–1.00
Maternal education: matriculation	0.12	0.33	0.00–1.00
Father's education: none	0.54	0.50	0.00–1.00
Father's education: primary	0.12	0.33	0.00–1.00
Father's education: secondary	0.11	0.31	0.00–1.00
Father's education: matriculation	0.22	0.42	0.00–1.00
Female	0.48	0.50	0.00–1.00
Age of child (in months)	17.20	4.36	12.00–24.00
Birth order	2.84	1.83	0.00–12.00
Productive assets index	2.76	5.35	0.00–37.00
Luxury assets index	2.26	3.16	0.00–27.00
Exposure to mass media	0.37	0.43	0.00–1.00
Mobility of household women	0.44	0.48	0.00–1.00
Mother's labor force participation	0.39	0.49	0.00–1.00
Scheduled caste	0.22	0.41	0.00–1.00
Scheduled tribe	0.14	0.34	0.00–1.00
Non-scheduled caste/tribe	0.64	0.48	0.00–1.00
Hindu	0.82	0.39	0.00–1.00
Muslim	0.12	0.33	0.00–1.00
Other religions	0.06	0.24	0.00–1.00

Source: 1994 Human Development Profile Index, India.

Individual-level dependent variable: child's immunization status

The dependent variable, *child's immunization status,* measures the degree to which a woman's last living child born 12–24 months ago is immunized. As per WHO guidelines, infants should receive one BCG vaccine (for tuberculosis) at birth, three doses each of DPT (diphtheria, pertussis, tetanus) and oral polio at 6, 10,

Table 2
District-level descriptive statistics

Variable	Mean	Standard deviation	Range
Proportion of literate females	0.31	0.16	0.08–0.84
Proportion of Muslims	0.10	0.12	0.00–0.70
Proportion of scheduled castes	0.17	0.07	0.00–0.37
Proportion of scheduled tribe	0.10	0.16	0.00–0.88
Wealth index	30.56	12.56	6.60–68.12
Healthcare access index	42.31	12.21	7.89–64.75

Source: Census of India, 1991.

and 14 weeks of age, and finally, one measles vaccine at 9 months or soon thereafter. The sample is restricted by age (12–24 months) because infants should receive all eight injections in the first year of life: completeness *and* timeliness of immunizations are critical for disease prevention. The 24th month was included in the analyses to provide a "softer" time limit to the 23-month immunization schedule.

Data from immunization cards and from mother's recall (when these cards were unavailable) was utilized to estimate coverage (Pande, 2003). Studies demonstrating the accuracy of mother's recall are convincing in their argument about not dropping cases where vaccination cards are *not* available; dropping such cases can cause severe sample attrition (Langsten & Hill, 1998; Desai & Alva, 1998).

The dependent variable is an ordered categorical variable coded as:

- *NONE* : if the child did not receive *any* immunizations at the time of the survey.
- *SOME*: if the child received *at least one but not all* eight immunizations.
- *ALL*: if the child received *all* eight immunizations (1 BCG, 3 DPT, 3 polio, 1 measles).

Descriptive statistics indicate that approximately 54% of all children between 12 and 24 months are completely immunized. 22% are incompletely immunized, while 24% have received no immunizations, making them vulnerable to six potentially fatal VPDs.

District-level contextual variable: female literacy

The macro-level independent variable used in this study is the proportion of adult literate women in a district and is expected to be positively related to the complete immunization status of a child residing in that district. The Indian census defines literacy as the ability to both read *and* write in any language. Reading any portion of the printed matter in the enumerator's instruction booklet (provided the person was familiar with the language used in the booklet) determines the reading test; writing a simple letter comprises the writing test. However, a person who can read but cannot write is not classified as literate, although it is not necessary that a person who is literate should have received any formal education or should have passed any minimum educational level.

According to the level 2 survey used in this analysis—i.e., the 1991 Census of India—the average female literacy rate across select Indian districts is 31% with the distribution of education across the districts being highly skewed and ranging from 8% to 84%. Although each woman may not interact directly with all other women in a district, the subgroup that she interacts with may itself be a part of the interaction chains that, in total, includes a part of the female population in the area. Besides, other indirect mechanisms may also be involved in creating a larger context of women's literacy (Kravdal, 2004).

Control variables: structural-level

District-level control variables in the analysis include: (1) social background: the proportion Muslims, scheduled castes, and scheduled tribes; (2) overall wealth index: constructed through census housing characteristics; and (3) health facilities index: a proxy for health amenities available. An urbanization variable (the share of district population residing in urban areas) was initially included, but later dropped because it did not significantly contribute to the model. The assumption was that proximity to urban areas might improve communication systems that are necessary for transporting services or ideas pertaining to child immunization.

Controls for the proportion of Muslims, scheduled castes, and scheduled tribes in a district are included in the analysis because these minority groups are disadvantaged in terms of resources and access to healthcare facilities, sanitation, and infrastructure (Jeffery & Basu, 1996). The wealth index serves as a proxy for the socioeconomic status of the district and averages the proportion of houses in the district with high quality roofing, wall, and floor materials, toilets (flush/others), electricity, water (piped water/others), and clean cooking fuels. Cronbach's alpha for the wealth index is 0.67, indicating an overall good fit. A quadratic transformation of wealth is also introduced in the analysis to test for nonlinearity. My expectation is that both poor *and* wealthy districts are likely to benefit from immunization programs: the former from government-organized immunization camps and the latter from their own resources. Finally, the health facilities index proxies immunization programs by measuring a district's access to trained health professionals in hospitals, dispensaries, and PC sub-centers and is expected to positively affect child immunization. A potential drawback of this index is the lack of information about the actual quality and type of facilities provided by these health centers.

Control variables: individual-level

Several compositional controls are introduced in Model 3 to test for the robustness of the contextual result. Because this study examines the relationship between district-level women's literacy and child immunization, *above and beyond* maternal education, I control for the individual-level education effect. Maternal and paternal education has four categories: (1) no education, (2) completed primary school, (3) completed secondary school, and (4) completed matriculation and higher. According to the HDPI survey, 72% of rural mothers with children between the ages of 12–24 months are uneducated; 12% have completed their matriculation and 8% each have finished primary and secondary school.

Other variables that, independent of education, affect child immunization are also incorporated in the analysis. Social background variables tapping social and cultural norms not captured by other variables include (1) household caste/tribe: scheduled caste, scheduled tribe, and nonscheduled caste/tribe and (2) religion: Hindu, Muslim, and others. Because income is not a reliable estimate of socioeconomic status in developing countries (due to underreporting and employment in the non-wage economy), ownership of luxury assets is a reasonable proxy for long-term household wealth. Unproductive consumption possessions (such as bicycle, radio, television, etc.) were first assigned specific scores and then summed up into an index. I also included productive household assets in the model, although it had minimal effect.

Bio-demographic controls for age (in months), sex, and birth order of child as well as mother's age (in years) are also incorporated. Women's access to information about immunization, measured through (1) their weekly exposure to mass media such as radio, television, and newspapers (at least once a week = 1, never = 0), (2) freedom to move outside the home (no permission needed = 1, not allowed to go outside = 0), and (3) mother's labor force participation (yes = 1, no = 0) act as compositional controls.

Selective migration constitutes another link between the individual and the community, with some individuals migrating to a particular community due to favorable characteristics. For simplicity, this mechanism is ignored in the analyses.

Estimation method

This study utilizes a two-level hierarchical generalized linear model (HGLM) with a three-category ordinal outcome. Cumulative probabilities are most appropriate to capture the ordered nature of the response variable, leading to the logic of the cumulative logit. Thus, the level 1 (individual-level) model assumes proportional odds, but instead of working with multiple thresholds that separates various categories m, HLM works with the *difference* in the thresholds, denoted by δ_{mj}, besides adding a common intercept β_{0j}. Thus, the threshold δ is typically held constant, though it could, in principle, vary, and is the difference in the log odds of category 2 versus category 1, holding constant the explanatory variables and the random effects (Raudenbusch & Bryk, 2002). Generalizing to M categories (where $m = 1, \ldots, M-1$), the level-1 model becomes

$$\eta_{mij} = \log\left(\frac{\varphi'_m}{1-\varphi'_m}\right) = \beta_{0j} + \sum \beta_{kj}(X_{ijk} - X\ldots_k) + \sum_{m=2}^{M-1} \mathrm{D}_{mij}\delta_{mj}, \quad (1.1)$$

where

η_{mij} is the cumulative logits for child i in district j,
β_{0j} is the intercept or the log odds of being in ordered category m for child i in district j,
β_{kj} is the slopes for k individual-level control variables X_{ijk} that are fixed across districts,
$(X_{ijk} - X\ldots k)$ are individual-level control variables that are grand mean centered,
D_{mij} is dummy indicator for ordered category m (for example, in this analyses, since the outcome variable has 3 categories, $D_{2ij} = 1$ if $m = 2$, $D_{2ij} = 0$ if $m = 1$) and
δ_{mj} is the threshold level.

In order to use the threshold correctly and to utilize the concept of cumulative logits, the dependent variable, immunization status, is reverse coded with 1 = fully immunized, 2 = incompletely immunized, and 3 = not immunized. A *positive* coefficient indicates that a *higher* value of the independent variable *increases* the odds of the *lower* value of the outcome relative to the other categories, that is, odds of being completely immunized relative to being incompletely or not immunized.

The level 2 (district-level) model is

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(\text{proportion of literate females}) + \sum \gamma_{0k} Z_{kj} + u_{0j}, \quad (1.2)$$

$$\beta_{kj} = \gamma_{k0}, \quad (1.3)$$

$$\delta_{mj} = \delta_m, \quad (1.4)$$

where

γ_{00} is the intercept for the log odds of being completely immunized (β_{0j}) relative to being incompletely or not immunized for a child in a district with average female literacy and a random effect of zero,

γ_{01} is the change in cumulative logits associated with the effect of proportion female literates in a district, holding all other variables constant,

u_{0j} is the error term for the district-level random effect on the intercept,

γ_{0k} is the district-level coefficients for k district-level control variables Z_{kj},

γ_{k0} is the constant coefficients β_{kj} across all districts and

δ_{mj} is the threshold level.

To summarize the equations above, η_{mij} represents the cumulative logits for the immunization status of a child i residing in district j as a function of various individual-level background characteristics X_{ijk} and the random error e_{ij}. The ordered logit coefficients reflect the change in the log odds that a predicted response for a child i residing in district j will be one level *lower*, given a unit *increase* in an explanatory variable with all other explanatory variables held constant.

All independent variables included in level 1 lead to level 2 equations where each coefficient at level 1 becomes an outcome variable at level 2. A variable that is "fixed" does not allow for variance between districts for that particular parameter. In these models, individual and contextual control variables are grand mean centered, with effects fixed across all districts; no slope has been modeled. The intercept is predicted by several variables at the district-level with individual-level variables acting as controls and is the immunization status of children with average individual-level characteristics in a district with average district characteristics.

Results and discussion

To reiterate, using generalized hierarchical linear models with an ordinal outcome, this study examines: (1) whether a statistically significant relationship exists between a child's immunization status and the proportion of literate females in a district, and (2) if the relationship can be explained away by compositional effects of maternal education, rather than the larger context of other women's education. Table 3 reports the stepwise results of the multilevel analysis.

Model 1 highlights the positive and significant relationship between the proportion of female literates in a district and a child's *complete* immunization status. Without any control variables, a one standard deviation increase (0.16) in the proportion of literate women in a district *increases* the log odds of a child being completely immunized (relative to being partially and not being immunized) by a factor of 1.83 ($\exp\{\gamma_{01} = 3.78^{*}0.16\} = 1.83$). The intercept ($\gamma_{00}$) indicates that the conditional log odds of complete immunization relative to incomplete or no immunization for a child residing in a district with average female literacy (and a random effect of zero) is 0.41.

Model 2 adds six district-level controls: health amenities index, wealth index, a quadratic wealth index term, and the proportion of the population belonging to scheduled castes, scheduled tribes, and Muslims. Despite a slight reduction in the main coefficient, the positive relationship from Model 1 persists. The log odds of being completely immunized increase by a factor of 1.40 ($\exp\{\gamma_{01} = 2.11^{*}0.16\} = 1.40$) for a one standard deviation (0.16) increase in the proportion of female literates residing in a district, lending further support to my first hypothesis.

Model 2 also underscores the significant negative association between a child's immunization status and the proportion of Muslims and scheduled tribes in a district. The log odds of a child being completely inoculated *reduces* with a one standard deviation increase in the district-level proportion of Muslims ($\exp\{\gamma_{04} = -2.17^{*}0.12\} = 0.77$) or scheduled tribes ($\exp\{\gamma_{03} = -1.28^{*}0.16\} = 0.81$). The unequal allocation of resources (reflected in lack of healthcare facilities and infrastructure) and socioeconomic disadvantages (higher poverty rates, lower incomes) experienced by Muslims and scheduled tribes may partly account for this inequity (Jeffery & Basu, 1996). A one standard deviation (12.21) increase in healthcare amenities index improves a child's log odds of being completely immunized by almost one and a half ($\exp\{\gamma_{05} = 0.03^{*}12.21\} = 1.44$). Finally, as expected, a non-linear relationship exists between health and wealth: increasing district wealth improves a child's log odds of complete inoculation, but the effect of wealth diminishes gradually at higher levels of socioeconomic development.

The traditional argument that districts with a large number of literate mothers have, by extension, a large number of healthy children could support the observation in Model 2. However, although urban areas are advantaged in terms of the quality of qualifications, level of care, and density of practitioners, the *effect* of women's education is likely to be greater in rural areas (Schultz, 1984). Thus, another way to justify these results would be to argue that districts with high female literacy rates have a *high* proportion of completely immunized children because even mothers with *no* educated may be getting their children immunized due to contextual factors such as knowledgeable social

Table 3
Hierarchical linear model results for compositional and contextual effects on a child's immunization status

	Model 1			Model 2			Model 3		
		Sig.	S. E.		Sig.	S. E.		Sig.	S. E.
District-level variables									
Intercept (immunization status) γ_{00}	0.41	***	(0.07)	0.42	***	(0.07)	0.36	***	(0.08)
Average female literacy rate γ_{01}	3.78	***	(0.48)	2.11	**	(0.58)	1.49	*	(0.63)
Proportion of scheduled caste γ_{02}				−1.82		(1.33)	−1.80		(1.32)
Proportion of scheduled tribe γ_{03}				−1.28	*	(0.53)	−0.84		(0.52)
Proportion of Muslims γ_{04}				−2.17	**	(0.62)	−1.73	*	(0.67)
Health amenities index γ_{05}				0.03	***	(0.01)	0.03	***	(0.01)
Wealth index γ_{06}				0.05	*	(0.02)	0.05	*	(0.02)
Square of wealth index γ_{07}				−0.00	**	(0.00)	−0.00	**	(0.00)
Individual-level variables									
Mother's educational attainment									
No education (ref category)									
Primary γ_{20}							0.22		(0.12)
Middle school γ_{30}							0.12		(0.12)
Matriculation and above γ_{40}							0.23	*	(0.12)
Father's educational attainment									
No education (ref category)									
Primary γ_{50}							0.11		(0.09)
Middle school γ_{60}							0.28	**	(0.10)
Matriculation and above γ_{70}							0.35	***	(0.09)
Sex of the child γ_{80}							−0.15	**	(0.06)
Age of the child (in months) γ_{90}							0.02	**	(0.00)
Birth order of child γ_{100}							−0.05	**	(0.02)
Assets of the household									
Unproductive luxury assets γ_{110}							0.08	***	(0.01)
Productive assets γ_{120}							0.00		(0.00)
Any HH female's exposure to mass media γ_{130}							0.11		(0.08)
Any HH female's physical mobility γ_{140}							0.17	**	(0.06)
Mother's labor force participation γ_{150}							0.03		(0.06)
Social Background									
Non sch. caste/tribe (ref category)									
Scheduled caste γ_{160}							−0.21	**	(0.08)
Scheduled tribe γ_{170}							−0.51	**	(0.11)
Religion									
Hindus (ref category)									
Muslims γ_{180}							−0.41	***	(0.10)
Others γ_{190}							−0.11		(0.08)
Threshold	1.11	***	(0.03)	1.11	***	(0.03)	1.15	***	(0.03)

*Significant at $p<0.05$. **significant at $p<.01$. ***significant at $p<.001$.

networks, effective use of healthcare systems, and institutionalized parental norms and expectations.

Finally, Model 3 introduces individual-level variables for mother's education and other relevant controls in order to test the robustness of the contextual education effect and to calculate the proportion of variance that is explained by compositional factors. Results remain significant and robust. Thus, independent of maternal education, the log odds of a child being fully immunized increases by a factor of 1.27 ($\exp\{\gamma_{01} = 1.49^{*}0.16\} = 1.27$) if the percentage of literates women increases by 16% in a district. A comparison of the coefficient in

Model 2 ($\gamma_{01} = 2.11$) with that in Model 3 ($\gamma_{01} = 1.49$) indicates that adding the control variables reduces the contextual female literacy effect by 40%. Thus, about two-fifths of the effect of women's literacy on a child's immunization status is explained by compositional variables. However, more importantly, almost 60% of the effect is still contextual, thus ratifying my second hypothesis.

Consistent with Model 2, residence in a predominantly Muslim area exerts a significantly negative effect on a child's odds of being completely immunized ($\exp\{\gamma_{04} = -1.73^{*}0.12\} = 0.81$), even after controlling for important individual-level characteristics such as socioeconomic and social background. Thus, even if a child has an educated mother, or comes from a well-off household, or is not a Muslim, just the fact that he/she resides in a predominantly Muslim area increases the child's risk of contacting vaccine-preventable diseases. In fact, almost 80% of the effect is contextual, while 20% is explained by compositional controls. Furthermore, at the individual-level, being Muslim reduces a child's probability of being fully immunized because of the socioeconomic disadvantages faced by them. This might be compounded, but not caused, by a *purdah* society where women's access to outside health services may be limited due to restrictions on their physical mobility (Caldwell, Caldwell, & Barkat-e-Khuda, 2002).[2]

Unlike the contextual Muslim effect, the effect of residing in a disproportionately scheduled tribe district is primarily compositional in origin. The significant relationship from Model 2 ($\gamma_{03} = -1.28$) disappears once individual-level controls are introduced in Model 3 ($\gamma_{03} = -0.84$). In fact, in preliminary analyses not included, the district-level relationship gets washed away by just adding the compositional control for social background, and no other variable. Thus, *belonging* to a scheduled tribe household, rather than *residence* in a disproportionately scheduled tribe area, may result in poor immunization status, which may be indicative of the disadvantages faced by these minority groups at the individual-level.

In the present analysis, completely immunized children live in households with high socioeconomic status, whose parents have completed their matriculation, and where women have physical mobility. Although the first two variables tend to be highly correlated, the persistence of the compositional education effect in Model 3 demonstrates that the context created by female literacy in a district *does not* negate the influence of maternal education on a child's immunization. Therefore, the influence of maternal education cannot be downplayed. However, surprising changes in the significance of regression coefficients in individual-level models (*without* district-level variables; results not included), when introduced into Model 3 of the stepwise models (*with* district-level variables) indicate that the *level* of educational attainment matters. Specifically, the individual-level coefficient for women with primary and secondary school education and a woman's exposure to the mass media, which are highly significant in the individual-level model lose significance when introduced into Model 3, implying that these effects are washed out by district-level contextual characteristics. Thus, mother's access to *higher* education—matriculation and beyond—influences preventive health-seeking behaviors.

Finally, girls, higher birth order infants, Muslim children, and children belonging to scheduled castes and tribes are less likely to be fully immunized. In results not included, individual-level analyses *and* significant constant coefficients for multilevel analyses where the slope for gender was modeled indicate that boys are more likely to be fully immunized than girls, despite arguments to the contrary. Thus, district-level development characteristics such as wealth and availability of healthcare facilities may be offset by other socio-cultural factors, resulting in the persistence of gender differentials in immunization across rural districts in India. Discrimination may be occurring at the household, rather than at the health system level, because families may choose not to return to primary health centers to complete a girl's immunization schedule.

In conclusion, the interesting finding from this study is that a child's immunization status is affected by more than his or her mother's education; it is also influenced by the larger context created and sustained by other women's education.

Conclusions

Despite large resource allocation and mass immunization campaigns, efforts to increase the number of fully immunized children in India have met with limited success, raising concerns about the effectiveness of public health delivery systems. Consequently, policymakers and researchers focus on maternal education as another channel of augmenting the use of preventive healthcare. However, the issue is more complex than that. Departing from previous studies that concentrate on the mother–child dyad and portray mothers as the sole agents of their child's well-being, this study incorporates the *larger* community of educated women in a child's environment. Thus, the strong correlation between women's education and child health in an area can be explained by the fact that even children of

[2]It is imperative *not to* misrepresent the results: rather than focusing on the deficiencies of the public health system, poverty, or lack of education faced by Muslims, public health officers and political parties in power often tend to emphasize their religion, ethnicity, and community practices (Das et al., 2000).

uneducated mothers may have better health due to the *externalities* generated by other women's education. In fact, because the challenges faced by the healthcare delivery system in India are fairly representative of other developing countries, the analysis could be generalized beyond the region itself.

Certain limitations regarding the use of specific variables in this analysis must be addressed. First, the explanatory variable "adult female literacy rate" fails to account for the *quality* and *consistency* of education between various districts. Das et al. (2000) argue that "there is a sharp difference between demand for and acceptance of vaccination between communities which have a thin layer of educated women versus those which may have literate women, but not educated women in the community" (p. 629). Yet, the present analysis demonstrates that even this crude indicator of education performs well in predicting inter-district variations in child immunization.

Secondly, lack of appropriate data precludes the elucidation of the *specific links* by which the relationship between aggregate female literacy and immunization status is maintained. Indeed, several researchers indicate that such effects are difficult to disentangle, although easy to conceptualize (Das et al., 2000; Moursund & Kravdal, 2003; Kravdal, 2004). The exploration of these mechanisms is left to future studies. Finally, while this analysis is restricted to rural districts due to the constraints imposed by the HDPI dataset, child immunization needs to be studied in the context of increasing urbanization, migration, and poverty. The reality is that urban and rural development is linked in complex ways, and we cannot assume that urban poverty is less acute or affects fewer people than rural poverty. Inclusion of data pertaining to urban areas will allow us to examine additional aspects of child health such as stunting or wasting that are more responsive to environmental factors.

The present analysis supports the view that increasing women's overall literacy levels within a community is an effective way of completing children's immunization schedules, especially in environments characterized by apathy and lack of information towards preventive healthcare. On the other hand, the effect of the mother's own educational attainment, especially higher education such as matriculation and beyond, cannot be downplayed. Thus, education at both the individual- *and* the community-level emerge as effective developmental tools, highlighting the need for concurrent social and economic change at various levels (micro and macro) of society (Presser, 1997). This is especially vital in medically pluralistic cultures (e.g., India) where personal identification with the medical system through interactions with educated individuals *or* through own education may make mothers willing to discard fatalistic attitudes, follow instructions, and persist with recommended scientific treatment (Caldwell, 1986). Public health priorities must also shift from an exclusive focus on immunization targets to issues of health education, with information being disseminated through formal education, the mass media, and diverse social networks, associations, and clubs. Could we thus argue that the processes of diffusion and socioeconomic development are complementary and additive, even though they may progress independently?

To conclude, ensuring the well-being of children, the next generation of citizens, is of critical concern for various actors occupying diverse societal levels. This goal can be effectively accomplished by providing education to women and encouraging them to be agents of their own, their children's, and the larger community's health-seeking behavior.

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