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The sanitation environment in urban slums: implications for child health

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Abstract

I examine the effect of improved sanitation on child health in urban Bangladesh to assess the relative importance of household versus neighborhood characteristics and of adult latrine usage versus safe disposal of children's feces. Using fixed-effects regression, I calculate the change in weight-for-height in 153 children as a function of changes in latrine usage in the surrounding community. The use of longitudinal data allows children to act as their own controls, a stumbling point of many other sanitation evaluation studies using cross-sectional or case–control methods. Results provide strong evidence that children's toileting matters more than adult toileting behavior in creating a safe, hygienic environment and reducing diarrheal disease. I conclude that investments in sanitation improvements offer important externalities, and that sanitation programs must encourage the safe disposal of children's feces in order to produce maximum health gains.

Keywords

Sanitation; Bangladesh; Child health; Slums; Program evaluation

Introduction

Inadequate sanitation remains a leading cause of diarrheal disease and mortality among children in developing countries, particularly in urban slums. The Global Burden of Disease Study undertaken by the World Bank (Lopez et al. 2006) indicates that 15% of all the deaths in children under 5 years in low- and middle-income countries are directly attributable to diarrheal disease. Eighty-eight percent of the diarrheal disease burden is caused by unsafe sanitation, water, and hygiene. In 2001, more than one million children in South Asia and Sub-Saharan Africa died of conditions related to unsafe water and sanitation. The Millennium Project Task Force on Water and Sanitation has called the lack of sanitation and water in these regions a “silent humanitarian crisis” (Bartram et al. 2005, p. 810). Reducing diarrheal deaths among young children clearly requires effective, targeted sanitation improvements.

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In this study, I evaluate how improved sanitation affects child nutritional status by limiting exposure to diarrheal pathogens and thereby reducing diarrheal disease burden. Diarrhea is a common and pernicious health problem for children in developing countries. Diarrhea is caused primarily by infectious pathogens (including viruses, bacteria, protozoa, and parasites) that are excreted in the feces of infected humans. This infected fecal matter can then be transported to the digestive tract of other uninfected humans via the hands, water, food, or insects (Curtis et al. 2000). Acute diarrhea causes life-threatening dehydration, while chronic diarrhea can compromise growth and development by preventing the absorption of nutrients. Chronic diarrhea can also increase susceptibility to future illness.

A prominent framework for the determinants of child health (Smith and Haddad 2000; UNICEF 1990) suggests at least two important routes for transmission of diarrhea-related pathogens to young children: the behaviors of the child and caregivers, and the health environment. Child care practices and hygiene behaviors can either facilitate or interrupt fecal–oral transmission routes and several specific hygiene behaviors are hypothesized to be relevant for diarrheal disease risk. Washing hands with soap, dirt, or ash after defecation produces less contamination than washing with water only, although rinsing with contaminated water can recontam-inate hands (Hoque 2003). A comprehensive review of handwashing interventions suggests a reduction in diarrhea risk of 42–47% associated with washing hands with soap, although the reviewers express concerns that poor methodology and publication bias may skew this estimate upwards (Curtis and Cairncross 2003).

While positive hygiene behaviors are important for the reduction of diarrheal pathogen transmission, the availability of sanitation infrastructure is also critical. Adequate sanitation prevents fecal matter from contaminating water supplies and the surroundings in which people live, work, play, and travel each day. Indeed, several studies demonstrate a strong association between improved latrines and reductions in diarrheal disease (Meddings et al. 2004; Moraes et al. 2003; von Schirnding et al. 1991; Young and Briscoe 1988). In their extensive review of diarrheal disease interventions, Zwane and Kremer (2007) note several problems with this literature, however. First, these studies rarely disentangle the effects of sanitation improvements from water supply improvements.[1] Second, the studies suffer from persistent methodological problems stemming from cross-sectional analysis and the lack of proper comparison groups. Specifically, sanitation improvements are often assessed in case–control studies comparing children who present at hospitals or clinics, introducing several potential sources of bias (Daniels et al. 1990; Ekanem et al. 1991). Third, few studies explicitly distinguish between improved sanitation at the household level (e.g., a household installing a new hygienic toilet) and at the community level (e.g., the overall sanitation environment in the surrounding neighborhood). The relative effects of these two measures of sanitation have important policy implications for allocating sanitation investments.

In the current study on the effects of latrine improvements on child health in an urban slum in South Asia, I investigate a neglected issue in the literature on sanitation improvements:

[1]An interesting exception to this is Bennett's (2007) study of the negative effects of water supply improvements on sanitation and hygiene behaviors in Metro Cebu, the Philippines. Bennett argues that water supply improvements reduce the incentives for households and communities to maintain adequate sanitation infrastructure, leading to worsening of hygiene behaviors that have negative health externalities.

how do parents dispose of children's feces, and does this behavior change when new sanitation infrastructure is installed? The safe disposal of children's feces has been identified as critical for children's health, but little is known about actual practices (Ahmed et al. 2004). In general, parents are reluctant to let children younger than 4 or 5 years use latrines on their own for fear that children may fall into the latrine or otherwise be hurt. At the same time, small portable toilets (potties) and diapers are not widely used in most of the developing world, and particularly not in South Asia (Gil et al. 2004). In rural settings, young children are often allowed to defecate in the yard or on land surrounding the household. In urban areas that lack sanitation infrastructure, however, parents may have few options for disposing of children's feces and so may leave them in common alleyways or drainage ditches (Shordt 2006; Yeager et al. 1999). This increases the likelihood that other children may encounter the fecal material during play and be exposed to diarrheal pathogens.

A review of 15 studies that either asked about, or observed, specific disposal behaviors for children's feces found a higher risk of diarrheal disease associated with “risky” disposal (open defecation, no removal of feces from household area) and lower risk of diarrheal disease associated with “safe” disposal (Gil et al. 2004). A detailed qualitative study in a dense informal settlement in Lima, Peru revealed several determinants of disposal behavior, including age of the child, effort required by the disposal method, and availability of resources for safe disposal of feces (e.g., toilets or latrines for shaking out diaper or emptying potties) (Yeager et al. 1999). The Peru study is one of a very few examinations of children's diarrheal disease risk that include direct and detailed observation of household behavior. In this study, I address the challenge of analyzing disposal behavior in the absence of such direct observations by using the differences in reported behavior between households with and without young children to proxy safe disposal.

Sanitation and child health in South Asian squatter settlements

The growth of urban slums has been one of the defining characteristics of the past decades in the developing world. Approximately one billion people live in urban slums, and the slum population is growing by 2.2% per year (UN-HABITAT 2006). Urban slums are characterized by crowding, extreme poverty, lack of land or property tenure, lack of services and infrastructure, and a predominantly informal economy. Because many slum dwellers are recent migrants from rural areas, many of them live without the social networks and kinship ties that can provide emotional, physical, and financial support in times of crisis (UN-HABITAT 2006). Sanitation in urban slums is a particular problem. More than one-quarter of the urban population worldwide has inadequate sanitation; the proportion is much higher for slum dwellers. Inadequate sanitation compels slum residents to use hanging latrines,[2] unhygienic pit latrines, or nearby open spaces, creating significant disease-related hazards (Ahmed 2005; Allan 2003; Hanchett et al. 2003).

[2]The latrine types discussed in the study are (1) a hanging or *katcha* latrine which is usually two boards placed over a sewer, a drainage ditch, or open water. Privacy is provided by flimsy bamboo screens; (2) an unsealed pit latrine that consists of a slab placed over a pit; (3) water-sealed latrines, also called “pour-flush” that are flushed with a bucket of water after each use, and have a u-shaped drain pipe that creates a water seal to prevent odors and flies from coming up from the pit; (4) community toilets that consist of several water-sealed latrines built in “blocks,” often with separate facilities for men and women.

The nutritional status of children in urban slums is often worse than that of rural poor children or urban children in non-slum settings. Poor children in rural areas, particularly in South Asia, typically exhibit high rates of stunting (short stature for age), while wasting (low weight for height) is usually less severe. In urban slums, both wasting and stunting rates are very high and have not improved over time as rapidly as such nutritional-based improvements in poor rural areas (BNSP 2002).

High rates of wasting can be attributed, in part, to frequent bouts of diarrheal disease among slum-dwelling children in South Asia. Recent estimates of the prevalence of having a diarrheal episode in the past 2 weeks range from 14% for children under 5 years in Karachi, Pakistan (D'Souza 1997) to 28% for infants under 1 year in Dhaka (Rahman and Shahidullah 2001). Because of the established link from sanitation to diarrhea to health, there have been many slum upgradation and sanitation initiatives; Bangladesh in particular has made a commitment to improving sanitation. Responding to a decentralized and NGO-driven “100% Sanitation” movement (Allan 2003), in 2005 the Government of Bangladesh outlined a National Sanitation Strategy to achieve this universal coverage by 2010. This is an aggressive goal given that only 33% of the population had access to a hygienic latrine in 2003 (Nurul Alam 2007).

This study is set in Dinajpur, a city of 250,000 residents located in the northwest of Bangladesh, about 400 km from the capital of Dhaka and near the border of West Bengal, India. Like many small- and medium-sized cities in Bangladesh and other poor countries, Dinajpur's annual growth rate is quite high, estimated at 6% for 2002, in contrast to an overall urban growth rate in Bangladesh of 3.5% (United Nations Population Fund 2007). Beginning in 2002, the city was the focus of a partnership between CARE-Bangladesh and the International Food Policy Research Institute. The partnership designed and implemented the SHAHAR[3] community development program, designed to strengthen the food and livelihood security of high-risk urban slum populations in Bangladesh. The main program components were sanitation infrastructure; health, hygiene, and nutrition education; income-generating activities; and community mobilization. The program was implemented in Dinajpur after successful implementation in Jessore and Tongi, two other cities in northwestern Bangladesh (Das Gupta 2003). Specific activities since 2002 have included filling ditches, installing hygienic latrines, and developing local Community Resources Management Committees (IFPRI 2002).

The gaps in the literature on sanitation discussed above and the goals of the SHAHAR project prompt several research questions: (1) Do improved latrines affect children's nutritional status? (2) Are household or neighborhood effects more important to child health —in other words, is the toileting behavior of the child's own household or neighboring households a stronger determinant of nutritional status? (3) Is it possible to disaggregate the health effects of new latrines into changes in adult latrine usage and changes in disposal of children's feces in order to identify the most effective behavioral inventions? (4) Are the health effects of sanitation conditioned by household characteristics such as food security or hygiene? Insight into these questions will contribute to the efficient allocation of limited

[3]SHAHAR is an acronym for Supporting Households Activities for Hygiene, Assets and Revenue.

resources for infrastructure investment as well as improve the design and evaluation of hygiene behavior interventions in slum settings. The study also demonstrates the ability to conduct impact evaluations using limited household survey data without detailed behavioral observations.

Methods

Sample

The data for this study come from the SHAHAR Dinajpur Survey, fielded in 2002–2003 by CARE-Bangladesh and the International Food Policy Research Institute (IFPRI) as a monitoring and evaluation tool designed to provide baseline and follow-up data on project communities and participants (Das Gupta 2003). The sampling frame included all 59 *bastis* (distinct slum communities) in Dinajpur. *Bastis* were assigned a vulnerability score based on observed levels of poverty, social cohesion, community size, and environmental hazards. Fourteen *bastis* were chosen for program intervention based on high vulnerability scores. From a complete census of these 14 *bastis*, a simple random sample of 614 households was selected for interviewing. The sample was not stratified by *basti* and does not require weighting. The sample size was chosen to allow for identification of statistically significant changes in child stunting. Because *bastis*, were selected for high vulnerability scores, the sample is representative of the poorest slum communities in Dinajpur and, as such, the results may be generalizable only to similarly vulnerable slum communities in South Asia.

From the initial sample of 614 households, enumerators successfully contacted and interviewed 583 households (95%) for the baseline survey in August 2002. A second round was fielded in March 2003, and 567 households were successfully interviewed (92% of the original sample, 97% of the 2002 interviews). The second round of data is not used in this analysis to avoid seasonal effects on children's weight. The final survey round took place in August 2003, with 554 households (90% of the original sample, 95% of the 2002 interviews) successfully interviewed. In each community, local informants also provided information on *basti* demographics, infrastructure, and social services availability.

The household sample includes 200 children aged 0–35 months at the time of the first survey in August 2002, 153 of whom have complete data for both survey rounds. An additional 36 children with data for one round only and 11 children without complete anthropometry or maternal or household data are omitted from the analysis. The analytic sample therefore includes 306 observations of 153 children (one observation in August, 2002 and one in August, 2003). Attrition analysis indicates that dropping out of the sample by 2003 is not associated with the health status of the child in 2002 nor with any maternal or household characteristics. In addition, there are no significant differences by *basti* in the probability of attrition from the sample by 2003.

Measures

The focal dependent variable is child nutritional status. I operationalize nutritional status as child weight-for-height, which captures short-term changes in food intake and disease status and responds quickly to changes in the environment, in care behaviors, or in household food security. A decline in weight-for-height can be caused by a severe bout of illness (particularly diarrheal disease), a short-term reduction in food intake, or both (Gibson 1990).

Weight-for-height is calculated by dividing the child's weight in kilograms by height (or length for children under 24-months old) in centimeters as measured by enumerators during the survey. I standardize the weight-for-height into *z*-scores using the widely-used CDC 2000 Growth Charts as the reference population (Kuczmarski et al. 2002). The weight-for-height *z*-score (WHZ) indicates the number of standard deviations away from the median of the reference population. The WHO defines a child with a WHZ of less than −2.0 as wasted (WHO Expert Committee on Physical Status 1995). Unlike height-for-age, which captures long-term and accumulated effects of dietary intake and disease status, as noted, weight-for-height instead captures more recent, short-term nutritional or disease insults, and is particularly appropriate for this study.

The focal independent variable, measured in both survey rounds, is the use of an improved latrine—with both household- and community-level indicators included. In the 2002 survey, the female head of household was given four choices to report the household's latrine usage: open space or field, a hanging or *katcha* latrine, a pit latrine (unsealed), or a water-sealed latrine. By 2003, two additional choices were provided due to the construction of new latrines by the SHAHAR project: community toilets, and unsealed but hygienic latrines. Based on discussions with the IFPRI staff and a review of other sources on latrine improvements in South Asia (Ahmed 2005; WHO/UNICEF 2008), I categorize each latrine type into “improved” (water-sealed, unsealed but hygienic, and community) or “unimproved” (unsealed/unhygienic, *hanging/katcha* latrine, and open space or field)[4]. Figure 1 summarizes the change in the proportion of households using improved latrines in 2002 and 2003 by *basti* community. Use of improved latrines increased substantially, from 35% in 2002 to 61% in 2003. There is considerable heterogeneity by neighborhood, however, with increases ranging from 13 to 57 percentage points. Large increases in improved latrine use can be attributed primarily to the installation of community toilets in some *bastis*. Unfortunately, there are no data available on the targeting or allocation process for new community toilets. I address this shortcoming below.

I construct several measures of improved latrine use reflecting both household use and community averages. The first is the female head of household's report of the type of latrine used by the household. The second is the number of available latrines per household as reported in the community survey. The third measure is the proportion of all households in the *basti* using improved latrines. To sidestep issues of correlation, I calculate this community-level measure for each household as a non-self mean, meaning that the household's own latrine use is not included in the numerator and the household is not counted in the denominator. To address the issue of the disposal of child versus adult feces, I calculate two additional proportions of latrine use at the community level: one for households with one or more children under 4 years (to proxy caregiver disposal behavior), and one for households with no children under 4 years (to proxy adult behavior). Again,

[4]Alternative categorization schemes for latrines are discussed below.

these are non-self means. All five measures of latrine use are calculated for both 2002 and 2003. Descriptive statistics for these measures are provided in Table 1.

There are three control variables included in the analysis that may also determine children's short-term nutritional status according to the child health framework discussed above: household food security, the mother's handwashing behavior, and whether the child is breastfed. In the absence of any standard food security measures, I consider a household to be food secure if the female respondent reports that no adult females skipped meals in the past seven days due to lack of food. The handwashing measure is dichotomized from a list of self-reported maternal handwashing behaviors including the use of soap, ash, dirt, water only, and other. Following other studies of child care practices using this dataset, I code use of soap or ash “1” to reflect adequate handwashing and all other choices “0” (Ahmed 2005; Garrett and Naher 2004). Current breastfeeding status, reported by the mother, is a dichotomous measure. Breastfeeding is an important source of calories, micronutrients, and immunity for infants and young children (Smith and Haddad 2000).

I do not include the household's usual source of water in this analysis. One hundred percent of the households in the SHAHAR sample reported using tubewell water, a safe source in this setting.[5] This universal access to safe water allows the analysis to focus specifically on sanitation as a determinant of child health.

Analytic approach

The analytic approach is driven by the third research question identified above— namely, how to compare the health effects of adults' use of improved latrines to the safe disposal of children's feces (e.g., through a caregiver's use of the latrines for disposal of children's fecal matter collected in and around the home). At the household level, I am not able to make this comparison, as the female head of household reports only the overall latrine usage for the entire household (not for individual members). However, I can exploit the fact that the full Dinajpur sample includes households with and without young children. The latrine usage of households in the surrounding area that have no children under 4 years proxies adult behavior. Latrine usage among households with at least one child under 4 years proxies the safe disposal of children's feces. I test this assumption with several additional analyses below and discuss limitations to this analytic approach.

Because the study evaluates the effects of a change from unimproved to improved latrines on children's health, there are obvious concerns about nonrandom program placement and selection bias in the adoption of new hygienic latrines. If communities that received new latrines were worse off than communities that did not receive latrines, then children in receiving communities may already exhibit worse nutritional status than children in communities without new latrines. This placement rule would underestimate the effect of latrines on nutritional status. Conversely, if communities received new latrines as a result of bargaining power, social capital, or community efficacy, these communities might also be able to command resources in support of child health, biasing effects of the new latrines

[5]Water drawn from tubewells in Bangladesh commonly contains toxic levels of arsenic. The SHAHAR project identified and marked standpipes with unsafe levels of arsenic to discourage use.

upward. At the level of the household, families that chose to use new latrines once available might also be the same households that were motivated to protect children's health; or, households most concerned about child health because of limited resources (e.g., food, a healthy environment) might be the most motivated to use new latrines.

To control for both nonrandom program placement of latrines in communities and selection bias in the use of available latrines, I employ an individual fixed-effects model. The fixed-effects model estimates the change in a child's WHZ as a function of change in latrine usage, time, and other control variables. Formally, the equation for this model is:

$$\mathrm{WHZ}_{it}=\alpha+\beta_1\,\mathrm{LAT}_{it}+\beta_2\,\mathrm{X}_{it}+\gamma Z_i+\delta\,\mathrm{TIME}_t+\varepsilon_i+\mu_{it},\,\mathrm{TIME}=0,1$$

The outcome of interest is child weight-for-height, standardized to a *z*-score (WHZ), measured for child *i* in time *t*. LAT captures the household's experience of latrine usage in one of the four measures described above. X is a vector of time-varying observed characteristics of the households that I expect to affect weight-for-height, including food security, handwashing, and breastfeeding. Z is a vector of time-invariant observed characteristics of the child and household (note no time subscript) including gender, household occupation, and parental education. Parameters to be estimated include α, β_1, β_2, γ, and δ. TIME is a dummy variable that equals zero when *t* = 0 and one when *t* = 1. Therefore, δ estimates the secular change in WHZ from period 0 to period 1. The error terms ε_i and μ_{it} capture time-invariant and time-varying error (including unobserved heterogeneity), respectively. To estimate the equation with the panel data, I subtract the equation for time *t* = 0 from the equation for time *t* = 1 and rearrange terms, leaving:

$$\Delta\mathrm{WHZ}_{it}=\Delta\beta_1\,\mathrm{LAT}_i+\Delta\beta 2X_i+\delta\,\mathrm{TIME}+\mu_i$$

Fixed-effects formulations are useful in program evaluations because they can control not only for selection bias into programs but also for nonrandom program placement at the community level (Frankenberg and Thomas 2001; Gertler and Molyneaux 1994). The fixed-effects approach is computationally equivalent to adding a dummy variable for each child in the analysis, and guarantees that any observed or unobserved characteristics of children, households, or communities that may have determined the placement and use of latrines and that did not change from 2002 to 2003 will not bias the estimates of the coefficients of the covariates (Wooldridge 2003). The appropriateness of the fixed-effects specification is tested via a Hausman test, with p-values reported in the tables.[6]

Using this fixed-effects approach, I estimate a series of eight models of the change in child WHZ from 2002 to 2003. To answer my first and second research questions (are latrine

[6]The individual fixed-effects specification does not correct for clustering at the community level. While this could ordinarily be addressed through a standard Huber-White correction, this is not an accurate correction when the number of clusters is small, as it is here with only 14 *bastis*. Following Cameron et al. (2007), I re-estimate all the models presented here with bootstrapped standard errors using 500 replications. Bootstrapped standard errors (not shown) are very close to the standard errors presented in Tables 2, 3, 4.

improvements associated with child health, and do household or neighborhood effects matter more), I test three measures of latrine usage described above singly: the household's use of an improved latrine, the availability of latrines in the community, and the proportion of households in the community using improved latrines (Models 1, 2, and 3 in results below). My third research question on the differences between safe disposal of children's feces and adult latrine usage is answered in three models (Models 4, 5, and 6) using two distinct measures of latrine usage: proportion of households using improved latrines among households with children under 4 years, and then among households without children under 4 years. Model 6 explicitly tests for different effects of latrine usage among households with and without young children by including them both in the same model. Finally, I evaluate the fourth research question on effect modifiers by testing for interactions between level of improved latrine usage in the community and two household characteristics—the household's own latrine usage (Model 7) and household food security (Model 8)—to see if the community effects depend on household behavior or socioeconomic status.

All models control for two other determinants of child WHZ that may have also changed as a result of the SHAHAR program: household food security and mother's handwashing behavior. To control for age-related declines in WHZ in this population, I also include the child's breastfeeding status, a dummy variable for the 2003 survey round, and the interaction of 2003 survey round and the child's age in months in 2002 in order to account for the age pattern of wasting in the fixed-effects model.

Results

Descriptive statistics by year of survey for the sample of 306 observations are presented in Table 1. Note that the sample ages twelve months from 2002 to 2003. Several variables reflect this aging process in predictable ways: mean WHZ declines slightly from −1.37 to −1.55 and breastfeeding prevalence declines. There is a steep increase at the household level in the use of improved latrines (from 33 to 59%) among these households. Effective handwashing and household food security also increase, most likely as a result of the SHAHAR program interventions.

The fixed-effects models shown in Table 2 assess the effect of changes in latrine availability and use on child WHZ. Model 1 tests the effects of a change from unimproved to improved latrine use at the household level. This measure has no significant effect on the change in child WHZ—suggesting that the household's toileting behavior does not generally matter for child health. Results for Model 2, in which latrine usage is measured by available latrines per household in the *basti*, are also not significant, suggesting that merely installing new latrines in the neighborhood is not sufficient to bring about improvements in child health.

In the third column, Model 3 includes the (non-self) percentage of all sampled households in the child's community (*basti*) that use improved latrines. Each percentage point increase is associated with an increase in WHZ of 0.013 standard deviations. For example, a child living in a community where the percentage of households using improved latrines increased from 35% to 60% over the course of the survey year (typical for neighborhoods in this sample) would experience an increase in WHZ of 25 percentage points × 0.013 = 0.325

standard deviations, net of the age-related secular decline and changes in food security, breastfeeding, and handwashing. This effect is larger than the weight gain attributed to an increase in household food security (0.254 standard deviations in WHZ).

Recall that Models 1–3 cannot distinguish between the disposal of children's feces versus adult use of improved latrines, as the sanitation measures simply capture the change of some or all household members from using an unimproved latrine type to an improved type. Turning to my third research question, I next focus specifically on the role of improved latrine usage just among households in the community with children under 4 years (37% of all surveyed households in both years have at least one child under 4 years old.) Results from this model are shown in Table 3, Model 4. The neighborhood effect (0.011) remains strong and significant, and of comparable magnitude to the latrine usage coefficient in Model 3. In Model 5, I replace the variable capturing latrine usage among households with young children with the variable representing latrine usage among the households with no young children. There is no significant relationship. Although the correlation between these two variables is large enough (0.687) to warrant collinearity concerns, in Model 6 I put both variables in the analysis and test the equivalence in the coefficients, which is rejected.

Taken together, Models 4, 5, and 6 present the key finding of the study: *latrine usage among neighboring households with young children is a strong predictor of an individual child's WHZ*; at the same time, latrine usage among households without young children makes no significant difference. A consistent explanation for this finding is that households with young children are changing how they dispose of the children's feces due to new sanitation infrastructure in the *basti*, and thereby reducing the exposure of other children to contaminated fecal matter.

These results can be used to calculate the predicted weight increases associated with sanitation improvements. Taking results from Model 4 in Table 3, I compare the weight of a 24-month-old girl at the fifth percentile of height-for-age (80 cm.) in 2003 living in *bastis* with different levels of improvements in community latrine usage among households with children under 4 years. The comparison is displayed in Fig. 2. With no improvement, there is no associated weight gain above the baseline weight of 9.37 kg. For the typical *basti* in the study, the proportion of households using improved latrines increases by about 25 percentage points from 2002 to 2003, resulting in a predicted marginal weight gain of $0.011 \times 25 = 0.275$ standard deviations in weight-for-height, or 0.207 kg, shown in the middle bar of the figure. The largest community-level gains in improved latrine usage approach 60 percentage points, or $0.011 \times 60 = 0.660$ standard deviations in weight-for-height, or 1.89 kg, shown in the right-hand bar of the figure. Given that the largest increases in improved latrine usage occurred in the *bastis* with lowest baseline prevalence, it is clear that the weight gains associated with improved sanitation are particularly important for children in the most disadvantaged communities in the study.

To address my fourth research question on potential moderators of the effects of sanitation, I examine interactions between household characteristics and the sanitation environment to determine which children benefit most from sanitation improvements. First, I test whether the large effects of community-level latrine usage on child weight-for-height depend on the latrine usage of the child's own household. It may be that changes in neighborhood levels of latrine usage are most beneficial for a child whose own household does not use an improved latrine. Conversely, the gains in health associated with changes in community latrine usage may only accrue to children in households where adults already use improved latrines. Model 7 in Table 4 presents results from a fixed-effects specification testing these competing hypotheses. I include the household's own latrine usage as well as the community-level measure, and the interaction between the two. Neither the zero-order term for household' 's own latrine use nor the interaction terms is significant, which has two important implications. First, the non-significant main effect of the household's own latrine usage (consistent with similar results in Model 1) suggests children are less susceptible to diarrheal pathogens generated by members of their own household. The non-significant interaction term indicates that the effects of community-level latrine usage on child weight do not depend on household's behaviors—for example, a child can benefit from community-level increases in improved sanitation use whether or not the child's own household uses an improved sanitation option.

Other household characteristics may also moderate the effect of community-level latrine usage on nutritional status. Improvements in community levels of latrine usage may be more important in households that are food insecure, for children who are not breastfeeding, or for children whose mothers do not practice thorough handwashing. All the three of these interactions were tested, both individually and in a full model. In all the cases, the only household characteristic that significantly moderated the neighborhood latrine usage effect was food security. Results from a model that includes only this interaction are shown as Model 8 in Table 4. Food security status attenuates the community effect by 0.013 standard deviations in WHZ for each percentage point increase in community prevalence of improved latrine usage. This suggests that the health effects of improved latrines are greater for children in food insecure households relative to those in food secure households.

Additional analyses

Additional analyses are undertaken to test the robustness of results to alternative explanations and to test underlying assumptions of the analytic approach. First, I attempt to confirm that observed improvements in children's WHZs are directly related to decreases in diarrheal disease prevalence by adding a measure of diarrheal disease (mother reporting that the child had diarrheal episode with in 15 days prior to interview) to Model 4 from Table 3 (results not shown). The coefficient on the diarrheal disease measure is not significant and does not attenuate the effect of latrine usage on child weight-for-height. I attribute this finding to the somewhat crude measure of diarrheal disease and lack of statistical power due to small sample size.

For a more direct test of the association between latrine usages on diarrhea, I also model the odds of having a diarrheal disease episode in the previous 15 days as a function of latrine usage among households in the community with children under 5 years. A fixed-effects specification is difficult here because the model would be estimated on only 48 observations for 24 children: 18 children who report diarrhea in 2002 but not in 2003, and 6 who report the opposite. Instead, I estimate a logistic regression on a pooled sample of 344 observations (including children who do not appear in both survey rounds), controlling for breastfeeding, handwashing, household food security, age, gender, survey round, and the interaction between survey round and latrine usage. I also adjust standard errors for clustered observations at the child level. Results (not shown) suggest that each percentage point increase in improved latrine usage in households with young children is associated with a reduction in the odds of diarrhea of 3%, a marginally significant finding in this pooled cross-sectional analysis. This provides at least weak evidence for the hypothesis that changes in latrine usage improve children's nutritional status by reducing diarrheal disease incidence. The interaction of latrine use and survey round is not significant, suggesting that the association of latrine usage with child health is not due to some other aspect of the SHAHAR program intervention that unfolded between 2002 and 2003.

A second set of additional analyses addresses the limitations of the fixed-effects specification. While fixed-effects models offer substantial benefits in terms of controlling selection bias, they rely heavily on the assumption that all unobserved characteristics of children, households, and *bastis* that are associated with nutritional status and with latrine usage are fixed between the two survey rounds. This raises two concerns. First, it could be the case that features of the SHAHAR program other than new latrines led to health and nutrition improvements in the sampled children, or that some other unobserved event changed the behavior of households with young children that was related to their health but not to latrine usage. I examine this possibility in three ways. First, the analyses shown above in Tables 2, 3, 4 include two household measures that should capture some of the other improvements related to SHAHAR: the household food security status and the mother's handwashing behavior. The inclusion of these measures does not attenuate the effects of community-level latrine usage.

I next employ a more general community-level measure: whether the community respondent reported that the community had come together to build something or start a new program in the previous year. A change in this variable from 2002 to 2003 might indicate an overall increase in activity, resources, or social efficacy that could improve child health independently of the latrine effect. This variable is not significant in any specification (results not shown), consistent with the explanation that sanitation improvements were responsible for increased WHZ. Finally, I estimate the use of an improved latrine at the household level as a function of latrine availability, the presence of young children, and the interaction of availability and presence of young children. Results (not shown) suggest that latrine availability is associated with improved latrine use more strongly for households with young children than for households without young children, which supports the findings presented above and reduces the possibility that an unobserved event has changed household behavior.

A second concern with the fixed-effects specification rests in the fact that the sample ages between the first and second survey rounds. It may be the case that the fixed characteristics that are removed from the model have an age-specific component that may be correlated with latrine use. To investigate this, I estimate three different models similar to Models 1, 4, and 5 discussed above, stratified by age group (ages 0–11 months, 12–23 months, and 24–35 months) and employing a community fixed effect. Results (not shown) suggest that the community-level latrine measure based on households with children under 4 years still has the strongest relationship to child weight-for-height, but this association is the strongest and most the significant for the children aged 12–23 months. This age group is the most vulnerable to poor nutrition during weaning and may also be most exposed to pathogens in the transition from crawling to walking. These results identify the caregivers of toddlers as a particularly important target for hygiene education efforts.

Weight-for-height is, of course, not the only measure of children's nutritional status. Height-for-age and weight-for-age are also commonly used. Height-for-age (HAZ), discussed above, is considered a measure of longer-term nutritional status, reflecting nutritional inputs and illness over the course of infancy and early childhood. Weight-for-age is a less precise measure that incorporates both WHZ (a short-term measure) and HAZ (a long-term measure). While my interest in this study was on the short-term effects of improved sanitation, similar analyses to those described above are also conducted for HAZ and WAZ (results not shown). There appears to be a marginally significant negative association between community latrine improvements and children's HAZ, a result which is attenuated for children in households that improved their food security between 2002 and 2003. This somewhat counterintuitive result may reflect the fact that latrine improvements tended to be greatest in the most deprived communities, which may have housed children whose age-related growth faltering (as measured by HAZ) could not be reversed over the one-year period of the survey. Results for WAZ are not significant in any models.

A potential concern with the analysis is the four-year-old cutoff for households with and without "young" children. Recall that this cutoff is used in order to create a proxy for the disposal of young children's feces by caregivers. If the same results are found when the cutoff is much higher, i.e., at an age when children are likely to be using latrines on their own, this would suggest that the measure is not a good proxy. Analyses are therefore repeated with the cutoff changed to households with children under 5 years old and then to households with children under 10 years (results not shown). Results for models using the five-year-old cutoff were very similar to results presented above. Results for models using the ten-year-old cutoff were directionally similar but much attenuated and only marginally significant, providing some evidence that the four-year-old cutoff is proxying, at least to some extent, a behavior such as disposal of young children's feces that is unique to that set of households.

A final set of additional analyses addresses the sensitivity of results to the classification of different latrine types as "improved" versus "unimproved". Analyses shown in Tables 2–4 are repeated for several other possible classifications of latrines (results not shown). Most importantly, I address the common argument that only a reduction in open defecation makes a difference for child health. To do this I include only "open defecation" in the "unimproved latrine" category. I also test a similar hypothesis by including only hanging latrines and open defecation in the unimproved category. In both of these scenarios, the community-level measure of hygienic latrine usage is not significant, suggesting that reducing the level of open defecation or hanging latrine usage in the community is not sufficient to improve children's health. These results are consistent with the fact that there is still considerable variation in the hygiene level of the "improved" latrine options across these two scenarios.

For example, the categorizations in these two scenarios would not capture the health effects of a change from an unsealed pit latrine to another form of hygienic latrine. Unsealed pit latrines often have minimal insect and odor control and may have unstable or unsafe slabs. It is reasonable to conclude that both adult toileting and child feces disposal behavior could change if unsealed pit latrines were replaced by more hygienic options.

I next employ three additional latrine categorizations that reflect the specific shifts away from hanging and unsealed pit latrines and towards community and unsealed but hygienic latrines observed in the data. Significant results could indicate that the broader SHAHAR project components (rather than latrine usage changes) were responsible for changes in children's health. In general, coefficients on community latrine use in these additional models are significant only when interactions with food security or handwashing status are included.

The negative interaction terms suggest that any benefits from the more general SHAHAR project efforts proxied by this community latrine measure accrued specifically to children in food insecure households or children of mothers with poor hygiene behaviors. I maintain that the latrine categorization used in the analysis is the correct categorization, due both to its consistency with recognized definitions of improved sanitation, and its ability to test the specific hypothesis I am interested in, namely that the available sanitation options in a neighborhood may change the behavior of adults responsible for the disposal of children's fecal matter.

Discussion

This study reveals that increases in the proportion of households in the surrounding *basti* that use an improved latrine are associated with improvements in child weight-for-height, an important measure of short-term nutritional status. Notably, the effect remains strong and significant if the community-level measure covers only households with children under 4 years, but disappears if the community-level measure includes only households with no young children. This novel finding provides strong evidence that children's toileting matters most to realizing health gains from sanitation investments. The use of longitudinal data allows children to act as their own controls, a stumbling point of many other evaluation studies using cross-sectional or case–control methods.

These results confirm previous findings on sanitation improvements and health: first, that it is the safe disposal of children's feces that provides the greatest health benefit (Ezzati et al. 2005; Shordt 2006; Yeager et al. 1999). A second finding confirmed here is that sanitation improvements are likely to make the greatest impact in crowded urban areas where fecal matter can easily contaminate residential areas (Esrey 1996; Ezzati et al. 2005). This study extends previous research by quantifying the differential impact on the health of adult toileting behavior versus the excreta disposal behavior of households with young children.

The Dinajpur case also demonstrates that public, shared sanitation facilities can be acceptable and may lead to substantial improvements in children's health. This contradicts the prevailing opinion in sanitation studies that communal latrines cannot be considered an improved or sanitary option (Cairncross and Valdamis 2006). Results presented here suggest that the financing of sanitation improvements, whether through public investment or private entrepreneurship, could be an important component of urban slum development (Shordt 2006). A case study in India demonstrated that latrine installations financed through micro-loans can improve health and household income (aUNDP-World Bank South Asia Water & Sanitation Program 1999a). A similar initiative demonstrated that individual slum residents were willing to build their own toilets once sewer lines were built under streets (bUNDP-World Bank South Asia Water & Sanitation Program 1999b). Other studies report successful operation of public pay-for-use toilets and sanitation blocks in South Asia urban slums (Srinivas et al. 2003; Water & Sanitation Program 1998), though these facilities can present maintenance challenges (Water for Asian Cities Programme (India), & Directorate of Urban Administration & Development (Government of Madhya Pradesh) 2006).

A limitation of the study is the lack of data on how community latrines were allocated to *bastis*, for example, whether *bastis* had to compete for a limited number of installations or whether latrine blocks were allocated to the most vulnerable communities first. There is also no information on latrine maintenance over time, and the survey permits identification only of short-term changes in nutritional status of children. Though the gains are impressive, it is impossible to know whether these results will persist. The fact that the sampling frame included only the most vulnerable *bastis* in Dinajpur may limit the applicability of the findings to other settings. As discussed above, the available data on diarrheal disease prevalence was not detailed enough to directly evaluate diarrhea as the mechanism linking sanitation improvements to weight gains. Finally, it is possible that observed improvements in weight-for-height are related to unobserved changes in households or neighborhoods, although I have attempted to rule out as many alternative explanations as possible.

The results on the importance of community-level sanitation measures highlight other analyses that could be fruitful here. First, spatial analysis that pinpoints the location of new community toilets and shows which houses within each *basti* changed latrine usage could provide additional insight into the specific mechanisms through which sanitation improvements work. Spatial analyses of cholera and diarrheal risk in Matlab, Bangladesh suggest that this approach can effectively incorporate multiple types of data and can also improve the applicability of results to other areas with different risk profiles (Ali et al. 2002; Emch 1999). Spatial analysis could also confirm whether the latrine usage of households in the same *basti* with young children is simply a proxy for the latrine usage of *nearby* households, regardless of the presence of young children and the safe or unsafe disposal of feces. This could be a concern if households with small children are spatially clustered within neighborhoods, a finding that is not evident in qualitative work on Bangladesh slum life. In addition, if the behavior of close neighbors is more important than the behavior of neighbors further away, then we might expect to find that the toileting behavior of the child's own household also determines child health, which is not the case here.

Approximately one billion people live in urban slums, and the slum population is growing by 2.2% per year (UN-HABITAT 2006). While more than one-quarter of the urban population worldwide has inadequate sanitation access, the proportion is much higher for slum dwellers. The Millennium Development Goal (MDG)— Target 10 calls for halving the number of people without access to safe water and basic sanitation by 2015. The United Nations declared 2008 the International Year of Sanitation in recognition of the importance on MDG Target 10 and to draw attention to the level of investment needed to meet the goal —up to $30 billion annually (Toubkiss 2006). Because current funding falls well below that level, the investments that are made must be as effective as possible.

Findings from this present study emphasize first and foremost that sanitation improvements offer positive health externalities. It also appears that the building of new sanitation infrastructure alone is not sufficient to bring about improvements in health—rather, the ways in which sanitation is adopted within households and across communities is critical. Where adequate improved latrines already exist, changing behavior may be an effective means of improving health without significant bricks-and-mortar investment. In addition, I conclude that latrine improvements projects that do not change the disposal practice for children's feces do not ensure improvements in children' 's health. Sanitation upgrades are also ineffective in improving child health when implemented in dispersed households, but more effective when implemented in neighborhood clusters. A key message from this study is that the environment versus behavior dichotomy is a false one. In Dinajpur's *basti* setting, a child's “environment,” at least in terms of diarrheal pathogen exposure, is largely shaped by the behavior of other children and adults in surrounding households. This implies that behavioral interventions (supported in part by social pressures) may be as important in determining the health environment as the placement of services or investment in infrastructure.

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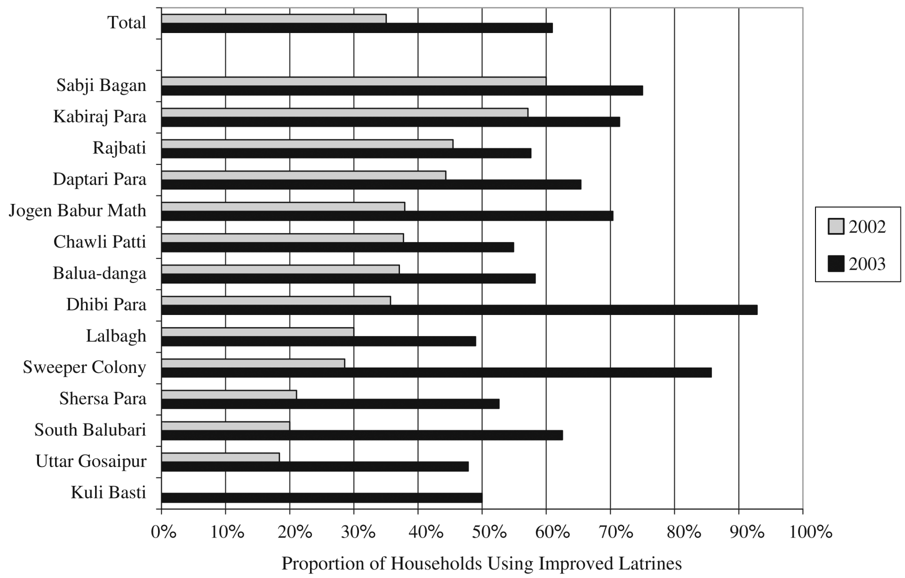

Fig. 1. Proportion of households using improved latrines by *basti* (slum neighborhood), Dinajpur, Bangladesh, 2002–2003

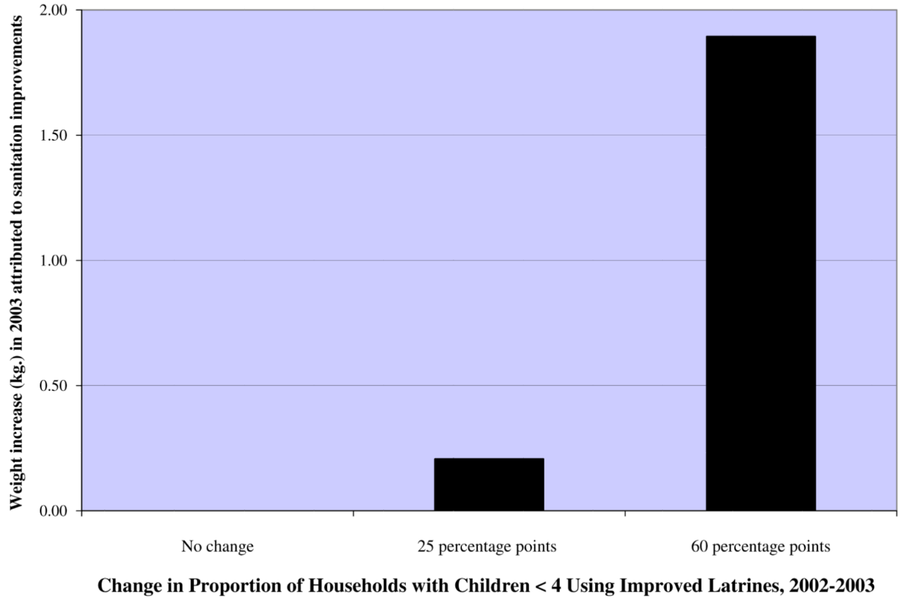

Fig. 2.

Predicted increase in weight (in kilograms) in 2003 attributed to community sanitation improvements for a 24-month old girl, 80-cm tall, by percentage point increase in improved latrine usage among households in same *basti* (slum neighborhood) with children under 4 years, Dinajpur, Bangladesh. *Note*: Increase in weight in 2003 was calculated by multiplying the coefficient on community-level latrine usage from Model 4, Table 3 (0.011) by the percentage point increase in community-level improved latrine usage from 2002 to 2003 (0, 25, or 60). The resulting change in WHZ was added to the starting WHZ of −1.645 for a 24-month old girl who was 80-cm. tall in 2003. The new weight was then calculated using the NCHS 2000 weight-for-height charts (Kuczmarski et al. 2002)

Table 1

Selected child, household, and community characteristics: SHAHAR-Dinajpur Survey, Dinaj-pur, Bangladesh 2002–2003

Characteristic	2002 Mean (SD) or proportion	2003 Mean (SD) or proportion
Child characteristics[a]		
Age in months	18.54 (9.93)	30.97 (9.86)
WHZ	−1.37 (1.16)	−1.55 (1.05)
Child is breastfed	0.88	0.63
Household characteristics		
Household uses improved latrine[b]	0.33	0.59
Household is food secure[c]	0.67	0.73
Adult female washes hands with soap/ash after defecation	0.83	0.95
Community characteristics		
Available latrines per household	0.26 (0.26)	0.37 (0.17)
Improved latrine usage, all households in *basti*[d]	0.34	0.60
Improved latrine usage, households in *basti* with children <4 years old[d]	0.31	0.58
Improved latrine usage, households in *basti* with no children <4 years old[d]	0.33	0.61
Community organized to secure resources or build infrastructure in last year	0.39	0.50
N	153	153

[a]Children were aged 0-35 months at the time of the first survey round in 2002

[b]Improved latrine categories include water-sealed, unsealed but hygienic, and community latrines. Unimproved latrine categories include unsealed, pit, *hanging/katcha*, and open space/field

[c]Food security is measured by a negative response to the question, “Did any adult women forgo meals in the past 7 days due to lack of food?”

[d]These measures are calculated as non-self means, meaning that the child's own household is not included in the calculation

Table 2

Coefficients for determinants of child weight-for-height *z*-score from individual fixed-effects models, Dinajpur, Bangladesh, 2002–2003

	Model 1	Model 2	Model 3
Health environment			
Household uses improved latrine	0.132 (1.07)		
Available latrines per household in community		0.060 (0.20)	
Community mean of improved latrine use			0.013 (2.00)**
Household food security			
Household is food secure	0.254 (1.77)*	0.252 (1.72)*	0.254 (1.79)*
Care variables			
Mother washes hands with soap or ash	0.309 (1.56)	0.321 (1.62)	0.375 (1.90)*
Child is breastfed	−0.153 (0.93)	−0.159 (0.96)	−0.164 (1.01)
Survey round = 2003	−1.287 (5.27)***	−1.287 (5.18)***	−1.613 (5.49)***
Survey round = 2003 × child age in months in 2002	0.032 (4.06)***	0.033 (4.17)***	0.032 (4.15)***
Constant	−1.709 (6.16)***	−1.685 (5.94)***	−2.15 (5.92)***
Number of observations	306	306	306
Number of children	153	153	153
Model R-squared	0.21	0.23	0.23
p-Value, Hausman specification test	<0.005	0.01	0.01

*Significant at $p \leq 10\%$;

** $p \leq 5\%$;

*** $p \leq 1\%$.

Absolute value of t-statistics in parentheses

Table 3

Coefficients for determinants of child weight-for-height *z*-score from individual fixed-effects models, Dinajpur, Bangladesh, 2002–2003

	Model 4	Model 5	Model 6
Health environment			
Household uses improved latrine			
Community mean of improved latrine use			
Households with children <4	0.011 (2.25)**		0.011 (2.06)**
Households with no children <4		0.005 (0.94)	0.002 (0.35)
Household food security			
Household is food secure	0.251 (1.77)*	0.258 (1.79)*	0.251 (1.77)**
Care variables			
Mother washes hands with soap or ash	0.374 (1.90)*	0.341 (1.72)*	0.379 (1.92)*
Child is breastfed	−0.133 (0.82)	−0.165 (1.01)	−0.137 (0.84)
Survey round = 2003	−1.582 (5.73)***	−1.427 (4.91)***	−1.626(5.36)***
Survey round = 2003 × child age in months in 2002	0.032 (4.23)***	0.032 (4.14)***	0.032 (4.20)***
Constant	−2.075 (6.39)***	−1.861 (5.49)***	−2.128***
Number of observations	306	306	306
Number of children	153	153	153
R-squared	0.23	0.21	0.23
p-Value, Hausman specification test	0.01	0.01	0.02

*Significant at $p \leq 10\%$;

** $p \leq 5\%$;

*** $p \leq 1\%$.

Absolute value of t statistics in parentheses

Table 4

Coefficients for determinants of child weight-for-height *z*-score from individual fixed-effects models, Dinajpur, Bangladesh, 2002–2003

	Model 7	Model 8
Health environment		
Household uses improved latrine	0.217 (0.85)	
Community mean of improved latrine use		
Households with children <4	0.012 (2.23)**	0.020 (3.21)***
Household food security		
Household is food secure	0.240 (1.68)*	0.784 (2.92)***
Care variables		
Mother washes hands with soap or ash	0.362 (1.84)*	0.311 (1.59)
Child is breastfed	−0.130(0.80)	−0.201 (1.24)
Survey round = 2003	−1.597 (5.76)***	−1.530(5.60)***
Survey round = 2003 × child age in months in 2002	0.031 (4.06)***	0.031 (4.02)***
Interactions		
Community latrine use × Household uses improve latrine	−0.001 (0.30)	
Community latrine use × Household is food secure		−.013 (2.29)**
Constant	−2.150(6.37)***	−2.314 (6.87)***
Number of observations	306	306
Number of children	153	153
R-squared	0.24	0.26
p-Value, Hausman specification test	0.01	0.02

* Significant at $p \leq 10\%$;

** $p \leq 5\%$;

*** $p \leq 1\%$.

Absolute value of t statistics in parentheses