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How can infrastructures reduce child malnutrition and health inequalities? Evidence from Guatemala

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Abstract: With the propensity score matching method, we carried out an average benefit incidence analysis that helps disclose those who really benefited from the sanitary services in Guatemala. Specifically, we tested the role of income, maternal education and social capital on how sanitary infrastructures affect child health. Results indicated that the child health benefits from infrastructure increase (decrease) with the household's socioeconomic status when the infrastructure is a complement (substitute) of the private inputs provided by the household, and that the role of the infrastructure (complement or substitute) itself depends on the household's socioeconomic status. Finally, results revealed that the battle against child malnutrition and health inequalities could be improved by combining sanitary infrastructure investments with effective public promotion of maternal education, social trust, and poverty reduction.

Keywords: Malnutrition, infrastructure, health inequality, Guatemala

1. Introduction

The nutritional status of a child is the result of a complex interaction between the food he/she eats, his/her overall state of health, and the environment in which he/she lives. Clinically, malnutrition is characterised by inadequate intake of protein, energy, and micronutrients, and by frequent infections or diseases. The World Health Organization (WHO) estimated that malnutrition has major role in half of the 10.8 million annual child deaths in the developing world, and continues to be a cause and consequence of disease and disability in the children who survive.[1]

In the battle against malnutrition, infrastructures have long been considered as an important determinant (McKeown and Record 1962). Considered by most authors as a positive factor for nutrition improvement, health infrastructure's complementarity with private inputs in developing better health status among the population also gains research attention since several years (Jalan and Ravallion 2003, Attanasio et al. 2004, Fay et al. 2005, Watson 2006, Mangyo 2008). Particularly, it is of interest to determine how the contribution of the infrastructure access to child health changes with the wealth and education situation of the households. For example, while Jalan and Ravallion (2003) found that child health from poorest and lowest educated households in India did not significantly improve by having piped water at home, this was not the case for children from more educated households. Similarly, Wolfe and Behrman (1982) found that child health and nutrition were positively associated with schooling, except in low-income rural areas. This reminds us the existence of "bottlenecks" in health care improvement in developing countries as mentioned by Attanasio et al. (2004): " […] low education does not allow other interventions to improve health care (as in Jalan and Ravallion, 2003) or poverty does not allow education to improve child health (as in Wolfe and Behrman, 1982)".

Our study investigated the effects of two infrastructures (flush toilet and piped water) in a Central American developing country (Guatemala) on child health, particularly for children under 6 years of age, based on a household-level survey conducted in 2000. Going one step further, our analysis will not only emphasise that expanding these infrastructures is not a sufficient condition to improve children's health, it also reveal the possibility of a negative effect if some household characteristics are not taken into account. We believe that the principal source of ambiguity lies in the uncertainty on how access to these infrastructures interacts with private health inputs provided by the child's parents (e.g. medical treatment, boiling water, hygienic water storage, and oral re-hydration therapy). It is now a well recognized fact that given the right combination of public and private inputs, malnutrition is almost entirely preventable. However, we cannot ignore the fact that public or semi-public inputs, such as access to toilet with adequate evacuation, can be either substitute or complementary to the private inputs contributed by the parents. Therefore, as mentioned by Jalan and Ravallion (2003), any potential child health gains from infrastructure could well bypass children in underprivileged families if we consider parental behavior of substitution in a situation of poverty.[2]

In the following section, our hypothesis relative to the theoretical ambiguity in the effect of access to infrastructures on children's health is introduced and some empirical evidence supporting them are provided. The methodology and the database for Guatemala are presented in Section 3 and 4, respectively, while the results and discussion are provided in Section 5. Some general remarks are given in Section 6 and lastly, the conclusion is presented in Section 7.

2. Working hypotheses

Similar to the remarks by Jalan and Ravallion (2003) in their theoretical model, we believe that child health benefits (losses) from infrastructure will increase with the household's socioeconomic status, if the infrastructure is a complement (substitute) for the private inputs provided by the household. Indeed, as parents care about more than just their children's health, an increase in access to infrastructures may change the direction and the quantity of privately provided health inputs, especially for poor family facing strict budget constraint. There is actually no conceptual framework that directly focus on this specific topic. Consequently, to understand the potential determinants for this complementary/substitution relationship between private and public or semi-public health inputs, we made the following hypotheses on three major types of socioeconomic status:

The first hypothesis is with respect to the household's per-capita income. Generally, as better infrastructures increase the marginal health benefits of the spending that parents make on their children's health and because such spending is a normal good, households are willing to pay more on health. We talk here about a "complementary effect" encouraged by the increase of marginal return of private health inputs However, for a poor household, the presence of public sanitary infrastructures can also slacken the necessity to spend time and money in purchasing private health input, therefore, the income saved may be redistributed to some usage with a marginal utility even higher. In this case, new infrastructures can be considered as a way to offload a part of their sanitary and health spending, so a "substitution effect" can be created. In this paper, we presume that the substitution effect between infrastructures and private inputs is more important for poorer families than the generally believed complementary effect. On this ground, better infrastructures would become a supplementary factor causing health inequality towards poor families.

The second hypothesis is with regard to mother's education. It is now widely believed that education of mothers improves children's health (Leibowitz 1974, Glewwe 1997, Block 2004). Better-educated mothers may be more effective in providing child health for a given amount and mix of health goods. At the same time, good education also leads to more efficient mix of health goods. According to Alderman et al. (2003): "At least five pathways establishing a direct link between education of the caregiver and their children may account for the additional role of schooling in improving child nutrition: (i) schooling may transmit information about health and nutrition directly; (ii) it teaches numeracy and literacy, thereby assisting care givers in acquiring information, for example, via access to newspapers; (iii) by exposing individuals to new environments *schooling makes them receptive to modern medical treatment; (iv) it imparts self confidence which enhances women's role in intrahousehold decision making and all individuals in their interaction with health care professionals; (v) it provides women with the opportunity to form social networks which can be of particular importance in isolated rural areas. Such social networks can support individual women and families in times of need." Therefore, we generally presume that better-educated mothers have fewer children, contribute more to the family income (higher income and/or productivity in self-employment), and are more capable in considering the complementarity between infrastructures and private health inputs. However, we still need to admit that schooling can affect parents' preferences on children's health in another way. Education also raises the opportunity costs of time, which tend to increase the time that mothers spend working outside and thus, reduces the time devoted to child care—this effect of schooling could diminish the level of child health by reducing both maternal time devoted to child care and the duration of breastfeeding. As a consequence, whether convenient access to infrastructure and private health inputs are complements or substitutes in producing child health is strongly influenced by mother's education (Thomas and Strauss 1992, Jalan and Ravallion 2003, Attanasio et al 2004, Mangyo 2008). For example, well educated mothers may make better use of convenient access to infrastructure than less educated mothers (e.g. by encouraging children to have better hygiene, by spending more time caring them, etc.) (Barrera 1990). Our hypothesis is that increasing parental education would make infrastructure projects more effective in promoting child health, whereas in households where mothers have few education and knowledge there is a possibility that infrastructures and private health inputs are considered as substitute.*

The third hypothesis is with respect to social capital. In the empirical literature, Poder and He (2010) have identified various ways in which social capital may affect health. However, in a context of interaction with infrastructure in producing health, the most obvious transmission scheme seems to be the one taken up by Woolcock and Narayan (2000), where social capital enables people to act collectively and exchange information and knowledge, including those concerning healthcare techniques. Similarly, some authors pointed out the fact that social capital can help to provide healthier and cheaper health goods, and educate how to use them more efficiently (Evans et al. 1996, Marmot and Wilkinson 1999, Alderman et al. 2003). In addition, Marmot and Wilkinson (1999) argued that a weak social capital can lead people to adopt harmful behavior for themselves and their circle, and generate chronic stress, making them more vulnerable to diseases (Segerstrom and Miller 2004), especially if they do not use sanitary infrastructure in a convenient way. Therefore, we expect a positive interaction between social capital and infrastructure in producing child health (e.g. social capital reinforces the complementarity between private inputs and infrastructure).

From an epidemiological standpoint, we assume that the potential health gains from a connection to infrastructure may well be of limited relevance and even negative for people who are constrained by income poverty, lack of education and knowledge, and weak social capital. Therefore, in this study, we attempted to quantify the child health gains in terms of children's growth from policy interventions that expand the infrastructures' access and to observe how these gains vary with the three household characteristics. The most important questions that we raised were: Is a child at less risk to be stunted *when he/she lives in a place with better access to infrastructures?; Which infrastructure is of critical interest?; Do income, mother's education, and social capital affect the health gains from these infrastructures?*

3. Methodology

The method used to estimate the causal effects of infrastructures on child health in a cross-sectional stratified sample without random placement is the propensity-score matching (PSM). This method allows balancing the distributions of observed covariates between a case group and a control group, based on similarity of their predicted probabilities of having a given facility. The PSM is a very flexible method because it does not require a parametric model linking the infrastructure placement to outcomes. Thus, arbitrary assumptions about functional forms and error distributions for the estimation of mean impact (including conditional impact) are not required.

In this setting, we identified two groups of households: those that have the infrastructure (denoted $D_i = 1$ for household i) and those that do not ($D_i = 0$). The formula used to match the units of the case group (with the infrastructure) with that of the control group (without it) is:

$$P(x_i) = Prob(D_i = 1 \mid x_i) \qquad (1)$$

where $P(x_i)$, the probability to have the infrastructure, comprises values between 0 and 1, and x_i is a vector of exposure control variables. The PSM uses $P(x)$ to select controls for each of those with facility. Exact matching on $P(x)$ implies that the resulting matched control and case subjects have the same distribution of the covariates. The PSM, thus, eliminates bias in the estimated treatment effects owing to observable heterogeneity.

As the data availability allowed us to study the health impacts of two types of infrastructure for each household, it was possible to have both, or just one or none of these two infrastructures. We therefore used predicted values from a multinomial logit model as the propensity score for each observation in the case and the comparison-group samples.[3] More precisely, for each household, the accessibility of the two infrastructures contains four possibilities: access to both infrastructure, access to flush toilet only, access to piped water only and access to none of the two infrastructures. Variables used in the multinomial logit model are presented in Appendix A1.

On the basis of the estimated multinomial logit model, six comparisons can be constructed for matching: both infrastructure vs. none, flush toilet vs. none, piped water vs. none, both infrastructure vs. piped water, both infrastructure vs. flush toilet, and piped water vs. flush toilet. The matched pairs for each of the six comparisons were constructed depending on how close the scores were across the two samples. Subsequently, the nearest neighbors to the ith individual with the given infrastructure were defined as the control subjects that minimise $[p(x_i)-p(x_j)]^2$ over all j in the set of control subjects. To *widen the probability distribution and to allow a greater number of matches, we employed odds ratio. The predicted odds ratio for observation k was $p(x_k)=\ln(P(x_k)/(1-P(x_k)))$.*[4] *In our empirical work, matches were only accepted if the bandwidth parameter $[p(x_i)-p(x_j)]^2$ was < 0.001.*

By this way, we were able to estimate the gain in child health attributable to the infrastructure. Thus, the mean impact can be given as:

$$\Delta\overline{H} = \sum_{i=1}^{T} \omega_i (h_{i1} - \sum_{j=1}^{C} W_{ij} h_{ij0}) \quad (2)$$

where h_{i1} is the case health indicator, h_{ij0} is the outcome indicator of one of the jth control subjects matched to the ith case, T is the total number of individuals with the infrastructure whose control subjects are identified, C is the total number of control subjects identified for ith case, ω_I are the sampling weighs used to construct the mean impact estimator and W_{ij} are the weights applied in calculating the average health characteristic of the matched control subjects.

Heckman et al. (1997) proposed several weights, ranging from "nearest neighbor" weights to non-parametric weights based on kernel functions of the differences in the scores. We decided to use a kernel function to calculate the weight distribution to give a larger weight to the closer control subject, which is given as:

$$W_{ij} = \frac{K_{ij}}{\sum_{j=1}^{C} K_{ij}} \quad (3)$$

In addition, unlike Jalan and Ravallion (2003), no limit was given to the number of comparison subjects inside the bandwidth parameter, when calculating the weighted counterfactual's health indicator. This means that c in equation (3) can take different values for different case subjects. Therefore, this kernel matching is a local averaging method that reuses and weights all the available comparison group observations inside the defined bandwidth parameter. In addition, we should note that replacement was done after each matching. The kernel function takes the form:

$$K_{ij} = \frac{1}{\sqrt{2\pi}} exp(-\frac{1}{2} v_{ij}^2) \quad (4)$$

where v_{ij} represents the probability distance between the comparison and the reference points, i.e., $v_{ij}=[P(x_i)-P(x_{ij})]$.[5]

For carrying out the multinomial logit regression to determine the predicted probability to have the infrastructure for each individual, clusters were used (Moulton 1990). The use of clusters corresponded to the aim of measuring the effect of aggregated variables on micro data. This was due to the consideration that general methods are based on the assumption of independent disturbances, which is typically not appropriate for data from populations with grouped structure. Indeed, the use *of aggregated variables could lead to issues of errors in variables, omitted variables bias, and aggregation issues, among others. If it is reasonable to expect that units sharing an observable characteristic (location, work industry, etc.) also share unobservable characteristics, then we have to consider the possibility that the random disturbances in the regression are correlated within the groups. Consequently, if the disturbances are correlated within the groupings that are used to merge the aggregate with micro data, then even small levels of correlation can cause the standard errors to be seriously biased. Clusters allowed us to control heterogeneity in our sample, specifying the existence of distinct specificities from one area to another. Such control allowed adjusting the variance–covariance matrix to these specificities. Thus, we assumed that the standard deviation is not the same for the whole sample, but is different for each group of individuals. In this study, clusters were defined by 44 Guatemalan regional areas.*

Another point that we would like to underline is that Guatemala was still in civil war by the end of 1996 (peace agreement signed in December 1996) and democratic elections were held in 1999. During the civil war and the few years that followed, civil institutions were weak, corruption very active and political patronage deeply rooted in people's minds. As a consequence, investments during this period did not contribute significantly to reducing disparities and social conflict (Commission Européenne, 2007). As a consequence, we believe, in general, that the rules used by the government in the allocation of public health resources before 2000 were not compensatory, (i.e. assignment of the infrastructure by the government was independent of the potential non-treatment health outcome). Under this consideration, we are confident that the accessibility of the infrastructure was random conditional on the set of covariates that we used to determine the propensity score, so the Conditional Independence Assumption (CIA) can be considered as valid for this study. Although it is impossible for us to be exhaustive in the inclusion of health-affecting factors in the health determination function, the fact that the distribution of the infrastructure was independent of the heath result actually guarantee the usability of the propensity score matching method in our study.

4. Data

Analyses in this study employed individual, household, and community-level data from the Encuesta Nacional sobre las Condiciones de Vida in 2000 (ENCOVI2000), a survey conducted by the Instituto Nacional de Estadistica (INE). The ENCOVI2000 comprises modules on household demographics, housing amenities, household expenditures, distance to facilities, and child anthropometrics, as well as a limited module on asset and land ownership. The original information was collected on 37,771 individuals for 7276 households. The anthropometric module covered about 5339 children under 6 years of age for whom we had complete data.

4.1. The health outcome

In empirical studies, child health outcome is generally represented by one of the following measures: (i) clinical measures; (ii) anthropometrics measures of height, weight, and body mass index; (iii) respondent-reported symptoms, mortality histories, and general health evaluation; and (iv) reports of a child's inability to undertake normal activities (Behrman and Deolalikar 1988). Measurement errors are inevitable in all kinds of measures, although they tend to be fewer in the case of the first two categories. Given the complexity and the costs associated with clinical measurements, the survey only retained the anthropometrics measures, which are generally preferred for evaluating health and nutritional status in empirical studies (Thomas and Strauss 1992).

Among all the anthropometric measures, the weight-for-height, height-for-age, and weight-for-age indicators have been used most extensively. Height-for-age, weight-for-height, and weight-for-age deficits are commonly interpreted as *indicative of chronic, acute, and total malnutrition, respectively. However, it is very important to recognise that height and weight are measures of growth attainment, rather than nutritional status per se (Martorell 1982, WHO Working Group 1986). Thus, height-for-age is an indicator of stunting, which represents the accumulated consequences of retarded skeletal growth; weight-for-age is commonly interpreted as an indicator of total malnutrition or under(over)weight; and weight-for-height is an indicator of wasting, a deficit in tissue and fat mass compared with the amount expected in a child of the given height. One of the main characteristics of weight-for-height is that it can move very rapidly and under favorable conditions, weight can be restored quickly. Hence, this indicator is too variable to capture the actual child health status in a cross-section. In addition, Keller (1983) demonstrated that deficits in weight-for-age were a composite of deficits in weight-for-height and height-for-age, and studying weight-for-age does not add any additional information. Consequently, we specially focused our attention on height-for-age, a measure of chronic health, which is of special interest in the case of infrastructures where the effects on child health are not always immediate.*

Evaluating the growth attainment of a population requires a reference population that allows normal variation within any age group. Although there are obvious differences between adults of different ethnicities, children of different ethnicities have the potential to achieve similar levels of growth in the first few years of their life. Data from India (Rao and Sastry 1977) and Guatemala (Johnston et al. 1973) suggested that ethnic differences in growth potential are minor prior to puberty, and only during this last stage, major differentiation between the ethnic groups occur. The reference population recommended by the World Health Organization was developed by the US Centers for Disease Control (CDC) based on data from the National Center for Health Statistics (NHCS). With children up to the age of 2 years, the sample was small and based almost exclusively on white, middle-class children from Ohio. For children aged from 2 years to adulthood, the sample was based on a relatively larger national representation, including non-whites and children from low-income households.

Using this reference population for children aged 0–6 years old in ENCOVI2000, we expressed the growth attainment of each child as a standard deviation from the median (z-scores). We made standardizing calculations with ANTHRO (Software for Calculating Pediatric Anthropometry), and results describe the degree to which a child's measurements deviate from what is expected for that child, based on a reference population. The formula used was:

$$z_i = \frac{(Y_i^{s,a} - H^{s,a})}{\sigma^{s,a}} \qquad (5)$$

where z_i = z-score for the child i; $Y_i^{s,a}$ = measured height (cm) for child i of sex s and age a; $H^{s,a}$ = median height (cm) for children of sex s and age a in the reference population; and $\sigma^{s,a}$ = standard deviation in height (cm) for children of sex s and age a in the reference population.

In the reference population, 2.3% of the children had a z-score of < −2, and 16% had a z-score of < −1. These levels are generally expected for a "normal population." In our original sample, these proportions were 43.4% and 70.4%, respectively. This reveals a relatively important stunt situation among the children in Guatemala. To avoid outliers, we previously decided to eliminate all the points for which the values were ≤ –5 and strictly > +3. Indeed, values that did not exist in this scale were generally considered as biologically improbable (WHO Working Group 1986).

4.2. The infrastructure variables

Based on the data collected by the ENCOVI2000, two infrastructure indicators were calculated: whether the household has access to a toilet that is connected to a drainage system or a septic tank, and whether the household has a direct access to piped water (inside the dwelling or within the property).

These two facilities are very important for children's health because they reflect the sanitary conditions and can provide safer environment. Indeed, places where these infrastructures are present are generally more effective in preventing *children from contracting specific diseases. In table 1, we have listed the percentage of people who originally have access to these facilities on the basis of their income level, maternal education, and social capital indicators.*

4.3. Individual and household characteristics

To estimate the multilogit regression for the probability of the household to be in one of the four above-mentioned infrastructure facility accessibility[6], we used a range of individual and household characteristics. A detailed statistical descriptive list is given in table A1 in the Appendix. The individual and household variables include demographics, education, ethnicity, income, housing conditions, Gini index for the community, assets, and dummy variables for geographical areas (some of these variables are plausible proxies for the omitted variables).

Subsequently, we considered the effect of infrastructures on child health to be conditional to three elements.

The first element is the income level. For this variable, we used an indicator of poverty created by the INE. It is a variable that was originally given the value 1 if the household was in extreme poverty, 2 if in a poverty position, and 3 if it is not poor. This poverty classification was defined by the Secretaria de Planification y Programacion de la Presidencia (Ministry for the Plan) according to two poverty lines—the absolute extreme poverty line is defined as the income amount necessary to satisfy the household's minimum calorie intake; and the absolute general poverty line is defined as the income amount necessary to satisfy the household's basic calorie and other non-dietary needs (health, clothes, transport, etc.). Based on this classification, we constructed three dummy variables with the value 0 or 1.

The second element is maternal education. The data provided by the household survey allowed us to distinguish three degrees of maternal education: the mother having no education (not even one year completed at school) and does not *know how to read and write; the mother having completed primary education or at least knows how to read and write; and the mother having completed secondary education or higher level.*

In addition, we equally considered the impact of two indicators of social capital on child health. These indicators correspond to two over three major dimensions of social capital usually mentioned in the literature (Bjornskov 2006), namely, associational activity and social trust.[7] Our first indicator is, thus, the participation of households in associations. If at least one person in the household participates in one or more associations, the household will be considered as participative, with a value of 1 for the dummy. The second is an indicator of solidarity and confidence within the neighborhood. This indicator is based on the following question: "If your neighbors suffered an important economic loss, who do you think would help them economically?" If the household answers that nobody will help them, not even themselves, then dummy takes the value of 0, or 1 if answered otherwise.

5. Results and discussion

5.1. Matching details and matching quality

Tables 2a and 2b show various t-tests on the health result differences over the matched pair to understand the conditional impact of our two facilities on health (average benefit incidence analysis). The information about the common support and the matching quality is given at the bottom of these two tables. As we used a Kernel matching, the common support is in fact not a problem. This is because for an individual in the treatment group, we calculated the health outcome of its observable pairs with a local average weighted by all the available comparison group observations inside the defined bandwidth parameter. With a bandwidth refined to $[p(x_i)-p(x_j)]^2 < 0.001$*, the "value-added" from the common support* *condition stays only marginal: the number of treated units for which we find a control pair stays the same after the common support constraint is imposed. Histograms of propensity score for each of the six matches are reported in appendix A3.*

The matching quality is measured in two ways: the standardized differences between treated and un-treated groups before and after matching and the method proposed by Sianesi (2004), which suggests re-estimating the propensity score on the matched sub-sample. We can see from tables 2a and 2b that the matching reduce significantly the standardized differences between treated and control group, except for the comparison between piped water alone vs. none. The Pseudo R2 for the propensity score estimation also shrinks largely after matching, which implies that differences between treated and un-treated groups in the distribution of the covariates are not systematic. Both measurements reveal therefore a satisfactory matching quality.

5.2 Impact estimates

The first line gives the general comparison results for the full sample. Following, we further stratified the full sample by poverty levels, mother's education attainment levels, household's participation in associations, solidarity and confidence indicator (whether the household considered that no one will help the neighbors in case of difficulty). Their corresponding comparison results in the health outcome are listed in the lower part of Table 2. Means and marginal impacts on z-scores are calculated for those with the facility. Means are the average health situation of the children who have access to the specified type of infrastructure. Marginal impacts indicate the gains from the access to the infrastructures.

On an average, we could observe that flush toilet and piped water had a positive effect on child health (table 2a). These results indicate that having facilities that improve the sanitary environment or allow the household to save time are often of great importance for child health. With regard to the stratified levels, the study indicated that the severity of stunting *fell with higher income, better maternal education, and social trust. In the same way, the positive effect of infrastructures grew with these socioeconomic indicators (table 2a and 2b).*

It is particularly remarkable to observe that for children living in the most underprivileged households, the effect of infrastructures on their health was significantly negative. This was especially true with respect to the household's poverty level and mother's education characteristics. In reference to our initial hypothesis, this observation can be explained by the slackening of the household's budget constraint and the lack of knowledge about how to efficiently use the infrastructures. Thus, by looking at the poverty level of the households, we can observe that infrastructure access does not begin to have the expected significantly positive effect, until the income reaches a certain minimum level ("poor" for piped water alone and "not poor" for all other combination of infrastructure). Similarly, with respect to different levels of mother's education, we can only obtain a positive impact of infrastructure on the children's health when their mothers are capable of reading and writing or had secondary education or higher. Therefore, the fact that the access to one of these two infrastructures or to a combination of these infrastructures has a significantly negative effect on children's growth in the most underprivileged households seems to indicate the possibility that the access to these infrastructures may encourage them to reduce or even stop investing in their children's health. This is easy to understand since these households are probably more inclined to consider the access to infrastructure as a means to discharge some of their daily budget constraint (such as purifying water, spending time to look after the place where children play, etc.), and insofar as the infrastructure is presumed to bring the solution to many problems. Such a behavior is all the more easy to adopt, as these households are facing strong financial constraints to ensure their survival, and the fact that the principal person in charge of the children can neither read nor write, which in many cases, deprives the household of the knowledge about how to make the best use of different elements available for the children, and/or to make the best usage of the time saved owing to the access to these infrastructures.

With respect to the households belonging to the intermediary categories, the impacts of infrastructures are often non-significant. This can be explained by the fact that for these relatively less poor households, the slackening in the budget constraint due to the access to the infrastructure service is probably weaker, or even null, which therefore, enables the purely health-enhancing effect of infrastructure to cancel the negative substitution effect on child care.

This is, however, not the case when we compared the impact of both infrastructures against only one of them (table 2b). In these situations, the impact on the "poor" household category remained significantly negative. Looking at these different combinations, we observed that having the two infrastructures is better than only having access to one of these, but only for the less disadvantaged, which indicated a possible higher substitution effect between the two infrastructures and private health inputs until the household reach a certain level of socioeconomic abilities. Until the household is a "not poor" household and have enough income to satisfy its basic calorie and non-dietary needs, having the two infrastructures is a "signal" for a stronger slackening in the budget constraint in health expenditures. This result may explain why, on average, the marginal impacts of flush toilet alone or piped water alone is higher than the marginal impact of the two combined: extremely poor and poor households are slackening their budget constraint with the introduction of one infrastructure and this slackening is stronger with the introduction of a second infrastructure (additive effect). When households are reaching the "not poor" and the "secondary education or higher" threshold, infrastructures started to be complementary with private health inputs.

Considering the marginal impact of one infrastructure over the other, our result indicated a stronger positive impact when introducing flush toilet as compared to piped water (table 2a). This is maybe due to the fact that flush toilet only need a punctual maintenance as compared to piped water that need a constant effort to be safe (to filter and boil water), especially in Guatemala where piped water is not always clean. Moreover, in some cases, flush toilet is a public service and do not need any effort of maintenance from the household using it. In addition, we observed in table 2a an always positive effect *(although not always significant) of flush toilet, whatever the socioeconomic category the household belongs to, whereas, with piped water the marginal impact start as negative and finish as positive. This may indicate that efforts to produce to maintain child health must be more important with piped water, especially when the household is disadvantaged (table 2a and 2b). However, we observed that the effect of flush toilet start to be significant only when households are "not poor" or have "secondary education or higher" (table 2a). This demonstrates the importance of income and knowledge to ensure a significant positive and effective use of flush toilet (maintenance and disease-prevention expenditures when the flush toilet is of the responsibility of the household) and the decision to provide private health inputs to children.*

Looking at the marginal impact of piped water alone in table 2a, we observed that primary education is enough to prevent a negative effect and turn it to a significant and positive one. Under this condition, it seems that even a "minimal" increase in knowledge allow a mother to use in an efficient manner different kinds of health goods (including infrastructures access) in order to improve the health of her children and to make better use of the saved time. From the moment when the mothers have a wide and open vision of the world owing to education and mastery of writing and reading skills, they may stop considering the infrastructures as a substitute for the care that they have to provide to their children, and might be able to distinguish more possibilities to improve their children's health position. As Jalan and Ravallion (2003) mention it, piped water still may need to be stored and may be boiled to make it drinkable. This process would require maternal knowledge and skills in health. Our results, as well as Jalan and Ravallion (2003), suggested that promoting child health would be a matter of not only drinking water itself but also maternal knowledge of how to make drinking water safe for children.

While looking at the effect of infrastructures on child health according to the approximated level of households' social capital, we quickly realised that only the results related to the dimension of social trust conformed with our initial assumptions (with the exception of flush toilet alone in table 2a). Indeed, with our variable of participation in associations we experimented *many discrepancies. Thus, our discussion on social capital begins with the dimension of social trust, and then attempts to understand the results obtained for the dimension of association activity.*

Our indicator of social trust revealed two situations: either the households believed that their neighbors would not receive any help if they were in difficulties, or they did believe. The first situation exhibits a local surrounding under which the households are probably isolated or obliged to always count on only themselves, without much willingness to help or the expectation to receive reciprocal helps from the community. This notion mainly revealed the lack of confidence of households in their local social environment. In this setting, with the exception of flush toilet alone in table 2a, the relatively small and non-significant impact coefficients in tables 2a and 2b demonstrate that the access to infrastructure actually cannot bring health gains to children of households having this opinion.[8] *The lack of health improvement capacities in this case can be explained by more difficult access to a useful network of information, psychological weakness, and adoption of harmful behaviors (laxism, consumption of alcohols, etc.) by these households. Conversely, for households believing that people will help, a larger and more significant health-improving effect of the infrastructures on child health was observed in both infrastructures. Compared with the corresponding average health gain recorded on the first line of table 2a, social trust brought a supplementary gain in z-score of 21% for flush toilet and piped water together, and 44% for piped water alone, derived through simple calculation. In the case of flush toilet alone in table 2a, the positive marginal impact of "no help" could be explained by the fact that flush toilet do not really need social interaction to be effective. However, why its marginal impact is higher than with "help" is counterintuitive.*

In the case of households' participation in one or more associations, results were, however, somewhat surprising. In fact, in four cases over six in table 2a and 2b, the participation in associations did not seem to make any difference with regard to the health-improving effect of flush toilet and piped water on children. On the contrary, we observed a more than doubled improving effect of piped water when the household did not participate (with respect to the average impact given on *the first line), whereas the same effect was missing when the household participated. To understand this against-intuitive phenomenon, we must know what is really reflected by the participation of the households in associations. On the basis of the model of health by Grossman (1972), goods and health services can be used to improve health as well as to satisfy a consumption need. The same dichotomy can be applied for the participation in associations. Thus, participating in an association can actually bring new social-network access to a household from which one can draw useful information in making good use of the existing resources, and mobilizing new resources that are good for children's health. However, participation can sometimes bring other utilities to the household apart from the health of its children, such as singing in a choral society or footing. We, therefore, suspect the variable participation to have different impacts on the health according to the type of association in which the households participate. To determine whether the effects differ, we built five groups of participation according to the type of association. In group 1, we gathered all associations having an economic topic (farmers groups, credit groups, etc.), in group 2, those related to leisure (sports groups, cultural groups, etc.) were included, while the religious associations were included in group 3. In group 4, associations that aim at improving community life (parents association, roads board, solidarity organization, etc.) were included, and group 5 comprised all the other types of associations. Results provided in tables A2a and A2b of the Appendix do not seem to indicate that the explanation resides on the aspect that we discussed, since most of the results were very often the same as those presented in tables 2a and 2b. The major exceptions are in the cases of both infrastructures against no infrastructure or against piped water; the two cases where tables 2a and 2b indicate results conform to our initial assumption, which may indicate that our results are driven by some kinds of associations. In these two cases, when households are classified according to their participation in group 1, 2 or 5, we observed obvious health-improving gains from the infrastructure access. This might be owing to the fact that these associations, especially those in "economic fields", do have certain health-improving impacts by helping people in sharing* *their knowledge about how to make better use of the infrastructures and increase their income. However, why their effect is non significant or opposite to our initial assumption in the remaining cases is still counterintuitive.*

Subsequently, we wanted to examine whether the results could depend on who is the real participant in a family. We thus distinguished the participation of mother and father in one or more associations. The results are given in the lower part of tables A2a and A2b in the Appendix. These results still confirm those previously established (tables 2a and 2b), and in some cases, they even accentuate the impression that to do not participate would be better for the health of children. This is particularly the case for piped water alone (tables A2a and A2b).

Why does participating in an association seem to constitute a handicap to an effective and beneficial use of infrastructures for the children's health? This might be because the association participation in fact reveals a source of selection bias, namely that the most disadvantaged would mainly participate in associations to find a solution to their problems (income, health, etc.). In these kind of associations, without effective external help (such as explaining how to make good use of the infrastructure access), mere participation might not bring health improvements. Furthermore, it is possible that some associations may seek to benefit from the credulity and weakness of the most underprivileged people with the principal aim of increasing the size of their associations and subsequently, their local authority (religious associations, etc.). Hence, organisers of these associations may refrain from offering necessary assistance to these underprivileged people for political reasons (Ron 1999) (see results of group 4 in tables A2a and A2b). In this case, the participation in associations is endogenous to the child health status along with other disadvantaged characteristics of the households, such as poverty, ignorance, etc. The endogenous potential is actually manifested by the mean health situation indicators given in table 2a for the group of participating and non-participating households, where we can easily distinguish the worse z-score for the participating group in flush toilet alone and piped water alone.

6. General remarks

The results obtained in this study clearly reveal the existence of an increasing conditional impact of infrastructures on child health with the improvement of household income, maternal education, and social trust. For example, the impact of possessing piped water alone inside the dwelling on stunt-reduction was four times higher for those with a mother having secondary education or higher, than for those with a mother having only primary education. The impact difference was 0.73 in terms of z-score, equal to a possible improvement of 37% in the z-score, if the mothers with primary education adopted the same behavior vis-à-vis the infrastructure as the one adopted by mothers with secondary education or higher. However, from the means calculated in tables 2a and 2b, it can be observed that the beneficial use of these facilities is not enough to bring children back to a normal nutritional status, which means a z-score of value 0. For example, in the case of flush toilet alone (table 2a), we noticed that in relation to a normal nutritional status, the facility did not allow a health gain of 100%, but only 27% for children sharing the same probability of access and same level of poverty (not poor). Similarly, ceteris paribus, the impact of flush toilet alone allowed gains of 51% for children with mother having secondary education or higher. In addition, the generalization of the access to infrastructure failed to resolve all differences in the health status among children of different household situations. On the contrary, our results in table 2a and 2b show that even if one individual of the most underprivileged situation possessed the same access to facilities, his/her health status would generally be lower than that of an individual belonging to a household with better education, income, or social trust. Indeed, as mentioned in the previous section, the household behavior vis-à-vis the infrastructure is different according to socioeconomic status. Thus, there exists a substitution effect between private health inputs and infrastructures for the most underprivileged households. However, this substitution effect gradually disappears with the household's progress in the social hierarchy to become a growing positive complementary effect. Consequently, given the current situation, if the infrastructures can allow an increase in children's *average nutritional status, above all, they especially facilitate a rise in health inequalities. In this setting, it is of great importance that the policymakers are well informed about these facts. Thus, an efficient policy aiming at reducing chronicle growth retard among the Guatemalan's children requires not only more generalised access to various types of sanitary infrastructure facilities, but also other development programs along with it which could facilitate poverty reduction, women education, and reinforce the development of social trust and solidarity. However, we should also mention that the results we obtained may be driven not only by factors associated to our hypothesis (i.e. conditional impact of infrastructures according to three socio-economic attributes), but also by other unknown factors. As a consequence, our results can also be partially explained by heterogeneity of impacts.*

7. Conclusion

In this study, we presumed that the parental choices about inputs to child health correspond to changes in the access to infrastructure. We tested two assumptions—the first is the potential health benefits that can be realised if an increase in access to infrastructure is not accompanied by a decrease in the private inputs provided by the household to the child health (i.e., inputs are not substitutable). The second assumption postulates that the health gains may be better for the more affluent, more educated, confident, and participating households. This may be owing to a less important slackening of the budget constraint for the richest, a better understanding of the complementarity between infrastructures and private health inputs, a better usage of gained time, and a larger diffusion of information and/or more efficient collective actions.

To quantify the expected health gains of children from infrastructures, and to examine how those gains vary according to income, maternal education, and social capital, we used the PSM method. As described earlier, this method was coherent *with our objective and allowed us to eliminate selection bias owing to observable differences between those with the infrastructure and those without it. The two facilities used were direct access to flush toilet and piped water.*

Our results demonstrated, on an average, a significantly better health status for children living in households with direct access to one or two of these infrastructures. With respect to the household's socioeconomic status, we found strong and significant health gains for the richest and the better educated, whereas the poorest and the less educated suffered significant health losses. Though we rather expected a null effect for the most underprivileged, these findings corresponded well with our initial assumptions of a positive (negative) effect of facilities on the child health with the increasing (decreasing) socioeconomic status. By considering the characteristics of the infrastructures, we observed that infrastructure whose proper use requires little effort (flush toilet) was able to do not act in a negative way on the child health. By cons, increasing the number of infrastructure for the most disadvantaged household may indicate an increase in the substitution effect between infrastructures and private health input provided to children.

With regards to social capital, we found that households that were inclined to help their neighbors in the event of difficulties (as an indicator of social trust) were able to improve the impact of flush toilet and piped water on child health, which revealed potential externalities. However, the results for households' participation in associations indicated no additional effects and/or a potential endogenous bias between their participation and social difficulties.

From our observation, we recommend policymakers to consider the various effects highlighted in this paper. It is particularly important that public investments in infrastructures combine their action with programs that promote health knowledge, poverty reduction, and trust within the community, to improve their effectiveness in the aspect of public health. Furthermore, if we do not prefer the gains in child health from these actions to be accompanied by an increase in health inequalities, we have to ensure that programs associated with the investments in infrastructures give priority to the most disadvantaged people.

Footnotes

1 - http://www.who.int/nutrition/topics/malnutrition/en/index.html (accessed June 11, 2009).

2 - In addition, there may also have a difference between short and long term impacts of infrastructure on child health considering the immediacy of the learning on how to use the infrastructure and whether the impact dissipate over time without additional further health communication. However, considering that our study used a cross-sectional database, which did not allowed us to distinguish between short and long term impacts, and that our health indicator is a z-score of height for age, which is a measure of chronic health, we only considered the long term impacts of infrastructure on child health.

3 - Dehejia and Wahba (1999) reported that their PSM results are robust to alternative estimators and alternative specifications for the logit regression.

4 - $p(x_k)$, k = i;j is the predicted probability to have the infrastructure for observation k.

5 - Our results are robust to different weights. Indeed, we found very similar results for linear and kernel weights to the nearest five neighbors when compared with the results for the kernel weights with no limit of neighbors' number (Table 2). We also experimented our method with a more stringent tolerance limit of 0.0001 for the bandwidth parameter, and the results were coherent with those presented in the paper.

6 - In the estimation, the discrete outcome takes a value arranging from 3 to 0, with the household having access to both facility as 3, those having only piped water or flush toilet as 2 or 1, and a value of 0 otherwise,

7 - Some authors such as Grootaert et al. (2004), postulated the existence of many other dimensions of social capital, e.g., action and cooperation, information and communication, social cohesion and inclusion, empowerment and political action. According to our data, we tested some of these particular dimensions and even a synthetic indicator of all these dimensions; however, no significant effect could be found.

8 - A further check in the distribution of income and education level in the “help” and “no help” sub-samples showed no difference between the two sub-samples and the whole sample.

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Appendix

Appendix A1: Descriptive statistics

	Mean	Std. dev.	Minimum	Maximum
Height-for-age	−1.760357	1.418675	−4.99	2.91
Flush toilet	0.3066731	0.461168	0	1
Piped water	0.4774753	0.4995526	0	1
Whether the household participated in associations	0.496266	0.5000463	0	1
Whether the neighbors received help	0.6244278	0.4843286	0	1
% area of household in extreme poverty	0.1310929	0.1163188	0	0.3872
Gini coefficient by area	0.5429064	0.2042117	0.1446	0.9444
Father's education (years completed)	4.605878	3.169783	0	13
Mother's education (years completed)	3.649723	3.305078	0	13
Head of the household is a female	0.0298723	0.1702555	0	1
Vegetable expenditures per capita per month (kg)	8.382979	13.5295	0.152	503.23
Fruit expenditures per capita per month (kg)	12.4447	13.23828	0.067	198.71
Sex of the child	0.5099976	0.4999603	0	1
Urban area	0.3613587	0.4804521	0	1
Norte region	0.1339436	0.3406328	0	1
Nororiente region	0.0585401	0.2347902	0	1
Noroccidente region	0.1811612	0.3851981	0	1
Suroriente region	0.1009395	0.3012849	0	1
Suroccidente region	0.143339	0.3504604	0	1
Central region	0.1874247	0.3902991	0	1
Petén region	0.1072031	0.3094085	0	1
Number of children under 5 years of age household	1.949892	0.8236822	1	6
Father's ethnic group	0.4685618	0.4990708	0	1
Mother's ethnic group	0.4483257	0.4973825	0	1
The household's access to electricity	0.6468321	0.4780119	0	1
Number of individuals per room	4.626521	2.521357	0.375	17
Distance to the market (min)	41.7444	56.4583	0	540
Size of the family	6.622982	2.597634	3	18
Whether the household owns a fridge	0.1710431	0.376592	0	1
Whether the household owns a radio	0.677668	0.4674256	0	1
Whether the household owns a television	0.4345941	0.4957633	0	1
Whether the household owns a phone	0.086967	0.2818206	0	1
Whether the household owns a washing machine	0.0279451	0.1648353	0	1
Whether the household owns its dwelling	0.7142857	0.4518084	0	1
Whether the dwelling has a kitchen	0.6104553	0.4877058	0	1
Whether the kitchen is of exclusive use	0.9672368	0.1780376	0	1
The dwelling is a formal house	0.8749699	0.3307929	0	1
The dwelling is an apartment	0.0040954	0.0638718	0	1
The dwelling is a room in a boarding house	0.0171043	0.1296758	0	1
The dwelling is a ranch	0.0867261	0.2814672	0	1
The dwelling is an improvised house	0.0144543	0.1193686	0	1
The household use of coal	0.0679354	0.2516654	0	1
The household use of beeswax	0.6364731	0.4810726	0	1
The household use of propane	0.3155866	0.4648051	0	1

Number of observations: 4151

Appendix A2a: Marginal impact of infrastructure according to various indicators of participation

	Flush toilet & piped water vs. none		Flush toilet alone vs. none		Piped water alone vs. none	
	Mean (SD)	Impact (P-value)	Mean (SD)	Impact (P-value)	Mean (SD)	Impact (P-value)
No household participation in group 1	−1.39	0.12*	−1.42	0.25**	−1.96	0.19**
	(1.27)	(0.08)	(1.37)	(0.01)	(1.44)	(0.00)
Household participation in group 1	−0.99	0.62**	−1.29	0.30	−2.30	-0.09
	(1.03)	(0.01)	(1.60)	(0.74)	(1.01)	(0.64)
No household participation in group 2	−1.40	0.14*	−1.46	0.22**	−1.99	0.16**
	(1.29)	(0.06)	(1.39)	(0.03)	(1.43)	(0.00)
Household participation in group 2	−1.25	0.15	−1.14	0.46*	−1.73	0.41**
	(1.16)	(0.36)	(1.22)	(0.08)	(1.36)	(0.01)
No household participation in group 3	−1.32	0.13	−1.41	0.27**	−1.88	0.24**
	(1.32)	(0.13)	(1.38)	(0.02)	(1.44)	(0.00)
Household participation in group 3	−1.48	0.17	−1.44	0.22	−2.14	0.08
	(1.16)	(0.12)	(1.35)	(0.20)	(1.39)	(0.31)
No household participation in group 4	−1.38	0.15**	−1.36	0.30**	−1.92	0.23**
	(1.27)	(0.04)	(1.34)	(0.00)	(1.44)	(0.00)
Household participation in group 4	−1.33	0.09	−2.04	-0.18	−2.27	-0.09
	(1.29)	(0.72)	(1.56)	(0.62)	(1.31)	(0.42)
No household participation in group 5	−1.39	0.13*	−1.43	0.24**	−1.96	0.19**
	(1.27)	(0.07)	(1.38)	(0.01)	(1.44)	(0.00)
Household participation in group 5	−0.97	0.52**	−1.10	0.63*	−2.11	0.08
	(1.20)	(0.03)	(0.64)	(0.05)	(1.24)	(0.63)
No participation of mother	−1.36	0.12	−1.44	0.20*	−1.87	0.25**
	(1.29)	(0.15)	(1.39)	(0.07)	(1.44)	(0.00)
Mother's participation	−1.41	0.21*	−1.36	0.41**	−2.20	0.03
	(1.22)	(0.08)	(1.33)	(0.03)	(1.37)	(0.71)
No participation of father	−1.36	0.13	−1.34	0.28**	−1.85	0.27**
	(1.28)	(0.12)	(1.39)	(0.01)	(1.47)	(0.00)
Father's participation	−1.40	0.16	−1.58	0.19	−2.15	0.06
	(1.25)	(0.14)	(1.33)	(0.24)	(1.35)	(0.37)
Total number of pairs	511		240		952	

** Significant at the 10% level*
*** Significant at the 5% level*
Notes:
Weights are calculated on the basis of a kernel function inside a bandwidth parameter of 0.001,
coefficients with significant impact represent difference between average z-score of case and control individuals,
means and impacts on z-score are calculated for children with the facility,
group 1 corresponds to associations in economic fields, group 2 to hobbies, group 3 to religion, group 4 to community and civic activities, and group 5 to other associations.

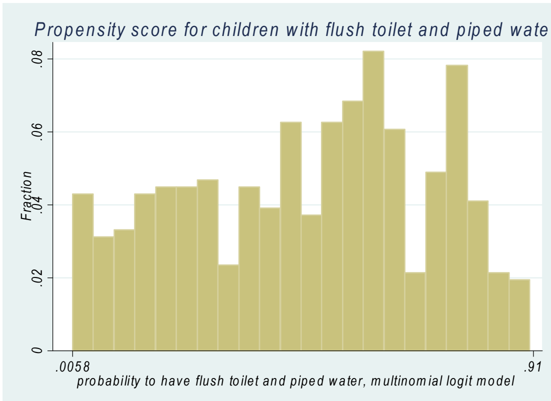
Appendix A2b: Marginal impact of infrastructure according to various indicators of participation

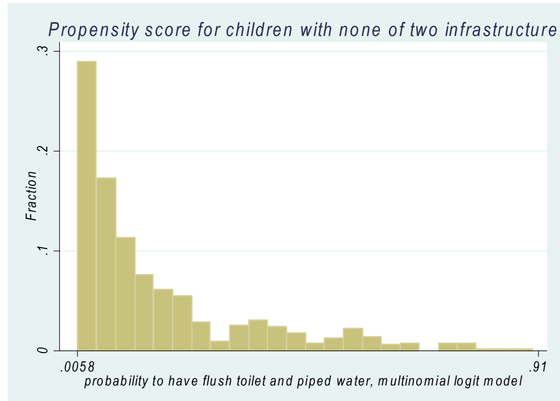
	Flush toilet & piped water vs. piped water alone		Flush toilet & piped water vs. flush toilet alone		Piped water alone vs. flush toilet alone	
	Mean (SD)	Impact (P-value)	Mean (SD)	Impact (P-value)	Mean (SD)	Impact (P-value)
No household participation in group 1	−1.28	0.11*	−1.24	-0.02	-1.91	-0.08
	(1.25)	(0.05)	(1.28)	(0.73)	(1.45)	(0.19)
Household participation in group 1	−0.90	0.57**	−0.90	0.11	-2.37	-0.32
	(1.06)	(0.00)	(1.17)	(0.68)	(0.99)	(0.23)
No household participation in group 2	−1.30	0.10	−1.27	-0.04	-1.95	-0.10
	(1.27)	(0.12)	(1.29)	(0.56)	(1.45)	(0.12)
Household participation in group 2	−1.07	0.29**	−1.04	0.09	-1.64	0.01
	(1.12)	(0.02)	(1.18)	(0.43)	(1.36)	(0.96)
No household participation in group 3	−1.22	0.13*	−1.18	0.02	-1.84	-0.00
	(1.28)	(0.07)	(1.32)	(0.79)	(1.47)	(0.98)
Household participation in group 3	−1.35	0.14	−1.32	-0.08	-2.11	-0.27**
	(1.17)	(0.13)	(1.18)	(0.40)	(1.37)	(0.01)
No household participation in group 4	−1.27	0.12**	−1.25	-0.01	-1.88	-0.06
	(1.25)	(0.04)	(1.27)	(0.85)	(1.47)	(0.40)
Household participation in group 4	−1.17	0.24	−0.98	-0.06	-2.21	-0.29*
	(1.18)	(0.24)	(1.30)	(0.77)	(1.25)	(0.06)
No household participation in group 5	−1.28	0.10*	−1.25	-0.02	-1.92	-0.09
	(1.25)	(0.07)	(1.27)	(0.78)	(1.45)	(0.17)
Household participation in group 5	−0.80	0.86**	−0.63	0.02	-2.13	-0.16
	(1.21)	(0.00)	(1.21)	(0.95)	(1.30)	(0.53)
No participation of mother	−1.26	0.11*	−1.23	0.02	-1.84	0.01
	(1.25)	(0.10)	(1.29)	(0.77)	(1.46)	(0.94)
Mother's participation	−1.29	0.18*	−1.23	-0.10	-2.16	-0.33**
	(1.23)	(0.06)	(1.23)	(0.33)	(1.38)	(0.00)
No participation of father	−1.27	0.08	−1.24	-0.00	-1.79	0.03
	(1.28)	(0.25)	(1.31)	(0.97)	(1.50)	(0.75)
Father's participation	−1.26	0.23**	−1.22	-0.04	-2.14	-0.27**
	(1.19)	(0.01)	(1.20)	(0.69)	(1.33)	(0.01)
Total number of pairs	710		728		818	

** Significant at the 10% level*
*** Significant at the 5% level*
Notes:
Weights are calculated on the basis of a kernel function inside a bandwidth parameter of 0.001,
Coefficients with significant impact represent difference between average z-score of case and control individuals, means and impacts on z-score are calculated for children with the facility,
Group 1 corresponds to associations in economic fields, group 2 to hobbies, group 3 to religion, group 4 to community and civic activities, and group 5 to other associations.

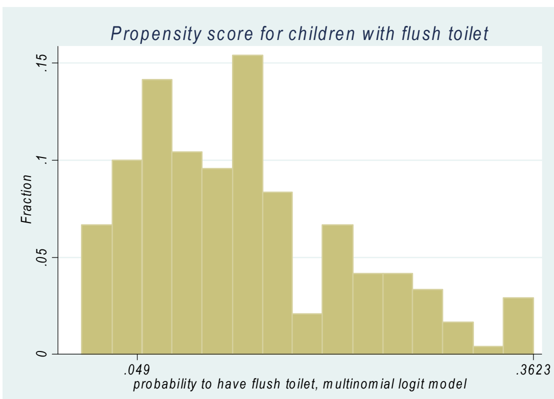
Appendix A3. Histograms of propensity score for the six matching cases

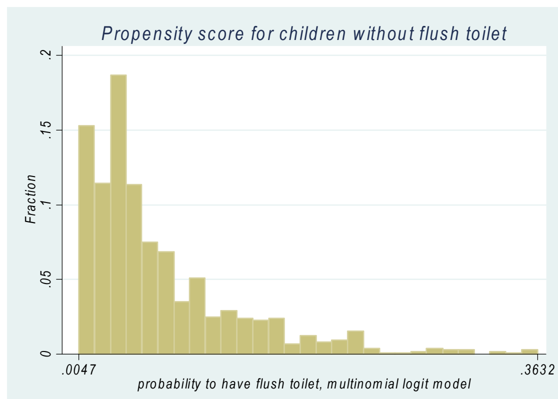
A3.1. Flush toilet and piped water vs. none



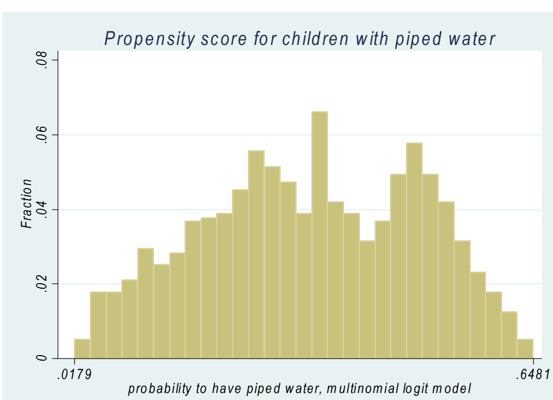


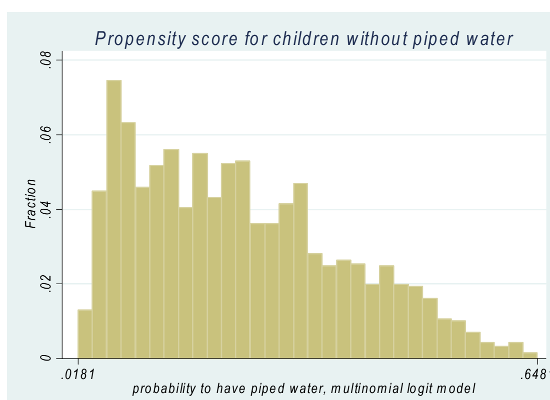
A3.2. Flush toilet alone vs. none



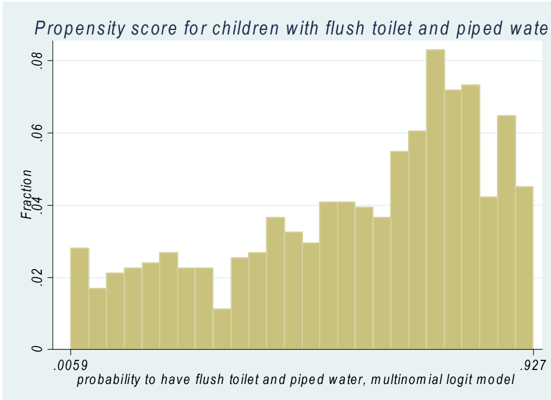


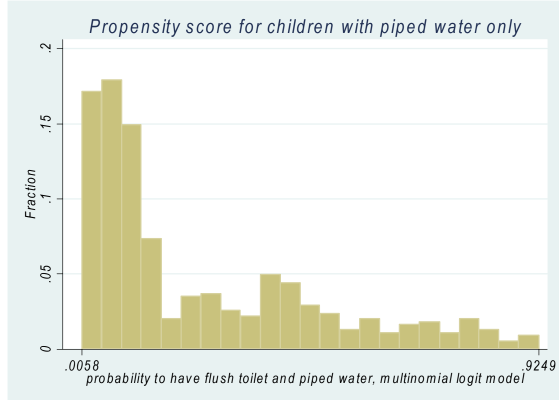
A3.3 Piped water alone vs. none



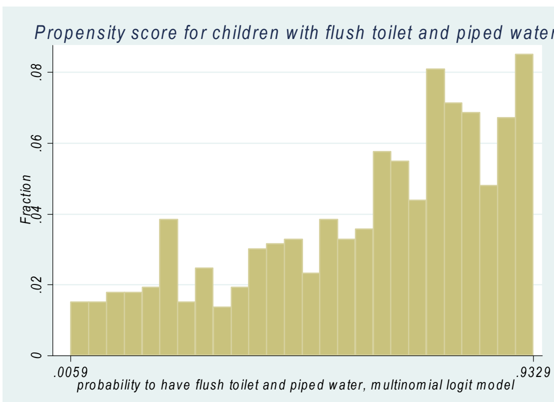


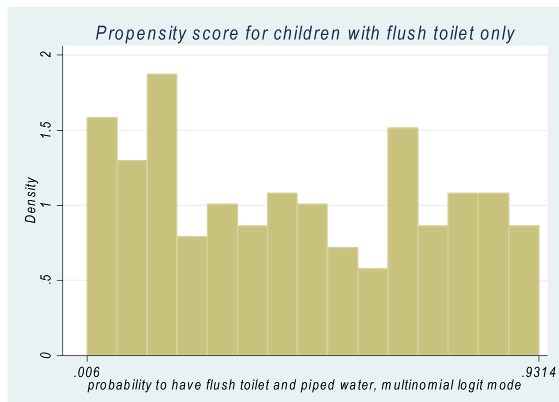
A3.4. Flush toilet and piped water vs. piped water alone





A3.5. Piped water and flush toilet vs. flush toilet alone





A3.6. Piped water alone vs. flush toilet alone