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AN IMPACT EVALUATION OF A POTABLE WATER AND SEWERAGE EXPANSION IN QUITO: IS WATER ENOUGH?

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An Impact Evaluation of a Potable Water and Sewerage Expansion in Quito: Is Water Enough?

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*This study was prepared by Virgilio Galdo and Bertha Briceño from the Office of Evaluation and Oversight (OVE), Inter-American Development Bank, Washington, D.C.

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ABSTRACT

This paper explores the impact that a water supply and sewerage (W&S) expansion had on child mortality in Quito, Ecuador. Studies have typically estimated the effects of this type of interventions comparing outcome indicators - at the aggregate level- of areas with the facilities and areas that lack them, quite often neglecting systematic differences between treated and non-treated areas. Moreover, at aggregate levels, on the one hand, less comprehensive information may imply greater unobserved and uncontrolled heterogeneity; on the other, heterogeneity within areas may jeopardize identification of impacts. To account for these key observations, we used propensity score matching (PSM) analysis at the individual level. Using indirect methods based on census data we constructed a mortality index at the motherhood level, and calculated five different impact estimators based on the propensity scores. We found that the average impact of the program ranged from 7.2 percent (local linear regression-kernel matching) to 9.0 percent (5-nearest neighbors matching). Matching difference-in-differences estimators also evidenced about an 8 percent reduction in child mortality levels. The reflexive or naïve evaluation for the cross-section would have estimated an average impact of 16.5 percent and the difference-in-differences naïve evaluation would have estimated an average impact of 19 percent, both clearly overstating the intervention's effects. When exploring heterogeneity of impacts, we stratified the sample by quartiles based on expenditure per capita, and surprisingly, no significant improvement among those in the bottom quartile was evidenced in relation to their matched individuals. However, we also observed that even in the poorest quartiles, if a woman had at least primary education, then the household obtained significant gains from W&S interventions. This would suggest the interesting observation that the overall insignificant effect for the bottom quartile was driven by the absence of impact in those who completely lacked education, thus stressing the importance of complimentary private inputs in order to reap the benefits of piped water, as other studies have suggested (Jalan and Ravallion, 2003a).

JEL classification: I12, O12, H43.

Key words: water supply, sewerage, child mortality, propensity score matching.

INTRODUCTION

Even though water and sanitation has attracted considerable attention since the early 1980s, approximately 3.4 million people, mostly children, still die annually from water-related diseases (WHO, 2002a, 2002b). These diseases are among the major causes of child deaths, accounting for between 12 to 21 percent of total global under-five deaths. In the Americas, diarrhea represents about 8 percent of under-five child deaths, and both diarrhea and malnutrition represent between forty and seventy percent of all their hospitalizations (PAHO, 2001).

Access to safe water supply and sanitation (henceforth, W&S) is fundamental in health and development terms, and as such, has been a frequent subject of international conferences and declarations, by which universal access has been repeatedly advocated. The Millennium Declaration in 2000 included a pledge to "reduce by half the proportion of people without sustainable access to safe drinking water" by 2015, a goal that under the pace of recent progress seems hardly to be achieved in significant parts of Asia, Africa, Latin America and the Caribbean, where population is expected to increase rapidly (WHO/UNICEF, 2000).[1]

By 2000 one-sixth of the world's population lacked access to improved water supply[2] and two-fifths lacked access to adequate sanitation, despite the efforts made during the International Drinking Water Supply and Sanitation Decade, which set the goal for achieving universal coverage in 1990. At the core of the challenge is that so far, efforts to extend coverage have been barely enough to offset the pace of population growth, urbanization and productive use. Meanwhile, water supply is limited and becoming increasingly polluted. It is thus not surprising that water and sanitation has been one traditional area of international cooperation intervention.

This document undertakes the impact evaluation of a water and sewerage expansion project in Quito, Ecuador, that the Inter-American Development Bank financed in the mid-90s. The project was an effort to address the increasing pressure on services provision resulting from the rapid urban expansion of the city to the south. According to the 1990 census, the estimated rates of coverage

[1] Provision for an additional 1.5 billion people, or 280 thousand per day, is required to achieve the goal set for Africa, Asia, Latin America and the Caribbean for 2015.

[2] "Improved" water supply technologies refer to household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection. "Not improved" include unprotected well, unprotected spring, vendor-provided water, bottled water, and tanker truck-provided water. Access to an "improved source" implies provision of 20 liters per capita per day at a distance no longer than 1000 meters (WHO/UNICEF, 2000).

of potable water and sewerage services in Ecuador were 38.2 and 39.5 percent, respectively.[3] These numbers became 60 and 71.6 percent when considering only Quito, but were still low in relation to other Latin American countries. Rather than reestablishing the widely known association between provision of water and health, the aim of this study is to quantify the impact that access to water and sanitation has on health indicators, and to explore the mechanisms through which these occur.

The first part of the document briefly reviews the association between water and sanitation infrastructure investments and development, what we know about the impacts and what previous evidence has shown (section I). The second part focuses on the project and its context, presenting the recent evolution in mortality levels in Ecuador, and then describing the project itself (sections II and III). The third part focuses on the evaluation, presenting in detail the data and methodology employed and the results obtained (sections IV, V, VI and VII). The last part concludes.

[3] Population and household census, INEC. *Sistema Integrado de Indicadores Sociales del Ecuador.*

I. W&S Infrastructure and Human Development

A. The Links

Interventions in water and sanitation are mainly grounded on extensive historical evidence of disease reduction and epidemic control that followed the establishment of the earliest water and sanitation facilities.[4] The idea of a universal right to protection from disease and the consequent pursuit of positive public health improvements emerged first in Europe, in the early 19th century, as a natural result from urban growth and the progressive Enlightenment thought. Yet, significant investments required to set up and improve urban health systems occurred only after major epidemiological disasters, once civic leaders gained enough political power to devise public sources of funding (Meckel, 1990; Szreter, 1988).

More recently, access to water as a right has been fundamentally associated to the right to health established in the 1948 Universal Declaration of human rights. In 2002, the United Nations has further recognized water itself as a fundamental right (WHO, 2003a). Minimum consumption standards vary, but in general it is considered that at least 15 liters a day per person are required for drinking and sanitation purposes (table 1).

There is a long history of evaluations of water and sewerage expansions, which have typically explored the effects on health indicators. Since the 19^{th} century, in France, early public health and social epidemiology researchers carefully documented the diverging incidence of mortality by districts in Paris, relating them to wealth differentials and the variation in sanitary facilities (Coleman, 1982; Szreter, 2003). Actually, diarrhea, anthropometric measures and mortality in children are the typical outcomes explored.

The recent history has attributed the largest health burden from water, sanitation and hygiene diseases to infectious diarrhea (Prüss et al, 2002). In 1980 diarrhea was estimated to be the major cause of death among children, accounting yearly for 4.6 million fatalities. The World Summit of Children in 1990 established the reduction in diarrhea deaths as one of its major goals (LaForce et al, 2001; Kosek et al, 2003). In a context of overall decrease of child mortality, it is estimated

[4] For a review see Van Poppel and Van der Heidjen (1997).

that by 2000 diarrhea accounted for between 1.5 and 2.5 million deaths of children under-five (around 12-21 percent of child deaths under the age of five).[5]

Table 1: Minimum Water Consumption Standards (Drinking and Sanitation)

Standard	Source
At least 20 liters per person per day	WHO/UNICEF (2000)
15 liters per capita per day	The Sphere Project (2004)
20 liters per capita per day	WELL/DFID (1998) Carter et al. (1999)
25 liters per person per day	Gleick (1996)

Though diarrhea has been identified as the major contributor to the burden disease caused by water, sanitation and hygiene, malnutrition and a variety of diseases of diverse origin have also been associated with this burden (table 2). Water, sanitation and hygiene related diseases mainly originate from the ingestion of contaminated water or contact with contaminated water, lack of water for adequate hygiene, poorly managed water systems and vectors that proliferate in stagnant water. Moreover, besides health impacts, it has been argued that water and sewerage services have wider important socioeconomic effects, which can be observed in land prices, manufacturing costs and household productivity (Galiani et al, 2005; Jalan and Ravallion, 2003a; Savedoff and Spiller, 1999).

Even though the health effects of W&S interventions have historically been self-evident, recent research has focused on quantifying its impact on water-related diseases and on understanding the mechanisms through which these occur. In fact, reductions in incidence and prevalence of major water related diseases have been associated to water supply and sanitation interventions and quantified in academic studies. A reduction of about 20 percent in diarrhea incidence and between 5-27 percent for child mortality is typically found. Appendix I summarizes the main findings of selected studies around the World.

[5] See World Bank (2004), WHO/UNICEF (2000), Kosek et al (2003), Victora et al (2000), and LaForce et al (2001).

Table 2: Water related diseases

Classification	Definition	Examples
Water-borne diseases	Diseases caused by water that has been contaminated by human, animal or chemical wastes.	▪ Diarrhea ▪ Dysentery ▪ Cholera ▪ Polio ▪ Hepatitis A and E ▪ Guinea worm (dracunculiasis)
Water-washed/scarce diseases	Diseases caused by inadequate volumes of water for personal hygiene (diseases that thrive in conditions where freshwater is scarce and sanitation is poor).	▪ Trachoma ▪ Tuberculosis ▪ Tetanus ▪ Diphtheria
Water-based diseases	Diseases caused by aquatic organisms that spend part of their life-cycle in water and another part as parasites of animals, then directly accessing humans by ingestion or through the skin.	▪ Guinea worm (dracunculiasis) ▪ Schistosomiasis ▪ Ascariasis
Water-related vector diseases	Infections transmitted by vectors that breed and live in or near both polluted and unpolluted water.	▪ Malaria ▪ Dengue ▪ Onchocerciasis ▪ Typhus ▪ Yellow fever
Source: Bradley (1977); Van Poppel and Van der Heidjen (1997), WHO (2003b)		

B. Is W&S infrastructure Enough?

To isolate the effect of water supply and sanitation interventions on health outcomes is not an easy task. Infrastructure interventions are rarely the subject of an impact evaluation. The reason is that the ideal randomized scenario for evaluation is almost never attainable due to ethical and political considerations; water and sanitation services should be deemed as a fundamental right. In addition, interventions are usually carried out on at least county or village level, making it harder to identify valid comparison groups, even when the interventions are designed on successive stages.

More importantly, several studies[6] have shown that multiple factors interact simultaneously with the infrastructure investments to determine health outcomes. The role of other inputs, particularly their complementary or substitutive effect in relation to health outcomes has increasingly gained attention in academic studies. Hygiene and education are two such typical interrelated factors.

[6] See table 3

Water supply and sanitation investments do not translate inexorably into health improvements because for its effects to occur, other things -mainly change in hygiene behavior- might occur as well. The mechanism presumes other conditions, such as adequate operation of facilities, their use, and sometimes even the existence of certain cultural or environmental conditions. As an illustration, a study by UN in six countries found that modern water supply facilities were in general associated with lowest mortality ratios. However, in some areas piped water was more vulnerable to contamination than well or stream water, and in these areas the relationship reversed (Van Poppel and Van der Heidjen, 1997).

Several studies that have attempted to unravel the complementary effects of inputs usually looked at differentials in health outcomes according to levels of education, income or hygiene practices (table 3). Differences in mortality outcomes according to dwelling or household characteristics have suggested that attitudes and behavior related to health practices and personal hygiene, usually associated with levels of education, play a role as significant as investments in relation to health outcomes.

Table 3: W&S: Evidence of Complementary/Interactive Effects

Variable	Author	Country	Findings
Breastfeeding	Butz et al. (1984)	Malaysia	Presence of modern water and sanitation systems seems less important in terms of mortality for infants who undertook breastfeeding without supplementation during six months.
Parental Education	Merrick, T. (1985)	Brazil	The key change in the population characteristics contributing to the decline in child mortality from 1970 to 1976 was the increase in parental education, with access to water having a significant but secondary role. Significant ameliorating effect of increased access to piped water on differentials in child mortality by income class but other household characteristics also crucial, particularly, education.
	Lee et al. (1997)	Bangladesh Philippines	Neither variation in water sources nor improvements in sanitation facilities appeared to significantly affect child survival, although wealth and parental schooling levels were significantly and positively associated with higher survival.
	Jalan and Ravallion (2003a)	India	Other things equal, health gains from piped water are significantly larger for households with more educated females suggesting the importance of private inputs such as water and illness handling.

Source: Authors' literature review.

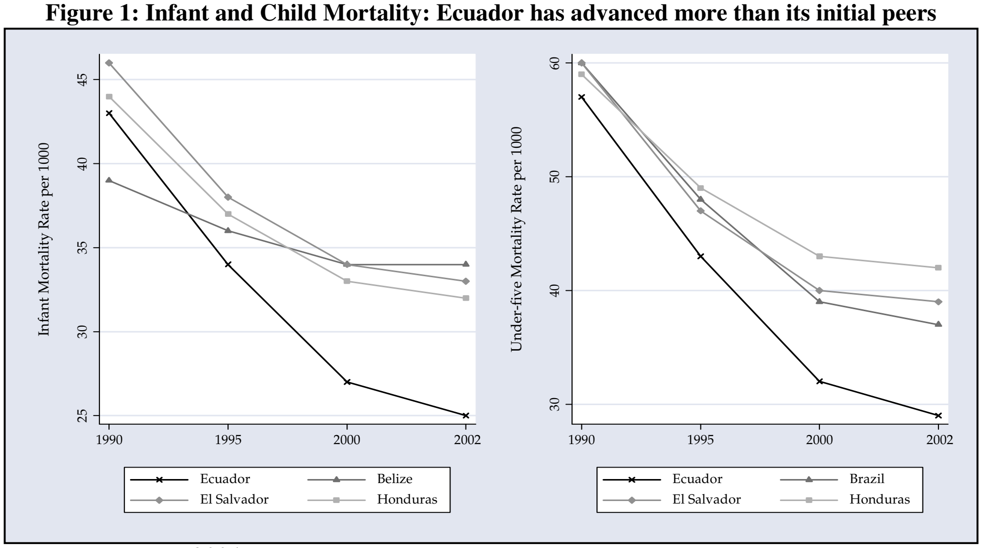
In particular, provision of piped water can improve the quality of water and/or induce greater water consumption, but, holding this element constant, the effect on health outcomes can be enlarged or minimized with practices such as oral re-hydration therapy, boiling and storage water, and with access to information and medical services. The possibility of finding heterogeneous treatment effects in the provision of water supply and sanitation constitute an empirical question to be addressed.

II. RECENT TRENDS IN CHILD MORTALITY IN ECUADOR: THE BIG PICTURE

As a guide to the context of the project at the time of the intervention, this section first examines child mortality at the national level. Examining the underlying general trend would provide an idea of the typical pace of change, thus helping to put in context the effects of the intervention before focusing our attention to the particular project results.

A review of child mortality shows that during the last twelve years the country has significantly improved the life conditions of its youngest population. According to UNICEF estimates, infant and under-five mortality levels have decreased considerably since 1990. Mortality of children under five years fell from 57 to 29 deaths per 1000 births, almost halving during that period. More significantly, the reductions achieved since the 90s exceeded the ones of countries with similar levels in that base year (Figure 1).

Figure 1: Infant and Child Mortality: Ecuador has advanced more than its initial peers



Source: UNICEF, 2004.

In relation to the world distribution of mortality, 55 percent of countries showed lower child mortality levels than Ecuador in 1991, while 46 percent did in 2002; suggesting somewhat a better position of the country in world and regional terms (Appendix II). Further reductions might be harder to achieve, since the lower the levels are, the more complex are the interventions required, usually involving reaching remote areas.

III. THE PROJECT

The Water Supply and Sewerage Project that began in 1994 aimed to respond to the increasing pressure for public infrastructure in the south of Quito, a geographical area that was experiencing a rapid demographic expansion. The recently created *Empresa Municipal de Agua Potable y Alcantarillado de Quito* (EMAAP-Q) undertook the project, with funds that amounted to $136 millions financed by the Inter-American Development Bank.

The principal objective of the project, according to the loan document was "to help improve the hygienic and health conditions of the population of the city of Quito by means of providing a more efficient and larger-capacity water supply and sewerage service". The project also included several specific objectives, some of which implied the realization of products while others implied the achievement of outcomes. Consequently, the project was basically an infrastructure expansion that planned provision of near 20 thousand household water connections and installation of approximately 300 Kms of sewers. The facilities covered around 22 neighborhoods in the south of the city. At the time of project completion, those initial targets had been surpassed, with about 22.4 thousand household water connections installed and around 400 Kms of pipelines provided.[7]

In fact, using GIS data we constructed maps to illustrate changes in access to potable water between 1990 and 2001 by *parroquias* (figure 2). In 1990, on average, 38.6% of households of *parroquias* in the south[8] had access to water. In 2001, this percentage became 73%. Similarly, at the city level, in 1990 the average percentage access was 60.7% while in 2001 the figure became 81.9%. Data confirms both that the percentage of households with access to water services increased significantly, and that the water expansion was skewed to the south of the city.

Besides the infrastructure investments, the project included both an institutional strengthening component and a master plan component. The former aimed to improve the administrative and commercial capacity of EMAAP-Q, and the latter aimed at establishing both a master plan for the expansion of the systems in the city and the medium and long-term investment program of the company.

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[7] Project completion report (IADB, 2003a).

[8] The area intervened, comprising neighborhoods in the following *parroquias*: Guamaní, Turubamba, La Ecuatoriana, Quitumbe, Chillogallo, La Mena, Solanda, y La Argelia.

In terms of impacts, the loan document anticipated explicitly some in terms of hygiene and health of the beneficiaries, in addition to others in terms of service, efficiency and institutional consolidation of EMAAP-Q. However, it is likely that unanticipated impacts of the water and sewerage expansion exist, even though these were not explicitly stated in the loan document.

Among these, it is reasonable to think of issues such as the formalization of land property and real state and their collateral effects; valorization in property; effects in complementary infrastructure investments such as education, health and transportation; expansion of commercial and industrial activities; and urban migration/displacement effects from marginal or low-income population to new areas of the city. [9]

Indeed, according to a long-time resident of one neighborhood in the south of Quito, the result of the project has been "*an increase in the property value and a significant improvement in the sanitary conditions.*"[10] Certainly, qualitative assessments could prove very useful in deciding which atypical impacts to explore. In any case, rigorous studies to assess the *general validity* of anecdotic evidence are highly dependant on available data. For this reason, those effects are beyond the scope of our evaluation. It is worth to note, though, that they can be incorporated into the evaluation design of new interventions.

Thus, considering the project's objectives and following the empirical literature as well as the data availability, we turn our attention to a child mortality indicator in order to evaluate this project. As a first glimpse, figure 3 illustrates the evolution of child mortality in Quito, based on our analysis of 1990 and 2001 census data. Two key observations stand up from these colored maps. First, we found a considerable decrease in overall levels of child mortality from 1990 to 2001, in accordance with the national trends analyzed. The second observation is that within Quito, the largest percentage change in child mortality levels has precisely occurred in the south of the city, namely our area of intervention. The obvious question that follows and that we intend to answer in the next sections, using impact evaluation techniques, is how much of this fall can be attributed to the water and sewerage expansion project?

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[9] According to the 1990 census about 70 percent of head of households living in the area of treatment were born in a different *parroquia* or city, and 11 percent of head of households used to live in a different *parroquia* or city five years before the survey was done. Using the 2001 census, those numbers became 68 percent and 10 percent, respectively.

[10] IADB (2003b). Authors' translation.

Figure 2
Urban Quito: Access to Potable Water; 1990-2001

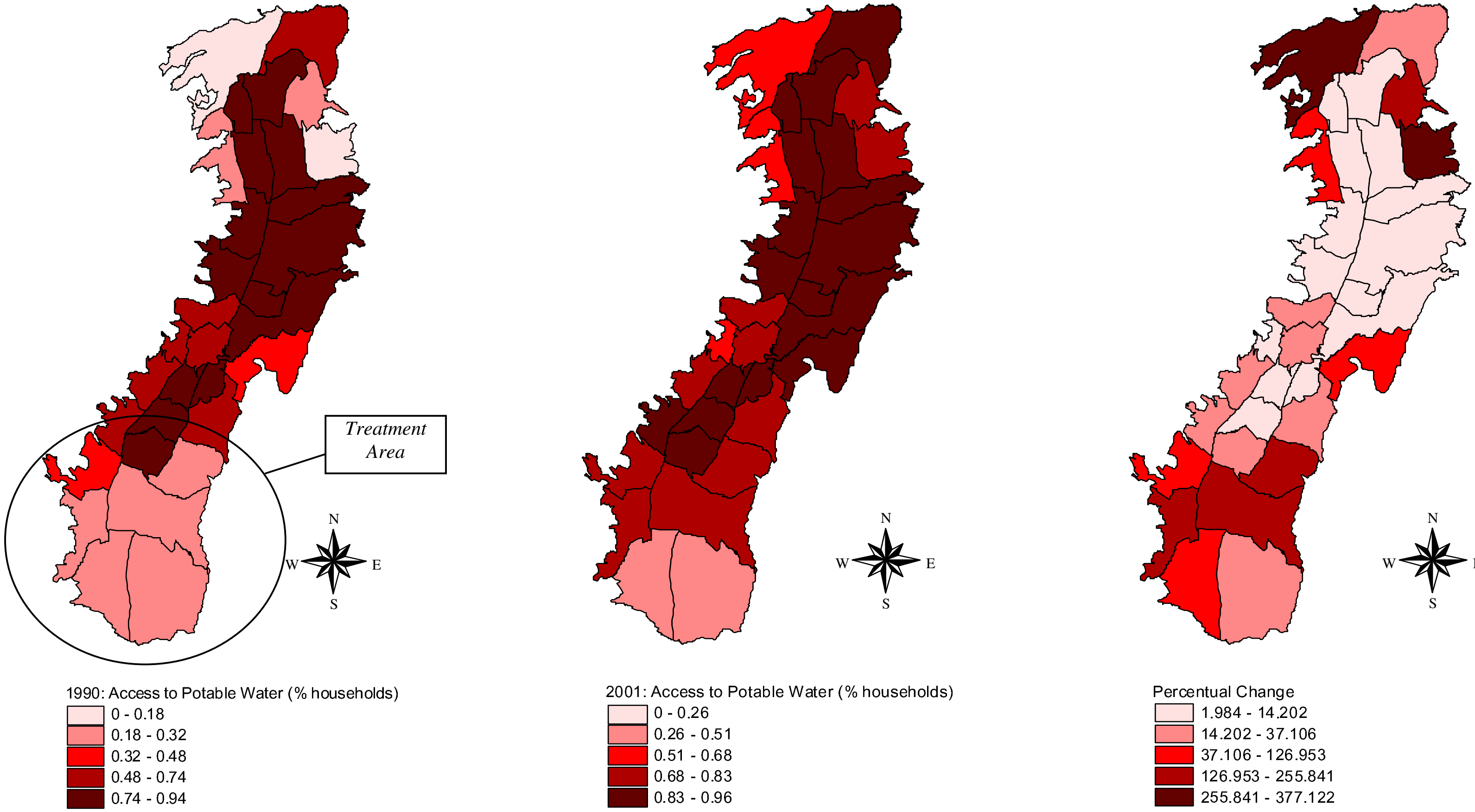
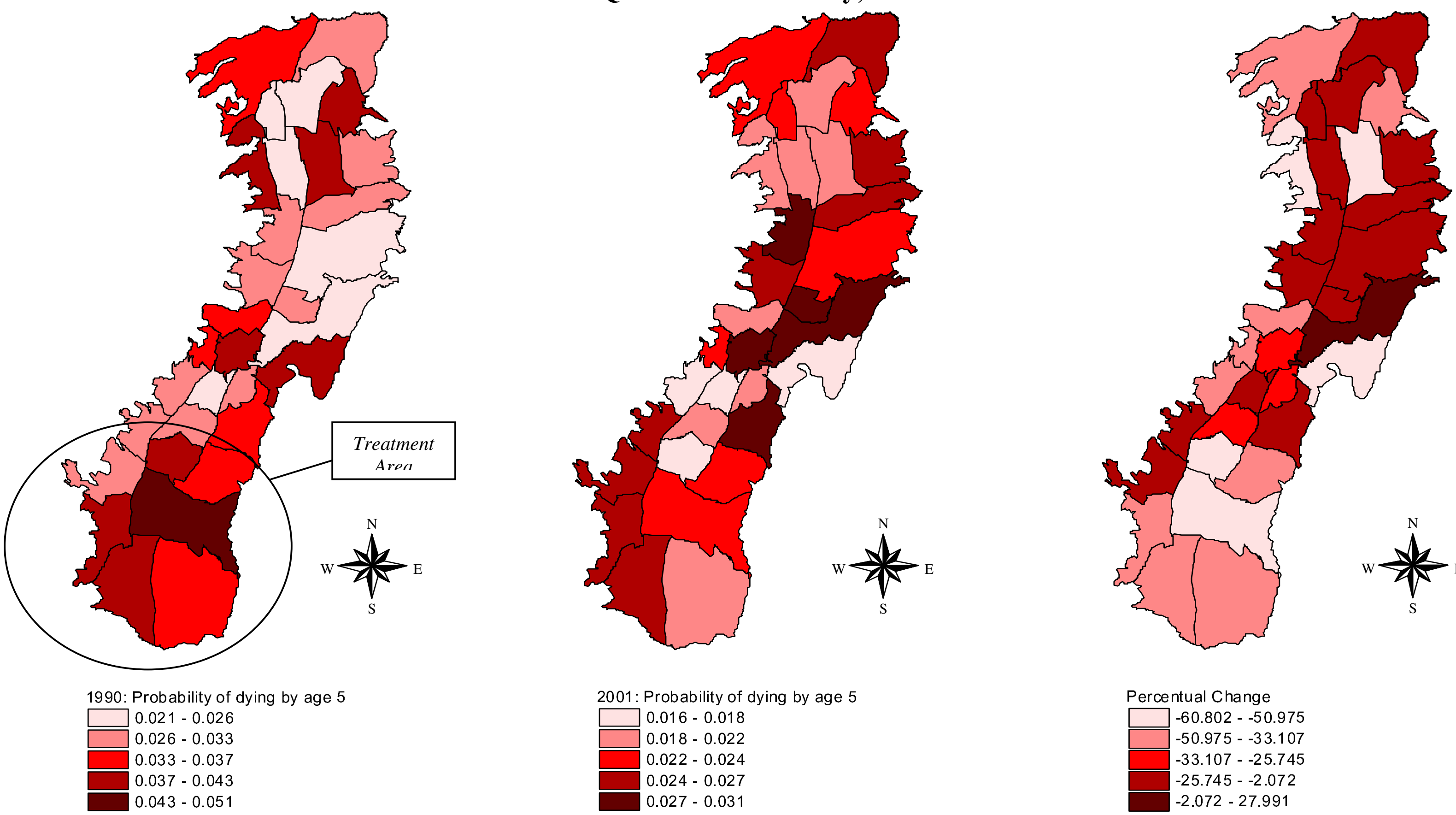


Figure 3
Urban Quito: Child Mortality; 1990-2001



IV. DATA

We took advantage of three sources of statistical information in order to evaluate the project's impacts:

A. Project Information

The EMAAP-Q has compiled information related to project implementation sequence. The data allow us to identify both the treated households and the date of treatment. Additionally, the data includes some information on water quality. Unfortunately, however, the information related to water quality is only available for treated areas.

B. Census, 1990-2001

We used census data gathered by Ecuador's National Institute of Statistics and Census (INEC) in November 1990 and November 2001. Both censuses comprised a large range of questions on demographic information and socioeconomic characteristics. In particular, both censuses included a specific module on mortality and fertility issues. Those variables allowed us to compute aggregate rates of infant and child mortality using the indirect methodology described below. Besides mortality measures, we were able to generate a large range of potential covariates at both woman and head of household levels, in addition to variables on dwelling features. Based on those covariates, we identified a comparison group using the propensity score matching method described below. Appendix III summarizes the information found in both censuses, referred to women aged 15 to 49, henceforth, our unit of analysis.

C. Encuesta de Condiciones de Vida (ECV), 1998

The *Encuesta de Condiciones de Vida* survey, a random sample of about 26,129 individuals and 5,801 households carried out between February and May 1998, contains data on a variety of household characteristics (including those on dwelling, demographics, labor and expenditure). Following Hentschel et al (2000)[11], we combined survey and census data in order to extrapolate a measure of household expenditure for the census. This measure is later used when analyzing the evaluation results for different levels of expenditure. The coefficients used in the extrapolation are presented in Appendix IV.

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[11] We will use this measure of expenditure to split our sample in a further exercise. We will not use this measure during the matching procedure.

V. MEASUREMENTS OF INFANT AND CHILD MORTALITY IN QUITO

Because of inadequacies on deaths registration, we employed indirect methods to estimate levels and trends of mortality.[12] Using the 1990 and 2001 census data, infant and child mortality rates were estimated from child survivorship data using the Trussell version of the well-known Brass Method. This standard demographic method is based upon retrospective reports of children ever born and children surviving. The technique comprises taking the proportion of the children dead to those ever born to women categorized by age group.[13] Those proportions are, then, converted into probabilities of dying. To do that, we multiply the proportion of children dead to those ever born to woman of age group by $k(j)$, an adjustment factor. Formally, the probability of children dying at age x, $q(x)$ can be expressed as follow:

$$q(x) = D(j) * k(j)$$

$$k(j) = \alpha_1 + \alpha_2 P_1 / P_2 + \alpha_3 P_2 / P_3$$

The adjustment factor is obtained by multiplying parity ratios by Coale-Demeny's West model coefficients.[14] Parity ratio P_1 / P_2 is the mean number of children ever born to woman aged [15-19] divided by the mean number of children ever born to woman aged [20-24]. Similarly, P_2 / P_3 is the mean number of children ever born to woman aged [20-24] divided by the mean number of children ever born to woman aged [25-29]. The coefficients α_1, α_2 and α_3 are taken from the standard Coale-Demeny life table model, in particular, we used the coefficients from the west regional family table. Hence, the method adjusts for the duration of exposure to the risk of dying, recognizing that the chances of death are naturally related to the age of the woman and to the timing of child-bearing.

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[12] Even when the National Institute of Statistics and Census (INEC) compiles mortality data from vital statistic registries, two kinds of problems were found when using Ecuador's vital registries to compute rates of mortality at disaggregate levels: (i) because the geographic location variable has only two levels of desegregation, it was impossible to obtain the ratios even at the relatively large *parroquias* level. (ii) it is also reasonable to expect certain level of underestimation using vital registries since those statistics are gathered only in hospitals.

[13] Following the standard method, seven age groups were considered: [15-19], [20-24], [25-29], [30-34], [35-39], [40-44] and [45-49].

[14] The West mortality model was employed because it resembles the most general path of mortality.

Thus, in a sense of cohort analysis, information of women in each age-group allow us to derive specific probabilities of dying, say $q(1)$, $q(2)$, $q(3)$, $q(5)$, $q(10)$, $q(15)$, or $q(20)$. For instance, survivorship data of women in age - group [25-29] and [30-34] are used to derive the probabilities of children dying by age 3 and 5, respectively. Furthermore, since we are usually interested in characterizing the evolution of age-specific mortality rates, say child mortality $q^c(5)$, we need to extrapolate the $q(x)$ values of each age group to a common $q^c(5)$ using again the west Coale-Demeny model life table. Naturally, the estimated $q^c(5)$ obtained from each age group is associated to the mortality level prevailing at some time prior to the census; as expected, estimates from elderly woman will be associated to earlier mortality levels. A reference date for each group is thus estimated. This reference date is derived in terms of a number of years prior to the survey, $t(j) = \beta_1 + \beta_2 P_1 / P_2 + \beta_3 P_2 / P_3$. The coefficients β_1, β_2 and β_3 are again those estimated in the standard west model life table (Trussell, 1975; Coale and Demeny, 1983; UN, 1983; UN, 1990).[15]

Figure 4 shows our estimated trends of infant and child mortality - $q^c(1)$ and $q^c(5)$, respectively- over the past 25 years in Quito. Several comments arise from figure 4. First, a decreasing trend is observed both in the urban and rural areas. Second, this decreasing trend is more pronounced in the rural than in the urban areas. In fact, we can observe that the child mortality rate of rural areas decreased from 94 per 1000 in 1976 to 24 per 1000 in 2001, corresponding to a 74 percent reduction. In contrast, we observe that the rate of child mortality in urban areas decreased from 63 per 1000 in 1976 to 21 per 1000 in 2001, meaning a 66 percent reduction. Third, even though there is a slight difference between rural and urban mortality rates in recent years, there is convergence. Fourth, there is an interesting consistence between the estimates of infant and child mortality derived from the 1990 and 2001 census, evident by the overlapping lines around 1990.

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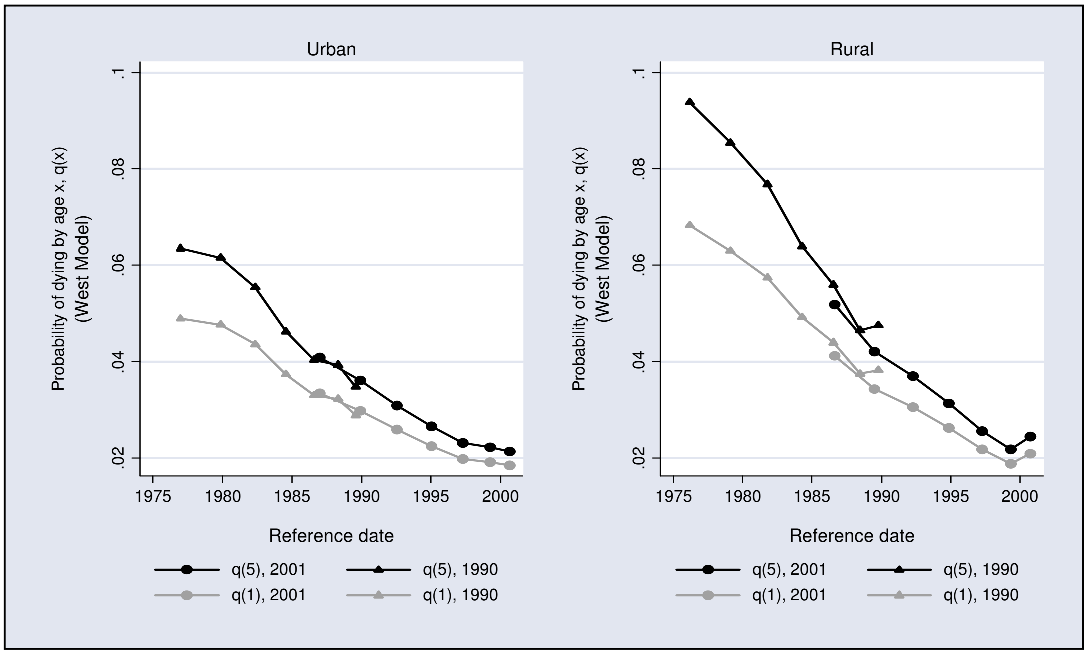
[15] Alejandro Aguirre (1993) proposes an alterative method by asking women, on the occasion of a birth, about the survival of their previous child. The proportion of previous children who have died produces an index of early mortality (π) close to q(2) [the probability of dying by age 2 described above]. The advantage of this method is the fact that it does not require to ask for the mother's age. However, we prefer to use the Trussell version of the well-known Brass method because its properties allow us to subsequently generate a measure of mortality at the mother level, which is important given the nature of the evaluation problem we face.

Figure 4: Canton Quito: Infant and Under-five Mortality1/

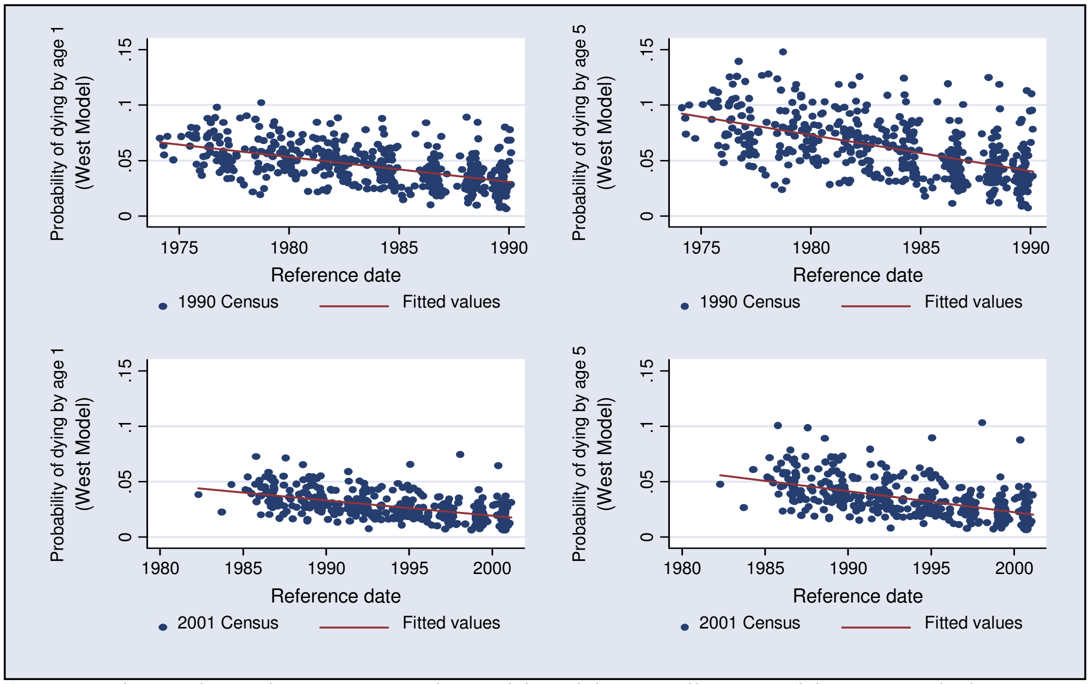


1/ Estimated using the Coale-Demeny mortality models and the Trussell version of the Brass method.
Source: Authors' analysis of 1990 & 2001 Ecuador Census.

The same procedure described above can be applied to census sub-samples. In particular, we applied the procedure at the *parroquia* level in Quito. Figure 5 shows that the levels of infant and child mortality fell from 1990 to 2001. The rate of child mortality in urban Quito ranged from 21 per 1000 to 51 per 1000 in 1990. Those numbers became 16 per 1000 and 31 per 1000 in 2001. Moreover, even though there are still differences in rates of infant and child mortality across *parroquias*, the dispersion across them has fallen since 1990 markedly.

The nature of the evaluation problem, however, requires a more disaggregated indicator of mortality. The alternative of using the number of children dead to women of different ages as an outcome is flawed. As mentioned before, the older the woman, the longer the period of exposure to childbearing and the longer the woman's children would have been exposed to the risk of dying.

Figure 5: Canton Quito: Infant and Under-five Mortality by Parroquia1/



1/ Estimated using the Coale-Demeny mortality models and the Trussell version of the Brass method
Source: Authors' analysis of 1990 & 2001 Ecuador Census.

Following Trussell and Preston (1982), Merrick (1985), Kabir (1993), Preston et al (2000), and Kiros and Hogan (2001), we constructed a mortality indicator at the individual level that controls for duration of risk and normalize the distribution of survival ratios. The mortality indicator M_i is constructed as the actual number of dead children reported by a woman divided by the expected number for her exposure group. The index was constructed considering only women between ages 15 and 49, which is deemed as the standard fertile period. It incorporated also some estimates from the Trussell-Brass method described above:

$$M_i = \frac{D_i}{q^c(5)/k(j)} = \frac{dead_i / born_i}{q^c(5)/k(j)} = \frac{dead_i}{born_i * q^c(5)/k(j)} = \frac{dead_i}{dead_i^e}, \quad i \in j$$

Where D_i is the observed proportion of children dead for woman i, $q^c(5)$ is the standard probability of dying by age 5 based, and $k(j)$ is the adjusted multiplier for the exposure group j.

VI. IMPACT EVALUATION METHODOLOGY

As Jalan and Ravallion (2003a) point out, traditional methods of assessing infrastructure impacts focus in the comparison of outcome indicators between geographic units that have the facility and those that do not at the aggregate level. Even though some studies have tried to control for some type of heterogeneity, failure to control for differences in characteristics or to properly weight units could bias the comparison between them. Also, the alternative of running a regression of the outcome indicator including a dummy variable for facility and control variables imposes functional form assumptions related the treatment and use the entire sample (Rosenzweig et al, 1982; Trussell et al, 1982; Wolfe et al, 1982; Merrick, 1985; Behrman et al, 1987; Esrey et al, 1991; Victora, 1988; Kabir et al, 1993; Gebre-Egziabher et al, 2001; Smith et al, 2003; Borooah, 2003).

A methodology that accounts for recent developments and allows us to identify properly the average effect of access to potable water and sewerage services on child mortality - the average impact of treatment on the treated (ATT) has tried to solve the problems mentioned above on the basis of estimations of propensity score functions. The basic idea behind the propensity score matching approach (PSM) is to balance the distributions of observed covariates in order to remove selection bias. In that sense, PSM also differ from past methods in that it takes only into account the matched units within a region of common support, while the remaining observations are dropped (Galliani et al, 2005; Pradham et al, 2002; Newman et al, 2002; Dehejia et al, 2002; Jalan and Ravallion, 2003a, 2003b).

A. The Evaluation Problem

The methodology briefly described below illustrates the nature of the evaluation problem we face, and it is suitable to evaluate not only the impact of improved water supply on child mortality but also on any other relevant outcome. A more detailed description can be found in Rosenbaum and Rubin (1983), Heckman et al (1997), Heckman et al (2000).

Let Y_0 and Y_1 be the child mortality indexes (potential outcomes). The problem arises because we only observe mutually exclusives states for the individuals but not both states at the same time: outcome Y_1 associated to treatment ($T = 1$) or outcome Y_0 associated to non-treatment ($T = 0$). Consequently, we cannot identify the impact of participation in the program for anyone, because of

missing data. What we can identify is the mean or distributional gains under some assumptions:

$$\Delta^{ATT} = E(Y_1 \mid X, T=1) - E(Y_0 \mid X, T=1) = E(Y_1 - Y_0 \mid X, T=1) \tag{1}$$

Because $(Y_o \mid T=1)$ cannot be observed, the evaluator's task is precisely to estimate the outcomes that would have been observed for participants had they not participated, Y_0. It is important to take into account that if we use the non-participants outcomes $(Y_o \mid T=0)$ to approximate the counterfactual $(Y_o \mid T=1)$ selection bias will remain, meaning that there may be systematic differences between treated and non-treated individuals (Heckman et al, 1997; 1998a). To solve this empirical problem, two estimators we used in order to calculate the average treatment on the treated, $\hat{\Delta}^{ATT}$: the Difference-in Differences (DID) estimator and Propensity Score Matching (PSM) estimator.

B. Difference-in Differences (DD)

Since those who participate could differ systematically from those who do not, we need an estimator that takes account for the time invariant unobserved heterogeneity. Thus, by using repeated cross-section data and estimating DD, we compare outcomes before and after a policy change (e.g. potable water provision) for both groups, those affected by the change (treatment group) and those not affected by the change (comparison group). Formally, we can write the difference-in-differences estimator as follows (Heckman et al, 1985; Mayer, 1995; Heckman et al, 2000):

$$\hat{\Delta}^{ATT} = E(Y_{1,t} - Y_{1,t'} \mid X, T=1) - E(Y_{0,t} - Y_{0,t'} \mid X, T=0) \tag{2}$$

C. Propensity Score Matching (PSM)

Heckman et al (1997, 1998) point out that when the impact of treatment on the treated is not homogenous across individuals, difference-in-differences estimates may suffer from two sources of bias. First, it is possible that some individuals are not truly comparable. Second, it is possible that the treatment and comparison group do not have the same distribution of observable attributes (X). Matching methods try to solve these sources of bias by paring treated individuals with non-treated individuals (comparison) that have the same distribution of observed characteristics. In other words, after matching the counterfactual outcome

distribution of the treated group is assumed to be the same as the observed outcome distribution of the comparison group (Rosenbaum and Rubin, 1983).

Propensity Score Matching (PSM) balances the distributions of observed characteristics between the treatment and comparison groups based on the similarity of their predicted probabilities of having treatment. In that sense, PSM is a weighing scheme, which determines what weights are given to units when estimating the treatment effect. Thus, when the observed characteristics of an untreated unit are closer to those of a treated unit, using a specific distance measure, the untreated unit receives a higher weight in constructing the match (Rosenbaum and Rubin, 1985; Heckman et al, 1997,1998a, 1998b).

The objective, therefore, is to identify a comparison group on the basis of the propensity score, $P(X) = \Pr(D = 1 \mid X)$. We used the odd ratio, $P(X)/1 - P(X)$, to pair each treated unit to some comparable untreated unit or group of untreated units by using a weighted scheme as follows:

$$\hat{\Delta}^{ATT} = \frac{1}{N_T} \sum_{j_T=1}^{N_T} \{Y_{1j} I^{CS} - (\sum_{i_C=1}^{N_C} W(i,j) Y_{0ij} I^{CS})\} \tag{3}$$

where Y_{1i} is the outcome for the treated units, Y_{0ij} is the outcome indicator of the *i*th non-treated matched to the *j*th treated, $W(i,j)$ are the weights applied in calculating the counterfactual mean, I^{CS} is a discrete variable that takes the value one is the units are in the common support region, N_T and N_C are the sample size of the treated and comparison.

Finally and taking into consideration that the differences among matching estimators are explained by weights, sample repetition, metric and common support, we used almost all the family of matching estimators to check out robustness: (a) 5-nearest neighbors, (d) Radius matching, (c) Kernel matching, and (d) Local linear regression-kernel matching.

VII. EVALUATION'S RESULTS

Before we describe the results, it should be recalled that our unit of analysis in this study is women aged 15 to 49. Also, it is important to mention that there are two caveats to account for in our study. First, the outcomes (child mortality index) we used to evaluate the project only reflect two years of treatment. It is therefore expected that any measure of impact still does not capture longer-time effects of the project. Likewise, given data availability, we relied on the assumption that observable characteristics of beneficiaries -from which the propensity scores are later derived- did not change significantly during the two years elapsed between the beginning of the project and the census survey. Second, our child mortality index accounts for all child death causes. It was not possible to construct an index that takes account for diverse death-typologies based on census data.

Prior to applying the matching methodology we tried to eliminate any evident source of bias. Given that we were interested in identifying potential beneficiaries that could serve as our matching units, we first dropped all the observations (women) that belonged to any dwelling geographically located outside the treatment area that already had access to potable water.[16] Also, we restricted our data set to observations within a common support area.[17]

Table 4 presents the estimates from the logit regression where the binary outcome takes the value of one if the woman lives in the treatment area and zero otherwise. The regressors comprise a wide range of both woman and head of household characteristics as well as dwelling characteristics.

Regarding head of household characteristics, we found that migrants are more likely to benefit from the program.[18] Similarly, we found a positive and significant association between participation in the program and years of schooling, married or permanent partner status and exclusive Spanish use. Migrant head of households are 5 percent more likely to be beneficiaries. These numbers for married and Spanish-fluently head households are 3.3 and 3.8 respectively. Also, we found a negative and significant association between age,

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[16] Unlike Pradham and Rawling (2002), we did not want to make the assumption that none of the households in the census had access to water in order to estimate the propensity score function.

[17] This was done by dropping treatment observations whose propensity score was above the maximum or below the minimum score of the potential controls.

[18] As already mentioned, the south area of Quito is a zone of rapid expansion due to a constant flow of migrant population.

years of residence in the area and male-headed of households and participation. Male-headed households are 4.4 less likely to be beneficiaries.[19]

Regarding women characteristics, we found again that migrant condition and Spanish use are positively associated with participation. Migrant and Spanish-fluently women are 3.5 and 4.5 percent more likely to receive treatment, respectively. Again, age and years of residence are negatively related with participation.

Table 4: Logit Estimation

Variable	Logit Coefficients	Marginal Effect
Characteristics of Head of Household		
Age	-0.0020	-0.0004
Migrant	0.2797	0.0502
Years of residence	-0.0027	-0.0005
Years of Schooling	0.0111	0.0020
Male	-0.2391	-0.0446
Married or	0.1875	0.0328
Speak only Spanish	0.2191	0.0376
Characteristics of Mothers		
Age	-0.0003	-0.0001
Speak only Spanish	0.2624	0.0445
Migrant	0.1953	0.0352
Years of residence	-0.0013	-0.0002
Characteristics of Household		
Proportion of males	0.0489	0.0089
Proportion of emigrants	0.1802	0.0326
Rooms per members	0.1369	0.0248
Has separate kitchen	0.3127	0.0538
Has room for economic activity	0.1519	0.0285
Nature of house: house	0.2376	0.0430
Nature of house: apartment	0.2389	0.0455
Nature of house: room in share house	-0.6774	-0.1084
Nature of house: shed	0.4519	0.0872
Has concrete roof	0.8167	0.1523
Has cement wall	0.9796	0.1499
Has parquet or hardwood floors	0.2354	0.0438
Has concrete structure	0.2257	0.0414
Has trash colleted by garbage truck	0.3121	0.0543
Has Electricity	0.1840	0.0319
Has telephone	0.1786	0.0330
Constant	-3.8725	
Number of obs	89699	
LR chi2(27)	13027	
Prob > chi2	0.0000	
Pseudo R2	0.123	

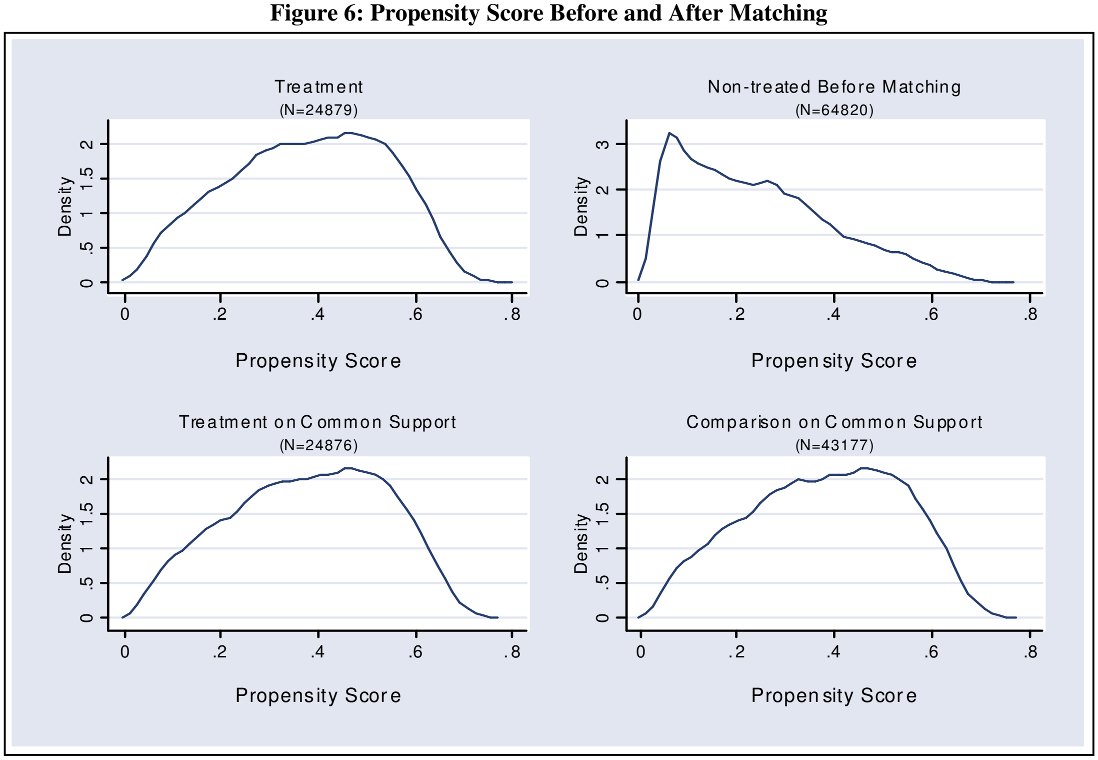
Standard error are in parentheses. * significant at 5%; ** significant at 1%.
Source: Authors' estimations based on data from 2001 Census.

[19] Jalan and Ravallion (2003a) found that female-headed households are more likely to have piped water in India too.

Regarding household characteristics we found that all the variables but the proportion of male members are statistically significant. We found that households with a large proportion of emigrants (3.3), more rooms per members (2.5), separate kitchen (5.4), room for economic activity (2.9), concrete roof (15.2), cement walls (15.0), hardwood floors (4.4), concrete structure (4.1), truck-garbage collection (5.4), electricity service (3.2) and telephone access are (3.3) percent more likely to be beneficiaries of the program. We also found that type of dwelling mattered.

Prior to matching, the average estimated propensity score for treated and non-treated units were 0.3780 (standard error of 0.1578) and 0.2387 (0.1526) respectively. After matching, those numbers became 0.3779763 (0.15783) and .3779751 (0.15782)[20] on the region of common support. Figure 6 reports the histograms of the estimated propensity scores for the two groups.

Figure 6: Propensity Score Before and After Matching



Note: The method used is the 5-nearest matching estimator.
Source: Author's estimation based on data from 2001 census.

[20] Those numbers correspond to the five nearest matching method.

Table 5: Propensity Score matching: Impacts of W&S on Child Mortality Index

	Mortality Index[1/]		
	n	Mean	Std. Err.
I). Naïve Evaluation [2/]			
Treatment	24974	1.1738	(0.0271)
Non-Treated	65036	1.3671	(0.0194)
ATT		-0.1933	(0.0356) **
II). 5-Nearest Neighbors matching [3/]			
Treatment	24876	1.1761	(0.0271)
Comparison	43177	1.2814	(0.0140)
ATT		-0.1053	(0.0305) **
III). Radius matching [4/]			
Treatment	24861	1.1768	(0.0272)
Comparison	64770	1.2645	(0.0036)
ATT		-0.0877	(0.0274) **
IV). Kernel matching [5/]			
Treatment	24876	1.1761	(0.0271)
Comparison	64820	1.2731	(0.0008)
ATT		-0.0970	(0.0272) **
V). Local linear regression matching [6/]			
Treatment	24876	1.1761	(0.0271)
Comparison	64820	1.2608	(0.0010)
ATT		-0.0847	(0.0272) **

Standard error are in parentheses. ** Indicates significance at the 5% level or lower; * Indicates significance between 5% and 10%.

1/ The mortality index is calculated as the ratio of observed proportion of children dead for woman j to the expected proportion of children dead for a woman j in her exposure group (See more detail in annex II).

2/ The naïve evaluation or cross-section estimator use non-participants outcomes to approximate the missing counterfactual participant's outcomes.

3/ Neigbor metric=pscore

4/ Kernel metric=pscore; Caliper, d=0.001

5/ Kernel metric=pscore; Kernel type= epanechnikov; We use h=0.1 as bandwidth parameter because it smooth the propnesity score. We also try with h=0.05 and the results do not differ much.

6/ Local linear regression metric = pscore, Kernel type= epanechnikov; Smoothing parameter, h=0.1.

Table 5 reports the average treatment on the treated (ATT) using four matching estimators (see equation 3).[21] Our estimated average impact of W&S on the child mortality index attributable to the 823/OC-EC project are all statistically significant. Child mortality among the population who received treatment would

[21] All estimates were obtained using Leuven and Sianesi's (2004) psmatch2 program for Stata.

be, on average, 8.0 percent higher without it. The average impact ranges from 7.2 percent (Local linear regression-kernel matching) to 9.0 percent (5-Nearest Neighbors matching). Those numbers are consistent with those usually found in the international literature (see Appendix I). As can be observed, the mean impact estimator differs significantly from estimates obtained with a naïve evaluation approach. In fact, using all the sample of non-treatment units as counterfactual, we would have estimated an average impact of 16.5 percent, overstating the intervention's effects.

In addition, one interesting result came to light when we looked at heterogeneity of impacts. Once we stratified the sample by quartiles based on expenditure per capita, no significant improvement among those in the bottom quartile is evidenced, as table 6 shows. There seems to be, however, significant and increasing impacts on child mortality in the top three quartiles. The counterintuitive finding of the poorest quartile, would suggest that the health gains not only depend on access to potable water but naturally would also depend on mother education, private allocations within the household (i.e., expenditure on combustible to boil the water or soap) along with other income-related factors (Wolfe et al, 1982, Jalan et al, 2003a).

In table 7 we report the joint effect of income and female education to rule out the hypothesis that income and female education interact jointly with access to potable water. Interestingly, we found that even in the poorest quartiles, if a woman has at least primary education, then the household obtains significant gains from water and sewerage interventions. This result would suggest that among poorest households, the education of women is a decisive factor to obtain the child-health benefits from water and sewerage interventions.

Finally, as a robustness check, we calculated the difference-in-differences estimators. Lacking an ideal baseline data collected immediately prior to the project, we were left with the 1990 census data as the main source to gauge the pre-project mortality situation, by identifying geographically the households that would become beneficiaries eight years later. Table 8 shows the difference-in-differences estimators we obtained. On the one hand, the so-called naïve estimator, which includes all non-participants as the comparison group, indicates that child mortality among the population who received treatment would have been 19 percent higher had the expansion not taken place. On the other hand, the matching difference-in-differences estimator, which comprises only those matched non-participants as the comparison group, attributes a mortality reduction of only about 8 percent to the project. Once again the naïve estimator seems to overstate the project's impact, something expected because while accounting for the time invariant unobserved heterogeneity, this estimator

ignores that treated and non-treated individuals are hardly comparable and may have different distributions on observable attributes. The matching difference-in-differences estimator aims to control for these two sources of bias. The results obtained with this estimator are pretty close to those obtained using the cross-section propensity score-matching estimators. Thus, the more sensible inference about the project's effects we can make, with the limited existent data, is that child mortality among the population who benefited from the W&S expansion would have been around 8 percent higher had it not occurred.

Table 6: Propensity Score matching: Impacts on Mortality by Expenditure Levels

		Full Sample		Bottom 25%		25%-50%		50%-75%		Top 25%	
	n	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
I). 5-Nearest Neighbors matching [1/]											
Treatment	24876	1.1761	(0.0271)	1.4370	(0.0555)	1.1902	(0.0539)	1.1373	(0.0544)	0.9397	(0.0531)
Comparison	43177	1.2814	(0.0140)	1.3347	(0.0282)	1.2931	(0.0282)	1.2595	(0.0274)	1.2390	(0.0280)
ATT		-0.1053	(0.0305) **	0.1023	(0.0622) *	-0.1029	(0.0609) *	-0.1223	(0.0609) *	-0.2993	(0.0600) **
II). Radius matching [2/]											
Treatment	24861	1.1768	(0.0272)	1.4370	(0.0555)	1.1908	(0.0540)	1.1374	(0.0544)	0.9414	(0.0532)
Comparison	64770	1.2645	(0.0036)	1.3280	(0.0087)	1.2873	(0.0075)	1.2410	(0.0071)	1.2018	(0.0086)
ATT		-0.0877	(0.0274) **	0.1091	(0.0557) *	-0.0965	(0.0545) *	-0.1036	(0.0549) *	-0.2604	(0.0539) **
III). Kernel matching [3/]											
Treatment	24876	1.1761	(0.0271)	1.4370	(0.0555)	1.1902	(0.0539)	1.1373	(0.0544)	0.9397	(0.0531)
Comparison	64820	1.2731	(0.0008)	1.3287	(0.0013)	1.2898	(0.0014)	1.2616	(0.0014)	1.2123	(0.0015)
ATT		-0.0970	(0.0272) **	0.1083	(0.0555) *	-0.0996	(0.0540) *	-0.1244	(0.0544) *	-0.2726	(0.0531) **
IV). Local linear regression matching [4/]											
Treatment	24876	1.1761	(0.0271)	1.4370	(0.0555)	1.1902	(0.0539)	1.1373	(0.0544)	0.9397	(0.0531)
Comparison	64820	1.2608	(0.0010)	1.3190	(0.0017)	1.2790	(0.0019)	1.2494	(0.0020)	1.1957	(0.0023)
ATT		-0.0847	(0.0272) **	0.1180	(0.0555) *	-0.0888	(0.0540) *	-0.1122	(0.0545) *	-0.2559	(0.0532) **

Standard error are in parentheses. ** Indicates significance at the 5% level or lower; * Indicates significance between 5% and 10%.

1/ Neighbor metric=pscore

2/ Kernel metric=pscore; Caliper, d=0.001

3/ Kernel metric=pscore; Kernel type=epanechnikov; We use h=0.1 as bandwidth parameter because it smooth the propensity score.

4/ Local linear regression metric = pscore, Kernel type= epanechnikov; Smoothing parameter, h=0.1.

Table 7: Impacts on Mortality: Interaction of Expenditure and Education

	Bottom 25% and at least Primary			25%-50% and at least Primary			50%-75% and at least Primary			Top 25% and at least Primary		
	Mean	Std. Err.		Mean	Std. Err.		Mean	Std. Err.		Mean	Std. Err.	
I). 5-Nearest Neighbors matching [1/]												
Treatment	1.0347	(0.0649)		0.9628	(0.0574)		0.9705	(0.0553)		0.8579	(0.0531)	
Comparison	1.3040	(0.0369)		1.2866	(0.0329)		1.2694	(0.0301)		1.2408	(0.0294)	
ATT	-0.2693	(0.0746)	**	-0.3239	(0.0662)	**	-0.2989	(0.0629)	**	-0.3829	(0.0607)	**
II). Radius matching [2/]												
Treatment	1.0347	(0.0649)		0.9634	(0.0575)		0.9707	(0.0553)		0.8596	(0.0532)	
Comparison	1.3286	(0.0071)		1.2800	(0.0087)		1.2393	(0.0074)		1.1984	(0.0092)	
ATT	-0.2939	(0.0653)	**	-0.3165	(0.0581)	**	-0.2686	(0.0558)	**	-0.3388	(0.0540)	**
III). Kernel matching [3/]												
Treatment	1.0347	(0.0649)		0.9628	(0.0574)		0.9705	(0.0553)		0.8579	(0.0531)	
Comparison	1.3232	(0.0017)		1.2896	(0.0017)		1.2620	(0.0016)		1.2107	(0.0016)	
ATT	-0.2886	(0.0649)	**	-0.3268	(0.0575)	**	-0.2916	(0.0553)	**	-0.3528	(0.0531)	**
IV). Local linear regression matching [4/]												
Treatment	1.0347	(0.0649)		0.9628	(0.0574)		0.9705	(0.0553)		0.8579	(0.0531)	
Comparison	1.3161	(0.0023)		1.2786	(0.0022)		1.2509	(0.0022)		1.1941	(0.0024)	
ATT	-0.2814	(0.0649)	**	-0.3158	(0.0575)	**	-0.2804	(0.0553)	**	-0.3362	(0.0532)	**

Standard error are in parentheses. ** Indicates significance at the 5% level or lower; * Indicates significance between 5% and 10%.

1/ Neighbor metric=pscore

2/ Kernel metric=pscore; Caliper, d=0.001

3/ Kernel metric=pscore; Kernel type= epanechnikov; We use h=0.1 as bandwidth parameter because it smooth the propensity score.

4/ Local linear regression metric = pscore, Kernel type= epanechnikov; Smoothing parameter, h=0.1.

Table 8: Difference-in-Differences: Impacts on Mortality

	Treated		Comparison		DD
	1990	2001	1990	20001	
Naïve Difference-in-Difference[1/]	1.4645	1.1738	1.3926	1.3671	-0.2652 **
	(0.0519)	(0.0271)	(0.0126)	(0.0194)	(0.0630)
Matching Difference-in-Difference with common support[/2]	1.4668	1.1762	1.4460	1.2738	-0.1184 **
	(0.0520)	(0.0271)	(0.0017)	(0.0007)	(0.0587)

Standard error are in parentheses. ** Indicates significance at the 5% level or lower; * Indicates significance between 5% and 10%.

1/ This estimator use all non-participants outcomes to approximate the missing counterfactual participant's outcomes.

3/ Kernel metric=pscore; Kernel type= epanechnikov; Smoothing parameter, h=0.1

VIII. CONCLUSIONS

Evaluations of infrastructure investments are rarely done since the need for universal or complete geographical coverage makes it harder to get valid comparison groups; indeed, water supply and sanitation services should be deemed as a fundamental right. This paper examined the impact of a water supply and sanitation program on child mortality in Quito, Ecuador. Studies have typically estimated the effects of this type of interventions comparing outcome indicators at the aggregate level of areas with the facilities and areas that lack them, quite often neglecting systematic differences between treated and non-treated areas. Improved water and sewerage services have typically been associated with child mortality, and we used it as our outcome of interest.

Because of inadequacies on deaths registration data, we used the Trussell version of the Brass method to indirectly estimate child and infant mortality rates, based on the 1990 and 2001 census data. According to our estimates, child and infant mortality in the Quito *canton* has decreased considerably during the last 25 years. We estimated that the child mortality rate fell 74 percent in rural Quito and 66 percent in the urban area. At the *parroquia* level, we found the same decreasing trend from 1990 to 2001, noting that although differences across *parroquias* remain, the dispersion across them has fallen notoriously.

In order to carry out the impact evaluation of the project with the available data, we needed a more disaggregated indicator of mortality. We constructed an index of mortality at the individual level, for women between ages 15 and 49, as a proportion of the number of children reported dead to an estimated expected number for her age group. Using this index as an estimator, GIS maps showed that, in fact, child and infant mortality fell considerably more in the south of the city, namely our area of intervention. However, in order to quantify the effect of the intervention and isolate it from potential confounding effects, we employed *propensity score matching* (PSM) techniques to gauge the project impact.

Our estimated average treatment on the treated (ATT) using four matching estimators -naïve or cross-section, nearest neighbors matching, 5-nearest neighbors matching, kernel matching and radius matching- were are all significant. Consistent with other studies found in the literature, we estimated that the average impact of the program ranges from 7.2 percent (Local linear regression-kernel matching) to 9.0 percent (5-Nearest Neighbors matching). Furthermore, to account for time-invariant unobserved heterogeneity, we calculated the matching difference-in-differences estimator using the 1990 census data, and found a reduction of about 8 percent in child mortality for the program

beneficiaries, resembling the results obtained with the PSM cross-section estimations. More importantly, we found that these estimates differ significantly from estimates obtained with the naïve approach. Indeed, considering all the sample of non-treated units as a counterfactual, we would have estimated an average impact of 16.5 percent with the cross-section estimator and of 19 percent with the difference-in-differences estimator. Both of these naïve estimates clearly overstate the intervention's effects.

Finally, one key finding of our study came to light when we explored how impacts varied across beneficiaries. Once stratifying the sample by quartiles based on expenditure per capita, no significant improvement among those in the bottom quartile was evidenced in relation to their matched individuals. In contrast, there seemed to be significant and increasing impacts on child mortality for the top three quartiles. This counterintuitive finding seemed explained once we looked at the heterogeneous impact of potable water access in terms of both income and female education. The results showed that even in the poorest quartiles, if a woman had at least primary education (access to information), then the household obtained significant gains from W&S interventions. This would suggest that the overall insignificant effect for the bottom quartile was driven by the absence of impact in those who completely lacked education, thus stressing the importance of complimentary private inputs in order to reap the benefits of piped water, as other studies have suggested (Jalan and Ravallion, 2003a).

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APPENDIXES

APPENDIX I: EFFECTS OF WATER AND SANITATION INVESTMENTS: SELECTED STUDIES

Study	Country	Data source	Indicators	Main Findings
Merrick, T. (1985)	Brazil	1970 Census and 1976 PNAD survey	▪ Child mortality at the individual (motherhood) level	▪ -0.1113 total effect of mothers' education on child mortality index in 1976 (-0.1099 in 1970) ▪ -0.1250 total effect of husbands' education on child mortality index in 1976 (-0.0762 in 1970)
Esrey et al. (1991)	Various	Survey of 144 studies from the 60s, 70s and 80s.	▪ Disease Incidence ▪ Disease Mortality ▪ Child Mortality	▪ -29% in ascariasis incidence (4 rigorous studies) ▪ -26% in diarrhea incidence (19 rigorous studies) ▪ -78% in dracunculiasis incidence (2 rigorous studies) ▪ -77% in schistosomiasis incidence (3 rigorous studies) ▪ -27% in trachoma incidence (7 rigorous studies) ▪ -55% in overall child mortality (6 rigorous studies)
Lavy et al. (1996)	Ghana	Second Ghana Living Standard Survey (GLSS) in 1988.	▪ Child survival ▪ Child anthropometric measures	▪ +10% in child expected survival time, –1/3 in rural-urban gap of stunting and –1/2 in rural-urban gap of underweight if rural water and sanitation facilities were upgraded to the level of cities. ▪ Child survival significantly related to poor quality of water and sanitation (drinking rain water and using latrines or pan buckets)

Study	Country	Data source	Indicators	Main Findings
Lee et al. (1997)	Bangladesh Philippines	1981-1982 Nutrition Survey of rural Bangladesh & 1984-1985 IFPRI Survey of Bukidnon, Philippines	▪ Child survival (proportion of children surviving to survey date) ▪ Child nutrition (anthropometric measures)	▪ No effect of water sources or sanitation facilities on probability of child survival ▪ Landholdings and parental schooling associated with higher survival ▪ No evidence of survival selectivity
World Bank (2000)	Nicaragua	FISE household survey	▪ % Δ in access to piped water ▪ % Δ in distance to nearest water source ▪ % Δ in stunting incidence	▪ +25% (aprox.) Δ in households with access to water upon FISE investments ▪ -600 mts Δ in distance to nearest water source upon FISE investments ▪ -11 percentage points (from 13.6% to 24.9%) in incidence of stunting upon FISE investments
Jalan and Ravallion (2003a)	India	Household survey by India's National Council of Applied Economic Research in 1993-1994.	▪ Prevalence of diarrhea among children under five years ▪ Reported illness duration	▪ -21.3% Δ in disease prevalence for those with piped water (PSM at household level) ▪ -29.4% Δ in illness duration for those with piped water (PSM at household level) ▪ Health gains from piped water are lower for children with less well-educated women in hh.
Galiani et al. (2005)	Argentina	1991 census and 1997 Encuesta de Desarrollo Social survey	▪ % Δ in child mortality rate (0 to 4 years old) ▪ % Δ in mortality by cause of death ▪ % Δ in proportion of households connected to water	▪ -6.7% Δ in Mortality rate (PSM, diff-in-diff) ▪ -5.2% Δ in Mortality rate (Kernel) ▪ -16.5 % Δ in Mortality rate from infectious and parasitic diseases ▪ -10.1 % Δ in Mortality rate from perinatal diseases ▪ + 1.8% % Δ in proportion of households connected to water (diff-in-diff)
Abou-Ali. (2002)	Egypt	Demographic and Health Survey 1995	▪ Infant, child and overall mortality	▪ -27% infant mortality for access to municipal water into the residence.

Source: Authors' literature review.

APPENDIX II: INFANT AND UNDER FIVE MORTALITY RATE PER 1,000 LIVE BIRTHS

Countries	1960	1990	1995	2000	2002	% change 90-02	Rank 1991	Countries Ahead 1991 (out of 129)	Rank 2002	Countries Ahead 2002 (out of 193)
Argentina	72	28	25	20	19	-32.1%	3	30.2%	3	30.1%
Bolivia	255	120	92	75	71	-40.8%	10	65.9%	10	66.3%
Brazil	177	60	48	39	36	-40.0%	7	48.8%	8	51.8%
Chile	155	19	14	12	12	-36.8%	1	24.8%	1	23.3%
Colombia	125	36	29	24	23	-36.1%	1	24.8%	5	38.3%
Ecuador	178	57	43	32	29	-49.1%	8	55.0%	6	46.1%
Paraguay	90	37	34	31	30	-18.9%	6	46.5%	7	48.2%
Peru	234	80	60	42	39	-51.3%	9	62.0%	9	53.9%
Uruguay	56	24	23	17	15	-37.5%	3	30.2%	2	25.9%
Venezuela	75	27	26	23	22	-18.5%	5	40.3%	4	37.8%

Countries	1960	1990	1995	2000	2002	% change 90-02	Rank 1991	Countries Ahead 1991 (out of 129)	Rank 2002	Countries Ahead 2002 (out of 193)
Argentina	60	25	22	17	16	-36.0%	4	30.2%	3	30.1%
Bolivia	152	85	70	59	56	-34.1%	10	71.3%	10	68.4%
Brazil	115	50	41	35	30	-40.0%	7	51.9%	8	52.3%
Chile	118	17	12	11	10	-41.2%	1	25.6%	1	22.8%
Colombia	79	30	24	20	19	-36.7%	2	27.1%	4	37.3%
Ecuador	107	43	34	27	25	-41.9%	8	54.3%	6	47.7%
Paraguay	66	30	28	26	26	-13.3%	6	47.3%	7	48.7%
Peru	142	60	46	32	30	-50.0%	9	61.2%	8	52.3%
Uruguay	48	20	20	15	14	-30.0%	3	28.7%	2	28.5%
Venezuela	56	23	22	20	19	-17.4%	5	41.1%	4	37.3%

Data source: UNICEF estimates, The State of the World's Children 1993 & 2004.

APPENDIX III: SUMMARY STATISTICS[1/]

Variable	1990 Obs	1990 Mean	1990 Std.	2001 Obs	2001 Mean	2001 Std.
Characteristics of Head of Household						
Age	372823	41.2640	12.9367	508263	41.2256	12.6154
Migrant	372823	0.5561	0.4968	508263	0.5533	0.4972
Years of residence				508263	47.9541	43.6727
Years of Schooling	372823	9.2915	5.4407	507282	9.5452	5.2812
Male	372823	0.7911	0.4065	508263	0.7280	0.4450
Married or Permanent Partner	371481	0.8288	0.3767	508066	0.8062	0.3952
Speak only Spanish	372823	0.9831	0.1287	508263	0.9598	0.1964
Characteristics of Women						
Age	372823	29.0151	9.2189	508263	29.8180	9.6460
Speak only Spanish	372823	0.9831	0.1287	508263	0.9595	0.1971
Migrant	372823	0.4783	0.4995	508263	0.4666	0.4989
Years of residence				508263	53.3959	45.37657
Married or Permanent Partner	368547	0.6027	0.4893	507774	0.5837	0.4929
Mortality Index	236356	0.9891	3.2361	325525	0.9759	4.2572
Characteristics of Household						
Proportion of males	372823	0.4303	0.1933	508263	0.4232	0.1992
Proportion of emigrants				508263	0.0397	0.1640
Rooms per members	372823	0.4952	0.2982	508263	0.5403	0.3032
Has separate kitchen	372823	0.8822	0.3223	508263	0.9095	0.2869
Has room for economic activity	372823	0.0926	0.2899	508263	0.0532	0.2244
Nature of house: house	372813	0.5256	0.4993	508263	0.5320	0.4990
Nature of house: apartment	372813	0.2336	0.4231	508263	0.2638	0.4407
Nature of house: room in share house	372813	0.1578	0.3646	508263	0.1172	0.3216
Nature of house: shed	372813	0.0762	0.2653	508263	0.0822	0.2747
Has concrete roof	372813	0.5297	0.4991	508263	0.6483	0.4775
Has cement wall	372813	0.8078	0.3940	508263	0.8964	0.3047
Has parquet or hardwood floors	372813	0.4159	0.4929	508263	0.5534	0.4971
Has concrete structure				508263	0.6021	0.4895
Has trash colleted by garbage truck	372813	0.7574	0.4286	508263	0.9001	0.2999
Has Electricity	372813	0.9425	0.2327	508263	0.9776	0.1481
Has telephone	372813	0.3475	0.4762	508263	0.5969	0.4905
Treatment	372823	0.0134	0.1149	508263	0.0491	0.2162

1/ All the statistics refer to women aged 15 to 49. Source: Author's analysis based on Quito's census data.

APPENDIX IV: ESTIMATES OF CONSUMPTION EXPENDITURES[1/]
(Dep. Variable: Logarithm of per capita consumption)

Variables	Coeficients		
Characteristics of Head of Household			
Years of schooling	0.0260	(0.0079)	***
Years of schooling squared	-0.0003	(0.0004)	
Potential experience	0.0072	(0.0030)	**
Potential experience squared	-0.0001	(0.0000)	***
Married	-0.0220	(0.0234)	
Male	0.0530	(0.0293)	*
Characteristics of Household			
Average years of schooling[1/]	0.0133	(0.0020)	***
Average years of schooling squared	-0.0001	(0.0000)	***
Size	-0.1898	(0.0212)	***
Size squared	0.0056	(0.0014)	***
Proportion of immigrants	0.4792	(0.3440)	
Proportion of immigrants squared	-0.2811	(0.2318)	
Rooms per members	0.0876	(0.0265)	***
Homeowner	0.0311	(0.0215)	
Has piped water within the home	0.0553	(0.0238)	**
Has piped sewage	0.0691	(0.0263)	***
Has electricity	0.2761	(0.0391)	***
Has telephone	0.1844	(0.0278)	***
Use gas to cook	0.3150	(0.0360)	***
Use electricity to cook	0.3395	(0.1471)	**
Nature of house: house	0.0497	(0.0273)	*
Nature of house: apartment	0.0814	(0.0356)	**
Has concrete roof	0.1425	(0.0571)	**
Has Eternit roof	0.2179	(0.0570)	***
Has zinc roof	0.1669	(0.0514)	
Has roof tile	0.0761	(0.0582)	
Has parquet floors	0.0730	(0.0362)	**
Has vinyl floors	0.0953	(0.0382)	**
Has cement floors	0.0953	(0.0227)	***
Quito	0.3539	(0.0335)	***
Coast	0.2364	(0.0327)	***
Sierra	-0.2354	(0.0362)	***
Constant	11.0460	(0.1626)	***
Obs	5616		
F	125.46		
R-squared	0.4336		

1/ Household members older than 14 and not considering the head of household.
Robust standard error are in parentheses. * significant at 10%; ** significant at 5%;
Source: Authors' estimations based on data from *Encuesta de Condiciones de Vida, 1998*

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