

Impact of piped water supply on infant mortality rate in Brazil

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Draft September 20, 2005

Submission for PAA 2006

Session 304 Handa - Child Well-being in Developing Countries

Session 802 Bilsborrow - Population & Environment: Water and Land

Short abstract

We examine the causal impact of piped water supply on the under one infant-mortality-rate (IMR) using a novel census dataset that divides Brazil into 3659 minimally comparable areas in 1991 and 2000. The first difference models, controlling for time invariant unobservables, indicate that the 14 unit improvement in percentage household with piped water supply between 1991 and 2000 reduced the under-1-IMR by 0.56 deaths per 1000 live-births, amounting to 3.5% of the mean decline in IMR between 1991 and 2000. The quartile regressions, that include the IMR for children aged 1-5, who are more resilient to water-borne diseases than children under 1, to control unobserved health inputs, indicate that the impact of piped water is more pronounced in areas with higher under-1-IMR. In 1991, a percentage point increase in piped water coverage reduced under-1-IMR at the 90th percentile by 0.25 deaths per 1000 live-births, but showed no reductions at the 10th percentile.

JEL codes: I-12, I-18, H41

Keywords: quantile regressions, spatial matching models, infant mortality, piped water

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1. INTRODUCTION

The Millenium Development Goals (MDG) aim to reduce by two thirds the under five infant mortality (Lenton et al, 2005). About 17% of the under 5 infant mortality between 2000-2003 is attributed to diarrheal diseases (UN, 2005). Improving access to safe drinking water is one of the proposed strategies to achieve this goal. This study estimates the impact of piped water on infant mortality in Brazil in 1991 and 2000. This estimate can serve as an input into cost-effectiveness analysis, that compares the provision of piped water with other MDG proposed public service interventions for the reduction of infant mortality in comparable developing countries. This study also explores the interaction between literacy rates and piped water supply, to detect the complementary, if any, of these two public investment goals.

Previous cross-sectional work may both understate and overstate the impact of piped water on infant mortality. Previous studies, by failing to address the selective placement of piped water supply, overstate the impact. Piped water is likely to be selectively placed in areas that enjoy superior medical care provision, and where higher incomes are used to purchase other health-related inputs (Rosenzweig and Wolpin, 1986). At the same time, previous studies, by focusing only on the mean effects of piped water on infant mortality, understate the impact. All things equal, the incremental effect of providing piped water may be larger in areas with a high infant mortality rate.

We make two contributions to the literature, first, data, and second, method. We use of the newly available census panel data from Brazil. The Brazilian Institute for Economic Analysis (IPEA), applying geo-referencing and aggregation techniques, have published data for consistently defined small geographical units in 1991 and 2000. This data, which divides Brazil into 3000 minimally comparable areas (MCA) provides the finest geographical resolution to date for Brazilian panel census data.² Prior to the publication of this data, the changes in geographical boundaries from one decade to another prevent the comparison of the 1991 and 2000 data at small spatial units, while the consistently

²The average and variance in the size of the AMC is.

defined spatial units at large levels of aggregation suffered from within unit heterogeneity.³

Our second contribution is the application of three estimation strategies to identify the impact of piped water (measured as percentage of households with piped water) on infant mortality (measured as the number of children under 1 who die per thousand live births). Using quantile regressions, we provide a range of estimates on the impact of piped water on infant mortality at varying levels of under 1 infant mortality rates. Our first estimation strategy is to use a first difference model, taking the difference between 1991 and 2000. This strategy controls for time invariant unobservables that may be related to both the provision of piped water and infant mortality. Our second estimation strategy is to use quantile regressions, to estimate the differential effect of piped water at varying levels of infant mortality, with mortality for children aged between 1-5 years old per 1000 live births as a control for unobservables. Public health researchers note that older children are more resilient against diseases inflicted by the lack of piped water (Butz et al, 1984). Our contention is that the ages 1-5 mortality rate can absorb the impact of other health-related inputs that have comparable effects on the mortality of children under 1 and on the mortality of children between ages 1-5. This method leaves the piped water supply variable to capture the effect of interest, i.e. the impact of piped water on under 1 mortality.

In our third strategy, we use matching model of neighboring MCAs, in order to compare spatially close locations that differ in their receipt of piped water supply but that are comparable in their proximity to Brazilian health facilities. All households in Brazil have a right to use the national health system and to receive treatment from facility that is funded or reimbursed by the national health care system. Households may therefore travel to public health facilities in neighboring MCAs. In contrast, households' receipt of piped water depends on their MCA location.

³ Potter et al (2002) use the previous version of decennial data, terminating in 1991, that divides Brazil into 518 microregions. Another data source, the household survey in Brazil, the Pesquisa Nacional Amostra de Domicilios (PNAD) also suffer from definitions of municipalities that are not consistent from one survey to another.

To our knowledge, previous studies on the impact of piped water on infant mortality have not used panel data, quartile models, or geographical matching models. Our results indicate that increased supply of piped water reduces infant mortality rate. The effect of piped water is more pronounced at higher levels of infant mortality.

2. PIPED WATER AND INFANT MORTALITY

Quality piped water supply can reduce exposure to waterborne diseases, such as diarrheal diseases, schistosomiasis, and cholera (Lenton et al, 2005).⁴ Diarrheal diseases are caused by bacterial (E Coli and Shigellosis), viral and parasitic enteropatogens. The most common cause of diarrheal diseases is E coli, that inflict epidemic and sporadic cases of diarrhea among infants. Shigellosis is most common among children aged two and four years old, and is usually mild, with treatment requiring only rehydration. Rotavirus cause serious sporadic diarrhea in young children. Common parasites are Giardia lamblia and Entamoeba histolica (Black, 1984 cited in Sastry and Burgard, 2002).

Transmission of pathogens occurs through the fecal-oral route as a result of person to person contact (such as hand to mouth contact) and exposure to contaminated food, water, and objects (Sastry and Burgard, 2002). Water supply, both quantity and quality, can reduce diarrheal disease by providing non-contaminated water supply and by enabling hygienic practices such as handwashing and proper food-handling (Sastry and Burgard, 2002). Piped water supply can potentially influence infant mortality directly and indirectly. Infants in Brazil are likely to be exposed to contaminated water and through poor hygiene from prepared food from an early age (Merrick, 1985) due to the short duration of breastfeeding (Anderson, 1981 cited in Merrick, 1985). Piped water supply can also influence infant mortality indirectly, by improving care provided to infants, when caregivers in the households are able to devote more time to childcare, instead of water collection activities.

⁴ Other waterborne diseases are trachoma, that is the leading cause of preventable blindness, and intestinal helminthes (ascariasis, trichuriasis, hookworm disease), that can lead to cognitive impairment, massive dysentery and anaemia. (Lenton et al, 2005)

We choose Brazil as a case study because diarrheal diseases are an important, though declining, cause of neonatal deaths Brazil. Diarrhea was a leading cause of infant mortality in the mid-1980s for Brazil, accounting for 17% of all infant deaths. By the mid-1990s, diarrhea was accounted for 8% of infant death (Victora, 2000). In Northeast Brazil, the poorest area within Brazil, diarrhea accounted for 41% of infant mortality in 1980, 25% in 1989, and 15% in 1995-7 (Victora et al, 1996, Victora, 2000).

To our knowledge, the one study with a longitudinal design is from the early 20th century United States. Cutler and Miller (2005) compare infant mortality before and after the introduction of clean water technologies in 19 US cities. Infant mortality declined with the introduction of these technologies, suggesting a causal relationship between clean water technologies and infant mortality. Plausibly, our results from present-day Brazil, which employs a longitudinal research design among other estimation strategies, may yield lessons that are directly transferable to other developing countries at similar stages of development in their provision of water supply.⁵ To date, most studies from developing countries have relied on cross-sectional evidence for the association between piped water and infant mortality. Merrick (1985) provides the most detailed study to date on the impact of piped water on infant mortality in urban areas in Brazil. Merrick (1985) uses 1976 cross-sectional data to estimate a structural model relating infant mortality to factors such as household level access to piped water, state-level piped water supply, maternal and paternal education and income.⁶ More recently, Jalan and Ravallion (2003) use propensity score matching techniques, so that they contrast households with piped water with households without piped water that are as comparable as possible on other observable dimensions, and by assumption, on other unobservable dimensions. In their sample of households in rural India in 1991, they find that the incidence of diarrheal diseases is higher in households without piped water.

⁵ Cutler and Miller (1995) write that the US in the early 20th century differs from present-day developing countries in important ways.

⁶ Merrick (1985) obtained piped water supply data from the 1970 Census that divided Brazil into 117 geographical units. In order to match the data to the PNAD household data, Merrick (1985) was forced to aggregate the data up to 25 states.

The cross-sectional models, that relate infant mortality and supply of piped water, suffer from unobservables that may bias the estimates. Unobservables include healthcare access and immunization coverage that are likely to be superior in areas where households have better coverage of water supply. In our quartile regressions, that relate under 1 mortality rate with percentage of households with piped water supply, we use mortality rate for ages 1-5 years old as a control variable for health-related unobservables. Our justification for the use of this control variable is as follows. Younger infants, when no longer breastfeeding, are more susceptible to mortality from diarrheal diseases compared to older children. While older infants may be more exposed to the environment and thus to pathogens, Butz et al, (1984) report that increasing resistance to the pathogens with age. For example, children more than 2 years old have substantial resistance to rotavirus diarrhea (Black et al, 1982b cited in Sastry and Burgard, 2002). Younger infants, while breastfeeding, obtain protection from pathogens that cause diarrhea, through the ingredients in breastmilk,⁷ and through exclusive breastfeeding that lowers the chances of infants being exposed to contaminated water and food (Sastry and Burgard, 2002). Diarrhea is likely to increase when the infant is first exposed to supplemental liquids or solids (Sastry and Burgard, 2002). This exposure is likely to occur at ages below 1 years old due to the fairly short duration of breastfeeding in Brazil (Sastry and Burgard, 2002). The Brazil-wide estimate of the duration for breastfeeding was 6.8 months in 1986, and 8.2 months in 1996 (Sastry and Burgard, 2002). The average duration of breastfeeding did not differ dramatically between the Northeast and the rest of Brazil (Sastry and Burgard, 2002). Variation by age in children's risk of mortality from environmental-related diseases is also reported in Esrey and Habicht (1986). Based on these facts, we argue that infants under 1 are more susceptible to mortality due to diarrheal diseases than are children between ages 1 and 5. The differences in mortality due to the access in healthcare facilities for these two groups may be smaller than that due to the lack of access to piped water. The mortality rate of children between 1 to 5 years as a control for unobservables such as access to healthcare facilities. To the extent that this variable can control for unobservables, and absorbs part of the effects of piped water interventions, our analysis provides lower-bound estimates of the magnitude of the impact of piped

⁷ Breastmilk contains specific rotavirus-neutralizing antibodies (Yolken et al, 1978).

water on reducing under 1 infant mortality rates. Lower-bound estimates of the magnitude of reduction that already suggest substantial benefits from piped water intervention would provide a strong justification for policy intervention. Nevertheless, we note that this strategy imperfectly controls for all unobservables. Several healthcare interventions, other than piped water, may have stronger protective effect for children under 1 than for children between 1-5 years old, such as immunizations. To the extent the unobservables act in this direction, our quartile regressions would overstate the impact of piped water on under 1 mortality in the quartile regressions. We deal with this issue, by presenting other estimation strategies, including the first difference model that is not biased by time-varying unobservables.

To identify the role of piped water, we control for access to healthcare facilities, in particular, the availability of public providers. The infant populations at risk of death from diarrheal diseases tend to be among the poorer population who would rely on public providers for basic healthcare. Public provision of healthcare in Brazil is through the Sistema Único de Saúde (SUS, Unified Health System), established in 1990 to provide healthcare for all citizens regardless of income. Facilities providing SUS services are financed publicly but vary in their ownership.⁸ County governments owned 69% of the clinics, while 27% are privately owned. State and county governments owned 8%, 23% and 67% of hospitals. (Pesquisa Assistencia Medico Sanitaria, 1999). Nevertheless, a person can seek care from any facilities that provide SUS services, including those outside her municipality of residence.

3. DATA

For the regression analysis, we use Brazilian census data from 1991 and 2000 at the level of minimally comparable areas (MCA). IPEA had generated this MCA level data from household level census data for those years. For the long-form interviews in 1991, 10% of the households were selected from municipalities with 15,000 inhabitants or more, and 20% for all others. To ensure that the 1991 and 2000 data covered the same spatial unit,

⁸ A private system, financed by private insurance plans, coexists with SUS. While the system provides superior care to the public system, only 25% of the population, i.e., those with higher incomes or employer provided insurance, use the private system (Alvarez, 1988).

IPEA aggregated the data up to 3659 minimally comparable areas or MCAs. The numbers of MCAs compare favorable with the number of municipalities in Brazil i.e. 4500 in 1991.⁹

4. ESTIMATION MODEL

We use under 1 infant mortality rate per 1000 live births as the dependent variable. Under 1 mortality rates from diarrhea, unavailable at the MCA level, would nevertheless have been a poor choice for an outcome variable, as vital statistics suffer from poor information on the cause of death, especially in poorer areas with high prevalence of diarrheal disease (Sastry and Burgard, 2002).¹⁰ As a starting point, we outline a linear model that relates infant mortality for children under age 1 and percentage of households with piped water at the MCA level.

$$Y_{kt} = \beta S_{kt} + \alpha X_{kt} + \varepsilon_k + \theta_{kt} \quad \text{Model 1}$$

where Y is infant mortality rate for children under age 1 per 1000 live births, regardless of cause of death.¹¹ S is the percentage of households with piped water supply. X represents a vector of other related health-inputs. ε is the time invariant error term, and θ is the time varying error term, k indexes the MCA (1, ...3000) and t indexes time (1991 and 2000). We run the cross-sectional model separately for year 1991 and year 2000. Control variables include variables on public services, such as MCA coverage for sewage facilities, garbage collection, and electric lighting. These variables are measured as percentage households in the MCA with these facilities. Other variables are literacy rates, rates of urbanization, the gini indicator of income inequality, income-based human development index, and the percentage of children living in poverty. In the cross-sectional model, we include dummies for 5 regions in Brazil, omitting one regional dummy, in order to account for geographical variations, such as temperature and rainfall. We exclude the potentially endogenous health expenditures variable because high infant

⁹ The absence of data on coverage of piped water at the MCA level prevents the extension of the panel analysis to other census years.

¹⁰ At present, IPEA has provided data for spatially compatible units in 1990 and 2000 for only a subset of census variable. For further description of the disease-specific patterns of infant mortality in Brazil we use decennial census from DATASUS at the municipal level.

mortality rates or disease rates may compel greater health expenditure. Regional dummies control for geographical variation (in rainfall and temperature) and regional-level administrative issues (e.g. investment in health).

The coefficient of interest, β , ideally, measures the impact of piped water on infant mortality. We include a range of control variables to control for other health-related inputs. Despite our inclusion of control variables, the cross-sectional model is likely to suffer from non-zero correlation between the error term ε_k and S , thereby leading to biased estimates of β . The correlation stems from the fact that areas with greater percentage of households with piped water is likely to also receive other complementary health inputs, which are variables omitted from Model 1.

Strategy one: first difference

$$\Delta Y_{kt} = \beta \Delta S_{kt} + \alpha \Delta X_{kt} + \Delta \theta_{kt} \quad \text{Model 2}$$

The first difference model, seen in Model 2, overcomes the estimation problem posed by the time invariant errors. However, the coefficient β estimated from Model 2 is still biased due the non-zero correlation between the time varying errors, $\Delta\theta$ and ΔS .

Strategy two: Cross sectional quantile regression with mortality ages 1-5 as a control for unobservables

OLS measures the mean change in the distribution of Y in response to a change in S . It is plausible that the response to S varies along the distribution of Y .¹² In other words, the impact of piped water on infant mortality may be more pronounced at high deciles of infant mortality rate than in the lower deciles. We use quantile regression to examine the impact of piped water at varying levels of infant mortality. A ‘simple’ quantile regression model is as follows:

¹¹ The AMC-level infant mortality data does not distinguish death from non-accidents and accidents.

Therefore, we are not able to apply a test for internal validity using infant mortality caused by accidents.

¹² OLS based on minimizing sums of squared residuals enable one to estimate models for conditional mean functions. Quantile regression methods offer a mechanism for estimating models for the conditional median function, and the full range of other conditional quantile functions (Koenker, x).

$$Y_{\rho kt} = \beta_{\rho} S_{kt} + \alpha_{\rho} X_{kt} + \delta_{\rho} H_{kt} + \varepsilon_k + \mu_{kt} - \text{Model 3}$$

where the subscript ρ indicates that the coefficients are for specific ρ quantiles. The coefficient β_{ρ} indicate the change in infant mortality, Y , due to changes in piped water supply, S , holding other variables (X and H) constant, defined for specific quantile.

The quantile regression, as seen in Model 3, suffers from the bias due to the unobservables. We cannot implement differencing within the quantile context to address the problems posed by the unobservables (Arias et al, 1999). Instead, we use infant mortality rate for children aged between 1-5 per 1000 live births, M , as a control for other unobserved health-inputs. In other words, the coefficient δ absorbs the effects from unobserved health inputs, leaving β to capture the effect of piped water on infant mortality rate for children under 1. Model 3 provides a lower-bound estimate for β because δ may have absorbed part of the variation in under 1 mortality that is due to piped water. Using this method, the correlation between the error term η_{kt} and ΔS can be as close to zero as possible. With the inclusion of the ages 1-5 infant mortality rate as a control variable, we interpret the results from model 4 as the causal impact of piped water on infant mortality.

$$Y_{\rho kt} = \beta_{\rho} S_{kt} + \alpha_{\rho} X_{kt} + \delta_{\rho} H_{kt} + \eta_{kt} - \text{Model 4}$$

where $C(S_{kt}, \eta_{kt}) = 0$

Strategy three: spatial matching model

We use a spatial matching model, in which we compare a MCA with neighboring MCAs within the same state. This strategy allows us to compare MCAs that have similar spatial proximity to SUS healthcare, and differ in their piped water supply. By comparing MCAs within the same geographical area, we are able to control for households' access to health-related inputs, such as access to medical care. In contrast, households' receipt of piped water supply would depend on their specific MCA location.

We plot the coordinates using ArcGIS.¹³ To identify the MCAs that are "spatially close" to a given MCA, we calculate the linear distances between the centroids of MCAs, where D_{km} = the distance between MCA k and MCA m . For MCA k , the MCAs that are its neighbors are those that fulfil the condition $D_{km} < \underline{D}$ where D is our defined cutoff. The vector V_k is a set of exclusive dummies that take the value 1 for MCA k and its neighbors, and zero otherwise. This vector of dummy variables allows us to compare MCA k with its neighbors. By restricting our comparison to neighboring MCAs, we control for the unobserved variation in medical care, (ε_k in Model 1), therefore, we expect the correlation between the error term and the piped water variable to be zero.

$$Y_{kt} = \beta S_{kt} + \alpha X_{kt} + V_k + \mu_{kt} \quad \text{Model 5}$$

where $C(S_{kt}, \mu_{kt}) = 0$.

Heteroskedastic-consistent standard errors are estimated for all three types of models, i.e., Models 2, 4 and 5.

5. DESCRIPTIVE STATISTICS

As seen in Table 1, the mean under 1 mortality rate declined from 49 per 1000 live births in 1990 to 34 per 1000 live births in 2000. Percentage of household with piped water grew from 58% in 1990 to 72 % in 2000. Spatial variation is detected in infant mortality rate and piped water supply. Infant mortality rates are highest and the supply of piped water is lowest in the Northeast region.

6. REGRESSION RESULTS

I review three set of results, first, the simple OLS, second, the first-differenced models, and third, the quantile regressions. The fourth set of analysis, from the spatial matching models, are in progress.

6.1 OLS

¹³Information on projection will be added shortly.

All estimates are statistically significant at conventional levels ($\leq 10\%$ level) unless otherwise stated. We begin with results from the OLS regressions in Table 2. The results from the cross-sectional OLS regressions are reported in columns 1-4. Column 1 and 2 report results from the first two regressions, that are sparsely specified, relating infant mortality under 1 (measured as infant mortality rate for children under 1 per 1000 live births) and piped water (measured as percentage of households with water supply). In 1991, an increase of 1 percentage point in piped water coverage is associated with a mean decline of 0.53 in the under 1 infant mortality rate. In 2000, the corresponding mean decline is 0.65.

The next two columns (columns 3 and 4) are results from fuller specification of the OLS cross-sectional model. As expected, with the additional controls, the magnitude of the association between piped water supply and infant mortality declines. In 1990, an increase of 1 percentage point in piped water coverage is associated with a mean decline of 0.14 in the under 1 infant mortality rate. In 2000, the corresponding mean decline is 0.19.

6.2 First difference

The next set of results (column 5-6) is from the first difference model. Column 5 are results from a sparse specification of the first difference model, relating the change in under 1 infant mortality rate and the change in piped water coverage. Column 6 indicates results from a second specification of the first difference model, with changes in age 1-5 mortality rate added as a control variable. The estimated coefficient in column 6 is similar to that in column 5.

As expected, the magnitude of the estimated coefficient is smaller in the first difference model relative to that in the OLS. Notably, the size of the coefficient remains statistically significant. An increase in piped water supply of one percentage point causes the under 1 infant mortality rate to decline by 0.04. It would be useful to assess the economic significance of these results. The mean improvement in percentage household with piped water supply between 1991 and 2000 is 14%. This mean improvement in piped water

supply reduced the under 1 infant mortality by 0.56 deaths per 1000 live births. The reduction amounts to 3.5% of the mean decline in infant mortality rate between 1991 and 2000 of 16 deaths per 1000 live births.

6.3 Quantile regression

Results from the quantile regressions are tabulated in Table 3 column 1-12. The ages 1-5 mortality rate is excluded in columns 1-6 and included in columns 7-12. Comparison of columns 1-6 and 7-12 indicate that, for the 50th and 90th deciles, the inclusion of the aged 1-5 mortality rate, as expected, reduces the magnitude of the decline in mortality rate that is associated with an increase in piped water supply.

We discuss in more detail the results from the specification that includes the 1-5 mortality rate in columns 7-12. Results for the cross-sectional quantile regressions for 2000 is in columns 7-9, and those for 1990 are in column 10-12. Results for the 10th decile are presented in columns 7 and 10, those for 50th decile are presented columns 8 and 11, and finally, those for the 90th decile are in columns 9 and 12.

A comparison of column 7, 8 and 9 indicate that piped water supply in 2000 has a more pronounced effect in the 50th and 90th decile of infant mortality rate than in the 10th decile. A percentage point increase in piped water coverage is associated with a decline in the under 1 infant mortality rate of 0.15 deaths at the 90th decile and 0.14 deaths at the 50th decile. In contrast, a percentage point increase in piped water coverage is not associated with a statistically significant decline in the under 1 infant mortality rate. Similar patterns are seen for piped water supply in 1990, evident in column 10, 11. and 12. A percentage point increase in piped water coverage is associated with a decline in the under 1 infant mortality rate of 0.25 deaths at the 90th decile and 0.18 deaths at the 50th decile. In contrast, a percentage point increase in piped water coverage is not associated with a statistically significant decline in the under 1 infant mortality rate.

6.4 Spatial matching model

In progress.

7 Conclusion and Policy Discussion

Our study examines the impact of piped water supply on infant mortality rate using three different estimation strategies, the first difference model, the quartile regressions with 1-5 mortality rate as a control variable, and a spatial matching model. We apply three identification strategies to control for unobservables: the first difference model between 1991 and 2000, a cross-sectional quartile model with mortality rate for children aged 1-5 as a control variable, and a spatial matching model to control for access to healthcare facilities. We present two main results, first, the first difference model indicate that the mean improvement in percentage household with piped water supply between 1991 and 2000 of 14% translates to a reduction in under 1 mortality rate of 0.56 deaths per 1000 live birth. This reduction accounts for 3.5% of the mean decline in infant mortality rate between 1991 and 2000 of 16 deaths per 1000 live births. Second, the quartile regressions indicate that the impact of piped water is more pronounced in areas with higher infant mortality rates, suggesting that mean regression analysis understate the benefits of improved water supply. In 1991, a percentage point increase in piped water coverage reduced under 1 infant mortality at the 90th decile by 0.25 deaths, but did not show reductions at the 10th percentile.

This study is subject to several caveats. For the quantile regression, mortality rate for children aged 1-5 is used to control for unobservables. Our assumption is that two groups of children, those below 1 year of age, and those between 1-5 years old, are similarly susceptible to the unobservable factors, and that the former are more susceptible to the lack of piped water. However, the assumption of comparable susceptibility to unobservables may not hold for some types of health interventions, such as immunization.¹⁴ Nevertheless, the first difference model, which eliminates time-invariant unobservables in a ‘cleaner’ manner than does the quantile specification with the 1-5

¹⁴ “Victora et al (1996) suggests that in Brazil, a large increase in the use of ORT played a central role in reducing deaths due to diarrhea, and moreover, that the reduction in diarrheal deaths accounted for a large part of the substantial increase in child survival from the mid-1980s to the mid-1990s.” cited in Sastry and Burgard (2002).

mortality rate as a control variable, still yields evidence that larger coverage of piped water supply for households causes a reduction in under 1 infant mortality rate.

Our causal-focused study shows that providing piped water supply to households can reduce infant mortality. About 17% of the under 5 infant mortality between 2000-2003 is attributed to diarrheal diseases (UN, 2005). Longer-term investment strategies such as the provision of piped water to households can contribute towards the reduction of infant mortality. The next step in our study is to calculate the social rate of return to investments in piped water supply.

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Table 1: Summary statistics	Mean	Std Dev
Percentage of households with piped water (2000)	72	27
Percentage of households with piped water (1991)	58	30
Mortality rate for children under 1 per 1000 live births (2000)	34	18
Mortality rate for children under 1 per 1000 live births (1991)	49	24
Mortality rate for children aged 1-5 per 1000 live births (2000)		
Mortality rate for children aged 1-5 per 1000 live births (1991)		

Table 2: Results for OLS and First Difference models

	(1)	(2)	(3)	(4)		(5)	(6)
Model	OLS	OLS	OLS	OLS		First Diff	First Diff
Depvar	IMR	IMR	IMR	IMR		D_IMR	D_IMR
Year	2000	1991	2000	1991			
Water	-0.53** (0.07)	-0.65** (0.08)	-0.14** (0.02)	-0.19** (0.02)	Dwater	-0.04* (0.02)	-0.04* (0.02)
Controls	excl	excl	incl	incl	Dcontrols Ddeath	incl	incl -0.03* (0.02)
Adj R-sqr	0.64	0.62	0.78	0.79		0.78	0.79
Obs.	3659	3659	3659	3659		3659	3659

IMR = Infant mortality rate for children under 1 per 1000 live births

D_IMR = IMR 2001 - IMR 1991

Water = the percentage of households with piped water

Controls = control variables, as described in the text.

Dwater = percentage in households with piped water in 2001 -
percentage in households with piped water in 1990

Dcontrol = control var in 2000 - control var in 1991, for the respective
control variables

Ddeath = Infant mortality rate (for children aged 1-5) per 1000 live births in 2001
Infant mortality rate (for children aged 1-5) per 1000 live births in 1990

Table 3: Results for Quantile Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Year	2000	2000	2000	1991	1991	1991	2000	2000	2000	1991	1991	1991
	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
Water	-0.10+	-0.16**	-0.17**	-0.06	-0.2**	-0.27**	-0.01	-0.14**	-0.15**	-0.08	-0.18**	-0.25**
	(0.06)	(0.01)	(0.07)	(0.07)	(0.02)	(0.08)	(0.05)	(0.01)	(0.06)	(0.06)	(0.01)	(0.08)
Ddeath	excl	excl	excl	excl	excl	excl	1.8**	0.8**	0.27**	0.79**	0.64**	0.40**
							(0.07)	(0.02)	(0.09)	(0.08)	(0.02)	(0.09)
Control												
var	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl	incl
Adj-R-sqr	0.77	0.78	0.78	0.78	0.78	0.79	0.60	0.80	0.80	0.80	0.82	0.82
Obs.	3659	3659	3659	3659	3659	3659	3659	3659	3659	3659	3659	3659

Notes: Variables are as defined in Table 2. Notes: ** statistically significant at the 0.05 level. * statistically significant at the 0.10 level

Notes: + statistically significant at the 0.15 level.