ABSTRACT

CHEEMA, MALIHA. The Impact on Health and the Willingness to Pay for Piped Water in Punjab, Pakistan. (Under the direction of Mitch A. Renkow).

Every year some 3.4 million people worldwide, mostly children, die from diseases associated with poor water quality, sanitation and hygiene. In Pakistan, it is estimated that about 200,000 children die every year of water-related diarrheal diseases. Piped water is commonly thought to mitigate the public health consequences of water borne diseases; however, the empirical evidence on the health effects of piped water is mixed at best.

This study measures the health effect of piped water in the Punjab, where most Pakistanis reside, by analyzing the impact of piped water on the incidence of diarrhea in children under the age of 5. The results show that piped water has no significant effect – positive or negative – on diarrhea in children in rural areas; that piped water has an adverse health effect in urban areas, and is associated with increasing the probability of diarrhea in children by an average of 2.2 percentage points; and that in both areas proximity of piped drinking water and wastewater confers additional health risks, presumably due to cross-contamination. At the very least, the empirical findings offer no support to the view held by some that publicly provided water has beneficial health impacts. Indeed, for urban areas they implicate piped water as contributing to negative child health outcomes.

Since poor service of public water systems often leads to customer dissatisfaction and lower collection of water tariffs, this study also analyzes the willingness to pay for piped water at the mean levels of service, and predicts how the willingness to pay may change if services were improved to provide better quality water, and for more duration per day. The results show that piped connections add a positive and significant value to the imputed house rental price in both rural and urban areas; that the value of piped water increases as water table depth, groundwater salinity, and duration of piped water flow per day increases; and that it falls as the percentage of households in a district with bacteria present in their piped water increases.

Taken together, these findings suggest that improving both the quantity (i.e., increasing the duration of flow daily) and water quality have a significant effect in increasing the willingness to pay for piped water. The results also indicate that households are willing to

pay more for an improvement in quality of piped water than for an increase in the duration of flow, and that the response is higher in areas where alternatives to piped water are harder or more costly to find.

The Impact on Health and the Willingness to Pay for Piped Water in Punjab, Pakistan

by
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DEDICATION

Alhumdulli Allah. All Praise to God.

To Ami and Abu

BIOGRAPHY

Maliha Cheema was born in Kaduna, Nigeria. When she was 2 years old, her parents moved to Dammam, Saudi Arabia, where she grew up. After high school she moved to Lahore, Pakistan to get a Bachelor's degree in Economics at the Lahore University of Management Sciences. During her senior year in college she worked on a project titled 'Why Are So Many Pakistanis Poor? An Empirical Study of the Factors Contributing to the High Poverty Rates in Pakistan' which was presented in the Asian Economic Conference in New Delhi, India in 2004 and won second place. During the project, she realized her interest in research on Economic issues, especially those concerning the South Asian region.

In 2004, Maliha joined North Carolina State University for a Master's degree in Economics. For one of her Master's courses she decided to further her research on the issues of development and poverty in Pakistan. It was then that she decided to pursue a PhD and take her research to the next level. On one of her research trips to Pakistan during this time, she realized the scarcity of safe water sources in her home province of Punjab, and decided to direct her research particularly on those issues.

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CHAPTER 1
INTRODUCTION

Water is essential for human beings to survive and develop. At the same time, water is a scarce commodity, and shortage very often results in crises. Almost 70 percent of the surface of the earth is covered with water, which by volume constitutes almost 1386 million km3. Despite being in abundance, almost 97 percent of that water is saline and only the remaining 3 percent is fresh water (Gleick et al. 2009). Humans use only 1 percent of freshwater, of which 99 percent is groundwater and the remaining is from surface water sources (PCRWR, 2010).

To complicate the matter, water is not evenly distributed throughout the world. More than half of the renewable freshwater supply is located in only about ten countries (Gleick et al., 2009). Moreover, water pollution (domestic and industrial) has reduced the amount of freshwater available for consumption. Global water demand, on the other hand, has been increasing due to an ever-rising world population and growing demands from agricultural and industrial users. The world's population has increased by almost 1.5 billion people since 1990 and 94 percent of this growth has occurred in developing regions. Between 1990 and 2008, the proportion of the world's population with access to improved drinking water sources increased from 77 percent to 87 percent (UNICEF, 2011). Despite this progress, a majority of developing countries are failing to increase access to improved drinking water sources in line with population growth.[1]

In addition to population growth, the process of rapid urbanization presents challenges to increasing access to improved drinking water. The proportion of the world's population that lives in urban areas has increased from 43 percent in 1990 to 50 percent in 2008.

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[1] Most developed countries have been successful in keeping pace with population growth. According to the U.S. Geological Survey, an estimated 86 percent of the U.S. population obtained water through tap water networks where households pay a fee for a certain level of water service, while the remaining 14 percent relied on private wells (Kenny et al. 2009).

Worldwide, the number of urban dwellers who gained access to improved drinking water – defined as sources that, by nature of their construction or through active intervention, are intended to be protected from outside contamination, and include piped water, public taps, tube wells, protected dug wells, and protected springs – between 1990 and 2008 was 1.052 billion, while the total urban population increased by 1.089 billion (UNICEF, 2011). Clearly, the increased supplies of improved water have not kept pace with the rapid urbanization.

Unfortunately, an increase in access of improved sources does not necessarily translate in to better quality water. Every year, some 3.4 million people, mostly children, die from diseases associated with poor water quality, sanitation and hygiene (UNICEF, 2009). Yet, investments to provide people with safe drinking water and sanitation facilitations have fallen seriously behind demand. This is especially the case in developing regions where the supply of clean water is still very limited due to a lack of water infrastructure. Recognizing the lack of safe drinking water, Goal 7 of the Millennium Development Goals includes “halving, by 2015, the proportion of people without sustainable access to safe drinking water” (UNDP, 2006).

The global scarcity of affordable and safe drinking water is manifested in Pakistan, where an estimated 44 percent of the population does not have access to safe drinking water. In rural areas, up to 90 percent of the population lacks such access (PCRWR, 2010). In 2005, Pakistan had a population of 153 million, with a density of more than 190 persons per square kilometer. The population of Pakistan is projected to rise to 229 million by the year 2025 and 295 million by 2050 (Khan and Javed, 2007). This increase in population will have a direct impact on the water sector for meeting the domestic, industrial and agricultural needs. Pakistan has now essentially exhausted its available water resources and is on the verge of becoming a water deficit country. Of the total annual water resources available to Pakistan, approximately 90 percent is used for irrigation purposes; and of the remaining 10 percent that is used by the domestic and industrial sector, 30 to 40 percent gets wasted. Per capita water availability has dropped from 5600 cubic meter in 1952 to 1200 cubic meter in 2003, and by 2012 the per capita water availability was less than 1000 cubic meter (Khan and Javed, 2007).

Along with a decrease in the quantity of water per capita, the quality of water is also deteriorating greatly due to municipal, industrial and agriculture wastes. As one indication of the intensity of the problem, it is estimated that about 200,000 children in Pakistan die every year of diarrheal diseases alone (UNIDO, 2003). Nevertheless, Water Supply and Sanitation (WSS) remains a neglected sector in Pakistan. Government spending in the WSS sector is lowest compared to other social sectors' spending, and at 0.25 percent of total GDP, Pakistan's investment in the water supply and sanitation sector is inadequate (Government of Pakistan, 2004).[2]

Punjab, the second largest province of Pakistan, is home to 55 percent of the country's 165 million inhabitants (Government of Pakistan, 2008). Only 15 percent of the total population of Punjab – and 8 percent of its rural population – procures drinking water from a piped water system, and the bulk of the supply of water in Punjab is via on-site pumps. The rest of the Punjab relies on sources of water, such as uncovered wells, rivers, and canals or rain-fed ponds. These are often distant which requires time for collection, often a task carried out by women or children (Government of Punjab, 2008).

Government documents indicate that 96 percent of rural and 98 percent of the urban population of Punjab has "access to improved water sources within 2 Km of the household" (Government of Punjab, 2008). However, it cannot be inferred that water is safe or that the quantity is adequate. In fact, as will be discussed in Chapter 3, in both rural and urban areas of Punjab 47 percent of all household water samples – and over 50 percent of piped water samples – have been found to be contaminated by bacteria.

The poor quality of service of piped water is evidenced by intermittent water supply and limited wastewater treatment. Together with leaky pipes, this has led to infiltration of contaminated water and subsequently major outbreaks of waterborne diseases. It is estimated that more than 1.6 million DALYs (Disability Adjusted Life Years) are lost annually in

[2] In a 2009 study by the Organization of Economic Cooperation and Development (OECD), it was estimated that the average level of spending on water infrastructure required by low-income countries to cover water service needs is between 0.71- 6.3 percent of GDP.

Pakistan as a result of death and disease due to diarrhea. Diarrheal mortality in children accounts for a bulk of the losses, reflecting the vulnerability of children to these diseases. The total health costs of water-related diseases, in terms of medical costs and lost productivity, are estimated at Rs.114 billion, or approximately 1.8 percent of GDP (World Bank (Pak- SCEA) 2006). A study conducted by UNICEF found that 20-40 percent of the hospital beds in Pakistan are occupied by patients suffering from water-related diseases, and that waterborne diseases are responsible for one third of all deaths (World Bank (Pak-SCEA) 2006).

As a result of the poor quality of public water services, users tend to be dissatisfied, and often a large portion of the already low water tariffs is left unpaid. Due to the low tariff revenue, service providers do not cover the costs of operation and maintenance and respond to such financial gaps by reducing service quality further, thus contributing to the vicious circle of poor performance, poor service, poor collection rates, and insufficient funding (World Bank 2006).

In sum, Pakistan suffers from a lack of safe water sources. Piped water may be exacerbating this problem, in part because poor maintenance may lead to leakages and cross-contamination in pipelines. Poor quality water, in turn, leads to detrimental health effects in terms of lost lives, especially those of children; and productivity. Although the costs of poor quality water are high, surprisingly little is known about the actual health impacts of piped water schemes, including the impact on diarrhea incidence in children. The empirical evidence is mixed, although most often no signs of improved health are found. Recent impact evaluations of interventions have shown that improved water and sanitation infrastructure, while showing positive outcomes in other dimensions, have rarely been found to translate into better health outcomes (World Bank, 2010).

In light of the preceding discussion, the objectives of this study are twofold. First, to assess the impact of piped water on the incidence of diarrhea in children in Punjab – home to the majority of Pakistanis. Second, to estimate households' willingness to pay for piped water – at mean levels of existing service, as well as at higher levels of water quality or service reliability.

This research makes a number of contributions to the existing literature. First, it analyzes the effect of piped water on the incidence of diarrhea in children in both rural and urban areas. Most previous empirical work on the health impacts of public water services in developing countries comes from rural projects, with only limited applicability to cities. In fact, urban and rural water supply and sanitation systems may differ considerably. In urban areas water sources are typically located more closely to dwellings, and delivery of water directly to the household doorstep is much more common. Rural-urban differences in sanitation practices also exist. Open defecation is less prevalent in urban areas. Instead, toilets and latrines are widely used with the associated wastewater being discharged into open sewers, underground cesspits, or piped sanitation systems. Finally, because urban areas tend to be more densely populated, pipelines are placed closer together. Likewise, maintenance of pipelines is more difficult in the more bustling urban areas than in rural villages (Government of Pakistan, 2008). This level of analysis is particularly important for Pakistan since a comprehensive health analysis of piped water in urban areas seems to be lacking.[3]

Second, the study uses household-level variables on bacterial presence in water to analyze the relationship of piped water (and other water sources) to the incidence of diarrhea in children. Such an analysis has not yet been carried out in Pakistan.

Third, the study measures households' marginal willingness to pay (MWTP) for piped water in both rural and urban areas of the Punjab, as well as households' MWTP for improvements in the quality and service of piped water. Presently there are very few studies on the willingness to pay for piped water in Pakistan based on samples that cover broad geographic regions (in this case, Punjab); most have focused on a small area or city (Altaf et al. 1993, Akram and Olmstead 2010).

[3] In fact no comprehensive study is found on the analysis of the heath impact of piped water in the urban areas of Punjab, Pakistan.

The rest of this study is structured as follows. The next chapter provides a background on the water sector in Punjab, and describes the datasets used. The primary source of household level information is the 2007-2008 Punjab Multiple Indicator Survey (MICS). Since information on salinity, water table depth, and duration of piped water flow are not available in the MICS, these household level data are supplemented with data obtained from the Directorate of Land Reclamation (DLR) of the Pakistan Irrigation and Power Department, and the Pakistan Council of Research in Water Resources (PCRWR). The chapter concludes with a brief look at the factors that may determine the public placement of piped water across tehsils.

Chapter 3 uses a logit model to measure the health effects of piped water in both rural and urban areas and across socioeconomic groups. The effect of piped water consumption on the incidence of diarrhea in children under the age of 5 is estimated. Then, the possibility of cross-contamination of water and sewage pipelines is explored as a possible explanation of the health effects observed. This is done by analyzing the interaction effects of sewage and water pipelines on the presence or absence of bacteria in water.

Chapter 4 uses a hedonic approach to econometrically estimate households' marginal willingness to pay (MWTP) for piped water in both rural and urban areas of Punjab. Also computed is the MWTP for public policy changes that improve the quality and service of piped water systems – specifically, by reducing contamination and increasing the duration of flow of piped water.

Chapter 5 summarizes the findings of this research and discusses its contributions. It then offers directions on future research relevant to the subject matter.

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CHAPTER 2
STUDY AREA

2.1 SETTING

According to estimates from 2008, Pakistan has a population of 165 million, of which at least 41 million (25 percent) are below the poverty line (UNDP, 2008); and more than 50 percent do not have access to safe drinking water (WHO, 2008).

Punjab, the geographical focus of this investigation, is the second largest of Pakistan's four provinces area-wise, has over half of Pakistan's population (90 million in 2008, according to estimations by the Punjab Bureau of Statistics), and is home to 19 percent of the nation's poor. Although more than 90 percent of the Punjabi population has access to improved drinking sources such as piped water, pumped water, public taps, covered wells, and springs, more than 50 percent of the sources have been found to be contaminated with bacteria (MICS report, 2008).

Punjab is bordered by the Indian state of Jammu and Kashmir to the northeast, the Indian states of Punjab and Rajasthan to the east, Sindh province to the south, Balochistan and Khyber Pakhtunkhwa provinces to the west, and the Islamabad Federal Capital Territory and Azad Kashmir to the north (see Figure 2.1). The capital and largest city of Punjab is Lahore. Other important cities include Multan, Faisalabad, Sheikhupura, Sialkot, Gujranwala, Jhelum and Rawalpindi. In the period of study (2007-08) Punjab had 35 districts and 144 tehsils.[4, 5]

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[4] The status of Chiniot was raised from Tehsil to district in 2009, increasing the number of districts to 36.
[5] All provinces in Pakistan are sub-divided into districts called zillahs. Zillahs are further subdivided into sub-districts called tehsils (roughly equivalent to counties). Tehsils may contain villages or municipalities. Some districts, incorporating large metropolitan areas, are called City Districts. A City District may contain subdivisions called Towns and Union Councils.

2.2 ECONOMY

Punjab is the most prosperous of Pakistan's four provinces due to the richness of its agricultural resources, and contributes to most of the total national GDP. The province's economy has more than quadrupled in real terms since 1972 (World Bank, 2008). Its share of Pakistan's GDP was 54.7 percent in 2000 and 59 percent in 2010. It is especially dominant in the service and agriculture sectors of the Pakistani economy, with its contribution ranging from 52.1 percent to 64.5 percent in the Service Sector and 56.1 percent to 61.5 percent in the Agriculture Sector (Government of Punjab, 2009). In 2008-09 Punjab had a growth rate of 6 percent – higher than the national rate of 4 percent (Livingston and O'Hanlon, 2011).

The incidence of poverty differs between the different regions of Punjab. Poverty rates in Northern and Central Punjab are much lower than in Western and Southern Punjab. Inhabitants of Southern and Western Punjab are also much more dependent on agriculture due to lower levels of industrialization in those regions (ADB, 2006).

2.3 PHYSICAL FEATURES AND TOPOGRAPHY

Punjab's area consists mostly of an alluvial plain formed by the southward flowing Indus River and its four major tributaries: the Jhelum, Chenab, Ravi, and Sutlej Rivers. The general slope of the land is from northeast to southwest, but it rises in the areas between rivers.

The five rivers comprise the main surface water resource of the province. About 79 percent of the province is underlain by the Indus Aquifer, a large body of groundwater underlying the vast Indus Plains. Rain, rivers, and other surface water bodies are the normal sources of recharge for this aquifer. The quality of water in the aquifer is, however, highly variable. Some 9.8 million acres are underlain with groundwater of less than 1000 mg/l Total Dissolved Solids (TDS), 3 million acres with salinity ranging from 1000 to 3000 mg/l TDS and 3.3 million acres with salinity more than 3000 mg/l TDS (Simi Kamal, 2009). The existing TDS standard is 1000 mg/l (Government of Pakistan, 2008).[6] [7]

Groundwater resources are generally in areas located near rivers (and other sources of recharge), and much less so elsewhere.[8] Fresh water is therefore relatively accessible in wide belts paralleling the major rivers. Saline groundwater occurs down gradient from sources of recharge, since a gradual increase in mineralization is found to occur with depth and distance from sources of recharge. This is particularly the case in the central parts of “Doabs” (strips of land lying between two confluent rivers). As well, the Cholistan area in southern Punjab is well known for highly brackish water, which cannot be used for drinking purposes.

The use of the freshwater resources is very unequal across Pakistan, with irrigation accounting for the dominant share. About ninety percent of Pakistan’s groundwater is used in irrigation (Shams ul Mulk, 2009), and the remaining 10 percent is divided between domestic purposes (including drinking, cooking, cleaning, etc.) and industrial purposes (Chaudhry and Chaudhry, 2009).

2.4 HISTORY AND WATER PROBLEMS

In the early 19th century, prior to large-scale irrigation projects, the average water table depth was 70 feet in most of the basin, and about 20 feet in the vicinity of streams and rivers. There were, nevertheless, annual variations in the water table depth depending on whether

[6] The existing standards of TDS published in Pakistan Health and Engineering Department (PHED) Design Criteria (1998) are in line with WHO Drinking Water Standard 1971. The WHO adopted a TDS concentration of 1000 mg/l in its Guidelines published in 1984. The WHO had not changed the guideline value for TDS in its drinking water Guidelines, 2004. It has been observed that increases in TDS beyond 1500 mg/l gives rise to taste that is objectionable to the consumers. However, in exceptional situations the standards may be relaxed in areas of acute water shortage having no alternate dependable water source meeting minimum water quality standards, provided that there is no potential health risks involved and that the end users are also willing to accept the lower level of water quality (Government of Pakistan, 2008).

[7] The salinity level of water is typically reported as either electrical conductivity (EC) or total dissolved solids (TDS). Conductivity is usually given as ds/m, which measures the ability of the sample to conduct an electric current. TDS is more precisely measured in the laboratory by evaporating a measured sample gently to dryness then calculating how much solids are left. Although TDS consists of other minerals in addition to sodium chloride, they are still considered as part of salinity.

[8] Sources of groundwater recharge include: rivers, canals, rainwater, return flow from irrigation, and domestic and industrial return flow.

the year was drier or wetter than the long-term average (Shams ul Mulk, 2009).

In the middle of the 19th century, construction began on a large number of irrigation barrages and canals. This introduced a new element into the water balance in newly irrigated areas. The application of additional irrigation water in hitherto unirrigated areas increased seepage into groundwater. This in turn changed the water table depth, and over the course of time groundwater levels rose substantially—even reaching the natural ground in many locations—and thereby created widespread waterlogging conditions (Shams ul Mulk, 2009). The rise in the water table above a critical level not only drowned plant roots, but also caused an upwelling of sub-soil saline elements which rendered the soil unfit for cultivation (Kaiser Bengali, 2009). This adversely affected agricultural production: by the middle of the 20th century Punjab was losing thousands of productive acres annually to waterlogging.

The absence of drainage infrastructure to facilitate the exit of excess water became a pressing issue. Remedial measures were researched and developed. Finally, in the 1960s, the Water and Power Development Authority (WAPDA) launched a set of Salinity Control and Reclamation Projects (SCARPs) to control the hazard of waterlogging and salinity (Shams ul Mulk, 2009).

Under the SCARPs program, 16,700 tubewells were installed in an effort to lower the groundwater table in order to create favorable crop growth conditions in the root zone and to reduce the risk of soil salinization (Bhutta and Smedema, 2007). The pumped groundwater was discharged into the existing public canal system to increase irrigation supplies (Qureshi et al. 2008).

Roughly coincident with the publicly financed installation of SCARP tubewells, there was a proliferation of private tubewell construction in Punjab. This was facilitated by the provision of subsidized electricity by the government, and by the introduction of locally-made diesel engines. These provided an impetus for a dramatic increase in the number of private tubewells. By 2008 about 800,000 small capacity private tube wells were working in Pakistan, out of which more than 90 percent were used for agriculture (Qureshi et al., 2008). At present, groundwater provides more than 50 percent of the total crop water use (Shah, 2007).

Figure 2.3 illustrates the steady growth in the number of private tube wells between 1965 and 2002 in Punjab. The 59 percent increase in the number of private tubewells during the latter part of this period was linked to severe drought conditions in the country between 1998 and 2002 (Bhutta and Alam, 2002). During this period, surface water availability declined by 26 percent and consequently groundwater from private tubewells became a more important source for irrigation and drinking water. With the improvements in surface water supplies after 2001, groundwater pumping from private tube wells was slightly reduced.

The development of the SCARPS and the accompanying increase in private tubewells brought about its own problems, however. The availability of inexpensive drilling technologies allowed even poor farmers to access groundwater to increase their crop production and improve livelihoods. Unreliability of surface water supplies caused more and more farmers to use groundwater for irrigation. However, due to unregulated and uncontrolled use by farmers, the water table has declined substantially; correspondingly, the relative accessibility of groundwater has diminished. The trend of continuous decline of the groundwater table that has been observed in many areas of the Indus basin illustrates a serious imbalance between removal and recharge. In areas dependent on groundwater irrigation, the lowering of the groundwater table has made pumping more expensive. Many wells have gone out of production, yet the water tables continue to decline.

With the increasing groundwater table depths, farmers and households were left with no choice than to drill deeper wells for irrigation and drinking water needs. This transformation led to increased installation and operational costs for farmers, households, and government. Under these conditions, access to groundwater was increasingly restricted to large, well-to-do farmers who could afford the increased cost of tubewell irrigation. Figure 2.4a illustrates the falling water table in the Punjab through the years, and 2.4b illustrates the resulting increase in the cost of pumping water.

Another effect of falling groundwater tables was the deterioration of groundwater quality. The quality of groundwater in the Indus Plains varies widely, both spatially and with depth and is related to the pattern of groundwater movement in the aquifer (Qureshi et al., 2008). Areas subject to heavier rainfall and consequently greater recharge, in the upper parts of Punjab, are underlain with waters of low salinity. Similarly, recharge occurring from the main rivers and canals has resulted in the development of wide and deep belts of relatively fresh groundwater along them. The salinity of the groundwater, however, generally increases with distance from the rivers, and also increases in areas where recharge is low. Therefore, in the lower parts of the Indus plain, the area of usable fresh groundwater is confined to a narrow strip along the Indus River. In central areas of Punjab a layer of fresh groundwater floats over the saline water. Due to excessive pumping of this thin fresh groundwater layer, the downward gradients are increasing thereby inducing saltwater intrusion into fresh groundwater areas.

To sum up, slower aquifer recharge has, over a long period of time, led to declining quality and increasing cost of accessing groundwater resources for irrigation and consumption purposes in Punjab (and Pakistan more generally). With regard to non-agricultural water uses, this has tended to make a (publicly-provided) system of piped water provision a potentially more viable and attractive means of satisfying private consumption demands.

2.5 INSTITUTIONAL SETTING

Two types of organizations provide Water Supply and Sanitation (WSS) services in the Punjab. These are Tehsil Municipal Administrations (TMAs) and Water and Sanitation Agencies (WASAs). They differ considerably with regard to organizational structure, responsibilities, competencies and staff qualification.

Prior to the formation of Local Governments in Pakistan in the year 2001, Water and Sanitation Authorities (WASAs) were responsible for the construction and maintenance of water and sanitation services in urban areas. In rural areas, services were provided by the provincial Public Health and Engineering Departments (PHEDs). The PHEDs were managed by qualified experts in the field of water supply and sanitary engineering. The staff of PHEDs was spread throughout the province. The planning, design, construction as well as the operation and maintenance (O&M) of water supply systems were the responsibility of these departments.

Under the Local Government Ordinance, three tiers of local governments were created: districts, tehsils, and union councils.[9] The responsibility for water supply and sanitation in five cities remained with WASAs[10], but in rural areas and the rest of the urban areas it was nominally devolved to Tehsil Municipal Administrations (TMAs), the second-lowest tier of local government in Pakistan.

As a result of the Local Governance Ordinance, the PHED was supposed to be merged into the Provincial Local Government Department, and the staff was supposed to be devolved at the TMA level. However, the decentralization has not been implemented in all areas. In 2007, it was reported by the Asian Development Bank that many PHEDs were still active in water supply development, operation and maintenance, particularly in areas where water systems spread across more than one tehsil. In those cases, the PHEDs usually developed piped-water schemes with little or no participation of TMAs. According to a 2003 document, the PHED remains fully functional in many areas of the Punjab province (Water and Sanitation Program, 2004).

Most of the small water systems in rural areas, however, have been transferred by TMAs to Union Councils, which are looked after by either the Council Chairman or somebody designated by the Union Council – usually a non-technical person who manages the system and takes decisions about collection of funds and operation and maintenance of the scheme facilities. He is usually assisted by an operator and a guard. The operator typically has primary level education and does not have the knowledge and expertise to carry out tasks and decision-making in an efficient manner (USAID, 2006).

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[9] Prior to the Local Governance Ordinance in 2001, policy decisions were made by Provincial Governments. After 2001, most decisions were devolved to local governments.

[10] The cities include Rawalpindi, Lahore, Multan, Faisalabad, and Gujranwala

2.6 FINANCIAL ASPECTS OF PUBLIC WATER PROVISION

2.6.1 Investment and Financing

The Punjab water sector strongly depends on internal and external financing. In 2002 the Ministry of Power and Water reported that 54 percent of the $404 million per year spent on total new investments in the water sector was financed by the government. 39 percent was financed by external loans, of which the Asian Development Bank (ADB) provided the majority share (25 percent of external loans).[11]

Annual contributions from private sector contributions to WSS, including the installation of private tube wells and community contribution to rural water supply and sanitation schemes have amounted to more than Rs.3 billion or 8 percent of total investments in WSS. In The Medium Term Development Framework for 2005-10, the Ministry and Planning Department recognized that, at 0.25 percent of total GDP, Pakistan's investment in the water supply and sanitation sector is inadequate.[12]

2.6.2 Tariffs and Cost Recovery

The World Bank calculates that the average fee for a water connection in Pakistan in the period 2004-05 ranged from US$0.70/ m^3 to US$3.50/ m^3 (World Bank, 2006). In a study by the Asian Development Bank, it was found that the typical domestic tariff was US$0.25 in Lahore (ADB, 2007).[13] Due to poor collection efficiency, overstaffing, lack of metered

[11] The other major lenders included World Bank, Overseas Economic Cooperation Fund (OECF), Japan Bank of International Cooperation (JBIC), International Fund for Agricultural Development (IFAD), and International Development Association (IDA).

[12] In a 2009 study by the Organization of Economic Cooperation and Development (OECD), it was estimated that the average level of spending on water infrastructure required by low-income countries to cover water service needs is between 0.71- 6.3 percent of GDP.

[13] Tariff rates are based on estimates provided by previous studies. Annual values of tariff rates at provincial or district level are unavailable due to a lack of metered connections and poor record-keeping.

connections,[14] and low tariffs, operation and maintenance (O&M) costs are seldom fully recovered. The Ministry of Power and Water reported in 2002 that in smaller cities and towns part of the O&M costs had been financed with local taxes until recently.

Service providers respond to the low tariff receipts by reducing service quality – either intentionally (through rationing daily hours of operation) or unintentionally (via more frequent breakdowns of equipment). Poor maintenance and poor operating efficiency thus contribute to a vicious circle of poor performance, poor service, and poor collection rates.

2.7 WATER PROJECTS

Like any public good, piped water infrastructure consists of fixed costs of construction, and variable costs of operation. The initial construction costs are large and benefit from economies of scale (Dharmaratna and Parasnis, 2002). The operating costs consist of staffing costs, energy costs, and maintenance costs. According to a World Bank report (2006), staffing costs make up a bulk of O&M costs of water infrastructure in Pakistan.

Until the 21st century, water sector policies in Pakistan were mainly focused on irrigation (Government of Pakistan, 2002). This has changed with the different Water Supply and Sanitation (WSS) policies adopted by the Ministry of Environment of Pakistan (as integral parts of the Medium Term Development Framework (MTDF) 2005-2010). Some of the main water projects that have been implemented in Punjab are described below.

[14] There are virtually no metered connections (World Bank, Urban Unit, 2006). Instead, a flat per household fee is the norm.

2.7.1 Projects funded by the Ministry of Environment and Local Organizations

National Water Quality Monitoring Program (2001):

The Pakistan Council of Research in Water Resources (PCRWR) initiated the National Water Quality Monitoring Program (NWQMP) in 2001. The NWQMP generated the first detailed water quality profile of 23 major cities in the country. In 2004, the program was extended to include rural areas and more districts. As a result, the rural and urban areas of 12 districts in Punjab were monitored for water quality.

Clean Drinking Water for All Program (2004-2005):

Approved in 2004, the $8.2 million Clean Drinking Water Initiative provided for the construction of water purification plants in all Pakistani tehsils. Through the program, the Ministry of Environment was charged with installing various plants at selected places on turnkey basis, and subsequently handing them over to local municipal administration for operation and maintenance. The resulting purified water was mainly used for bottled water and not for network supply.

The much larger $168 million Clean Drinking Water for All Program (2005) increased the quantity and capacity of the purification plants, and one purification plant was installed in each Pakistani Union Council. Each purification plant had the capacity to serve 2-20 percent of each Union Council's population. Average population of Union Councils is 20,000 inhabitants.

National Environmental Policy (2005):

The National Environmental Policy (NEP), prepared by the Ministry of Environment, was approved in 2005. The main aim of the policy was to protect, conserve and restore Pakistan’s environment. Through the NEP, the Ministry of Environment promoted the use of safe drinking water, increased coverage of water supply, and established a water quality monitoring system.

2.7.2 Projects funded by International Organizations

Islamabad and Rawalpindi Water Supply Project (1989-2000):

In 1989 the Japan Bank of International Cooperation (JBIC) approved two loans to support two Metropolitan Water Supply Projects in Pakistan, amounting to a total of US$109 million. The projects were aimed to transfer bulk water from the Khanpur Dam and the Simly Dam in the Punjab to urban areas. The Khanpur project, implemented between 1994 and 2000, aimed at increasing bulk water supply to Islamabad and Rawalpindi from the Khanpur Dam.[15]

An ex-post evaluation of the project in 2003 judged that the project did not fully meet its targets (JICA, 2003). The amount of water supplied was only 41 percent of what had been planned, and there were various problems with the executing agency (the Capital Development Authority). These included a scarcity of personnel, and underdeveloped institutions.

Punjab Rural Water Supply and Sanitation Project (1995):

In 1995, the ADB approved a $46 million loan for the Punjab Rural Water Supply and Sanitation Project (PRWSSP). The PRWSSP provided least-cost and low-technology water supply and drainage schemes to selected communities in seven districts in rural Punjab. The project had three components: (i) water supply and drainage construction in about 300 communities, (ii) a hygiene education program, and (iii) strengthening institutional support to PHED. It envisaged generating several direct and indirect benefits through the provision of safe and reliable water supply and improved sanitation facilities to 900,000 residents in about 300 rural communities. The PRWSSP was also expected to significantly reduce the incidence

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[15] Although the two cities (Islamabad and Rawalpindi) belong to the Islamabad-Rawalpindi Metropolitan Area, Islamabad city is part of the Islamabad Capital Territory, while Rawalpindi is part of Rawalpindi District, which is part of the province of Punjab.

of waterborne illness, unsanitary conditions, and the child and infant mortality rates. The hygiene education program and institutional strengthening were expected to complement and reinforce the economic and health benefits associated with WSS, and to ensure that the initial gains could be sustained and enhanced.

The project completion report (PCR) by the Asian Development Bank (2009) noted that the project design was highly relevant to the Government's development strategy to improve rural WSS and ADB's strategy of supporting projects with potential to satisfy basic needs, reduce poverty, and improve the environment. But on the ground the PRWSSP was considered to have underperformed. Coverage was 39 percent less than projected. Other weaknesses identified included inadequate water pressure, design and implementation problems, weak social mobilization, no disinfection facility, a reduced hygiene education program, and only partial achievement of institutional strengthening. The PRWSSP was rated inefficient in implementation because of various delays encountered during start up, in the recruitment of consultants and contractors, and during the handover of the completed schemes. The PCR estimated that the economic internal rate of return for the selected subprojects was higher than the 10 percent opportunity cost of capital, but the anticipated health benefits were not realized.

Punjab Community Water Supply and Sanitation (Sector) Project (2002-2007):

The design of the PCWSSP followed from PRWSSP implementation lessons, and ADB approved a $50 million loan for this project on 28 November 2002, which became effective on 29 April 2003. As per schedule, the loan closed on 30 June 2007.

The PCWSSP extended water supply, drainage, and sanitation coverage to poor villages that did not have access to organized water supply and were located in brackish or dryland (barani) areas of Punjab. It also provided technical help to the TMAs for operation and maintenance of the water schemes, implemented a hygiene education program, and implemented a social-uplift and poverty-eradication (SUPER) program to help use the time saved not fetching water in productive livelihood activities, particularly for women, through a microcredit system.

The PCWSSP covered 30 districts of Punjab and served 750 communities – 500 of them with new construction and 250 by rehabilitating inoperative schemes – servicing approximately 2.3 million people.

In an Impact Evaluation Report (2009), the ADB concluded that the PCWSSP was successful overall in expanding water supply coverage, reducing drudgery associated with fetching water, and increasing enrolment of girls in schools. However, it was also found that the project did not significantly reduce the amount and severity of waterborne illness like diarrhea in rural areas.[16]

Punjab Municipal Services Improvement Project (2006-2013):

The World Bank contributed a loan of US$50 million to improve municipal services in Punjab. The project was implemented by the provincial government of Punjab, with about half the funds going to water supply and sanitation. The objective of the Punjab Municipal Services Improvement Project for Pakistan was to improve the viability and effectiveness of urban services provided by the participating TMAs, and to make such improvements sustainable and replicable in other TMAs through the creation of a performance-based management framework at both TMA and provincial levels. The project is still ongoing, and the effectiveness has not been evaluated yet.

Although there have been numerous projects aimed at improving piped water service in the Punjab, with some having succeeded better than others, evidence of the impact of piped water on health and household welfare has been modest at best. Therefore, further research is needed to quantify the health and economic benefits of public piped water.

[16] However, disaggregated analysis revealed that the incidence of diarrhea was reduced significantly in the middle socioeconomic group.

2.8 DATA

The analysis in this study relies on three sources of data. The primary source of household level information is the 2007-2008 Punjab Multiple Indicator Survey (MICS). Since information on salinity, water table depth, and duration of piped water flow are not available in the MICS, these household level data are supplemented with data obtained from the Directorate of Land Reclamation (DLR) of the Pakistan Irrigation and Power Department, and the Pakistan Council of Research in Water Resources (PCRWR). The DLR provided district level data on water table depth and salinity, and the PCRWR provided data on the average daily duration of piped water flow per district. This section describes those datasets, provides some descriptive statistics, and provides an analysis of the placement of water delivery infrastructure.

2.8.1 Punjab Multiple Indicator Cluster Survey (MICS) 2007-08

The Punjab Multiple Indicator Survey 2007-08 is the second round of a series of MICS surveys for Punjab, the first one having been conducted in being in 2004-05.[17] It is a provincially representative survey of households, with a special emphasis on the health and well-being of women and children. With a total sample size of 91,280 households, the survey provides data on more than 70 different types of indicators of water and sanitation, health, household characteristics, income, and education. The survey was designed and implemented by the Punjab Bureau of Statistics with technical collaboration from UNICEF. The survey fieldwork was carried out between December 2007 and April 2008.

Questionnaires for the Punjab MICS 2007-08 were based on a MICS template created by UNICEF, with some modifications and additions to accommodate additional indicators

[17] The MICS 2004-05 was the first round of a series of MICS surveys for Punjab. It consisted of a sample of 30,932 households, and data on 42 different types of economic, health, water and sanitation, maternal, and child indicators. The MICS 2007-08 extends the work of the MICS 2004-05 and has a much larger sample size, and more variables. The MICS 2007-08 dataset also has more variables on water and sanitation, which were missing in MICS 2004-05, particularly variables on the quality of water and type of water treatment.

selected by the Government of the Punjab. Each household questionnaire contained three major sections: (a) a module on socioeconomic information (such as income, education, water and sanitation) for all household members; (b) a women's module on marital status, education, and maternal health, for each ever-married woman aged 15-49 years; and (c) a module on child health (including the nature and treatment of illnesses) that was administered to mothers or caretakers of children under 5 years of age.

The sample was selected in two stages. Within each of 273 sampling domains, enumeration areas (enumeration blocks in urban areas or villages in rural areas) were selected, and the probability of selection was proportional to the size of the enumeration area. Household listing was carried out within each randomly selected enumeration area and a random sample of 12 households in urban areas and 16 households in rural areas was randomly drawn. Using this method, 59,546 rural households and 32,006 urban households were selected, for a total sample size of 91,280 households. The rural households therefore constituted about 65 percent of the total sample.

Response rates were high across all districts and areas of residence. Of the 91,280 households selected for the sample, 91,272 were found to be occupied and 91,075 were successfully interviewed. In the interviewed households, 87,279 ever-married women (age 15-49) were identified and 86,148 were successfully interviewed (97 percent currently married and 3 per cent formerly married), yielding a response rate of 99 percent. Of the 71,507 children under 5 years of age listed in household questionnaires, 70,226 child questionnaires were answered, a response rate of 98 percent. The overall response rates for women and under-fives were 99 and 98 percent respectively.

Distribution of Water Sources

The Punjab MICS 2007-08 identifies 12 different sources of water, which can be divided into the following five categories:

1. Pumped water: This consists of either motorized pumps, or hand pumps that are privately installed by households on premises by drilling boreholes in the ground and abstracting ground water from the aquifer. The cost of installation of hand pumps and motorized pumps is directly proportional to the water table depth. Since hand pumps are operated manually, their operational cost is zero.[18] As motorized pumps use electricity, their operational cost is proportional to the cost of electricity and the water table depth.
2. Piped in-home water: In this mode of service delivery, the respective government body (WASA, PHED, or TMA) lays pipes from a tube well or other water source to the doorsteps, and a connection is made with the house of the end-user.[19] The user can provide further connections for water utilization in the kitchen, bathroom and courtyard according to requirements.[20]
3. Public tap: As in the case of piped water, public taps are also linked to a public water supply. However, in this mode of delivery, taps are installed at a public location – e.g., street corners or town squares – and are therefore available off-premises. Households using public taps must fill buckets or containers at public stand posts and bring them back home for consumption, requiring time and energy.

[18] Although the operational cost of hand pumps is zero, they do accrue a time cost for the time taken to pump the water manually.

[19] The public water supply schemes use water obtained from surface (canal, dam) and groundwater (tubewells, springs) sources. In a technical assessment survey report on water supply schemes by the Pakistan Council of Research in Water Resources (2011) it was found that around 87 percent of the public water supply schemes use groundwater sources while 13 percent of the public water supply schemes obtain water from the surface water sources. Groundwater as source of water is prominent in districts where groundwater is sweet (for example, Bhakkar, Gujranwala, Gujrat, Hafizabad, Jhang, Kasur, Mandi Bahauddin, Nankana Sahib, Narrowal, Okara, Sheikhpura and Sialkot) while surface water source is dominant in brackish and arid districts (for example, Toba Tek Singh, Chakwal and Attock).

[20] Most of the pipeline networks were constructed by the Pakistan Health and Engineering Department (PHED) prior to the devolution of 2001. After devolution, responsibility for operation of most existing water networks were handed to local governments. Regrettably, data on the construction and layout of the networks appears to have been lost during the period in which responsibility was transferred.

4. Other improved sources: These include covered wells, protected springs, bottled water, and tube wells.[21] These sources are usually located off-premises in a central location (except for bottled water). Households are required to fill water from these sources and carry it home for consumption.
5. Unimproved sources: These include surface water, rainwater, unprotected wells and springs, etc. These sources are also usually located off-premises.

While pumped water and other improved and unimproved sources can be installed privately, public taps and in-home water connections are provided by the government, and their availability is dependent on their provision in the area.

Figure 2.5a illustrates the distribution of water sources across the Punjab. Nearly three quarters of households (73 percent) obtain water from pumps located on their own premises. Around 15 percent households use piped water, 3 percent obtain water from a public tap, 6 percent use other improved sources, 3 percent use unimproved sources.

Figure 2.5b illustrates the distribution of water sources in the rural areas. The most common source of water is pumped water; almost 80 percent households obtain water from this source. Only 8.3 household use piped water, 3.7 percent obtain water from public taps, 5.5 percent use other improved sources, and 2.9 use unimproved sources.

Figure 2.5c illustrates the distribution of water sources in the urban areas. As in rural areas, pumped water is also the predominant source of water in urban areas. However, the percentage of households that use piped water is higher in urban areas at almost 30 percent. 1.9 percent household obtain water from public taps, 7.1 percent use other improved sources, and 2.5 use unimproved sources.

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[21] While covered wells are found within the community, tube wells are either installed by the government or privately in farmlands for irrigation. Some households use the water from irrigation tube wells for their consumption needs.

Water Quality and Treatment

Tests of household drinking water quality were conducted as part of the survey. These data reveal that the water of about half of the surveyed households contained bacteria that rendered it unsafe for drinking, and that significant geographical variations exist in the distribution of bacterial contamination across districts as well.

In spite of the high incidence of bacteria found in water, only an average of 5 percent households actually treat water in the Punjab. Of these, more than half the households use water treatments that are not effective in killing bacteria, as shown in Figure 2.6a (the "ineffective" forms of treatment correspond to all forms of treatment other than boiling and chlorinating). In rural areas only 2.3 percent of households use some form of treatment, the predominant method being merely letting the water stand to allow the salts and sediments to settle (shown in Figure 2.6b). This method is not effective in eliminating bacteria in the water. In urban areas 11.2 percent households treat water; around half of the households that treat water do so by boiling their water (Figure 2.6c).

Diarrhea Incidence

In the pooled dataset, 7.6 percent of children under 5 years of age had diarrhea in the 2 weeks preceding the survey. This is considerably lower than the values found in the MICS 2003-04 and may be attributed to the winter season when diarrhea outbreaks are usually low (See Table 2.1). The prevalence was slightly lower in rural areas (7.3 percent) than in urban (8.2 percent).

2.8.2 Directorate of Land Reclamation (DLR) Dataset

The data for groundwater salinity and water table depth was obtained from the Punjab Directorate of Land Reclamation (DLR), Irrigation and Power Department. The DLR collects data for water quality and depth to water table twice a year, once in the pre-monsoon season (May-June) and again in the Post-monsoon season (Oct.-November).[22] There are 1820 water table depth measuring stations and 2853 water salinity measuring stations throughout the province. The depth to water table is recorded with the help of Water Level Detectors. The groundwater samples are chemically analyzed in DLR laboratories for water quality. The salinity of groundwater in measured and reported in terms of the electrical conductivity (EC) of the sample.[23]

These data indicate that the average water table depth in Punjab is about 40 feet below ground level. In rural areas, the mean water table depth is around 39 feet below ground level and in urban areas the mean water table depth is 44.7 feet below ground level.

The average salinity of groundwater in Punjab is around 1.9 ds/m. The mean level of salinity in rural areas in 1.95 ds/m, and a slightly lower 1.80 ds/m in urban areas.[24] In both areas the mean level of salinity is higher than the standard set by the DLR, which deems levels higher than 1.5 ds/m as unfit for drinking (DLR, 2008). Figure 2.7 illustrates the spatial distribution of salinity across the Indus Basin in Pakistan. As the figure shows, fresh groundwater is found in wide belts around the banks of the rivers, and the level of salinity rises towards the central Doabs, away from the rivers.

[22] For the analysis, the salinity and water table values for the post-monsoon season on 2007 were used to be roughly consistent with the interview period of the MICS 2007-08 dataset.

[23] Water and soil salinity are measured by passing an electric current between the two electrodes of a salinity meter in a sample of soil or water. The electrical conductivity or EC of a soil or water sample is influenced by the concentration and composition of dissolved salts. Salts increase the ability of a solution to conduct an electrical current, so a high EC value indicates a high salinity level. The standard set by the Directorate of Land Reclamation is that an EC less than or equal to 1.5 ds/m is permissible, and more than 1.5 ds/m is considered unfit.

[24] The DLR sets groundwater table and quality check posts in various locations within the rural and urban areas of a district. Since the water table and salinity levels vary slightly across different regions within a district, the averages for the values from rural check posts are slightly different from the averages from urban check posts. However, the variation within districts is not as large as the variation across districts (DLR, 2008).

2.9 DETERMINANTS OF PIPED WATER PLACEMENT

In the Punjab Drinking Water Policy Document (2010), the Government of Punjab realizes that in making water placement decisions, "resource allocation is not based on need assessment, criteria, and data." Since Pakistan lacks a clear structure in its management and provision of public infrastructure, there are different theories explaining the potential determinants of whether a certain locality is provided with an in-home piped water system, ranging from geographical to political and socio-economic factors. These are discussed below:

Ground water salinity

The quality of groundwater varies greatly within the province. While the majority of the province has freshwater, the Central Doabs are mainly brackish, with salinity often rising to levels that render the water unfit for consumption. This is particularly the case in the south Cholistan desert (Bahawalpur and Bahawalnagar districts). Since these areas do not have easy access to sweet water, they are given priority in the placement of pipe connections (Altaf et al., 1993).

Groundwater Table Depth

The northern areas of the Punjab are mountainous, and therefore ground water is very deep and hard to reach. Water table depths also vary within the central region of the Punjab – for example, areas in the Rechna Doab have particularly deeper water tables than the rest of the central region. Since water is harder to reach, often obtainable only by the use of expensive motorized pumps, these areas are thought to be in a greater need of public water provision (Chaudhry and Chaudhry, 2008)

Socio-economic Variables

In Pakistan the wealthier, more powerful individuals often have a greater voice in public policy decision making than the common man. They are, therefore, able to influence decisions on public policy, such as whether their region should be provided with public water connections (Khan, 2008).

Agricultural lobbyists

Currently around 96 percent of Punjab's water is used in agriculture, and only 2 percent is directed towards household consumption (Chaudhry and Chaudhry, 2009). Until the 21st century, water sector policies in Pakistan were mainly focused on irrigation (Government of Pakistan, 2002). This is due to the importance of irrigation to agricultural production – e.g., more than 75 percent of national food production is grown on irrigated land (Ministry of Information and Broadcasting, 2009). Although issues related to public provision of water for consumption has been debated more often in recent years, agriculture still plays an important role in water policy in Punjab. Since water table depths are increasing due to over-pumping, farmers increasingly rely on the government to supply water for irrigation (Qureshi et al., 2008). Many prominent Pakistani politicians are large landowners who use their political status to push for the provision of piped water connections in areas where they own agricultural land to have a convenient source of water for irrigation. Aside from its use in irrigated agriculture, that water also frequently is made available for human consumption by diverting some of it to serve nearby farmhouses.

Empirical Analysis

To determine the relative importance of the factors influencing the public placement of in-home piped water connections, the following tehsil-level equation was estimated:

$$\begin{aligned}\text{Piped Water}_{\text{Tehsil}} &= \beta_0 + \beta_1\text{Salinity}_{\text{Tehsil}} + \beta_2\text{Water table depth}_{\text{Tehsil}} \\ &+ \beta_3\text{Mean wealth index score}_{\text{Tehsil}} + \beta_4\text{Mean irrigated land area}_{\text{Tehsil}} + \varepsilon\end{aligned}$$

The dependent variable, Piped $\text{Water}_{\text{Tehsil}}$, takes a value of 1 if at least one household in the tehsil has piped water, and 0 otherwise. The idea here is that if there is even one household in the tehsil that has piped water then surely there must be a publically placed piped network in the tehsil. If no household has piped water in the tehsil, it is a strong indication that no publically placed piped network exists in the area to connect to.

As for the independent variables, mean salinity and water table depth for the tehsil capture the geographical component; mean wealth index score at the tehsil-level (discussed below) captures the socio-economic component, and the mean irrigated land area at the tehsil level is meant to capture the political influence of the agricultural lobby.[25]

The wealth index scores merits more discussion. Calculated by the Punjab Bureau of Statistics as part of the MICS dataset, a wealth index score is assigned to each household by using information on household goods and amenities (assets) and assigning weights to each asset.[26] These weights reflect the distribution of assets across the entire sample. Figure 2.8 illustrates the distribution of households by wealth class for rural and urban areas. The figures show that most households in rural areas are in the lowest and second-lowest quintiles, while in urban areas almost half of the population is in the highest wealth index quintile. Therefore, on average, urban households are wealthier than rural households.

Descriptive statistics for variables used in the analysis are shown in Table 2.2.[27] In rural areas, 80 percent tehsils have at least one household with piped water, whereas in urban areas 86 percent tehsils have at least one household with piped water. The mean water table depth is around 39 feet below ground level in rural areas and 44.7 feet below ground level in urban

[25] Although the appropriate measure for irrigated land in the analysis would exclude all privately irrigated land (so that only publically irrigated land is used), such information is unavailable.

[26] The MICS adopts the Demographic and Health Survey (DHS) Wealth Index to calculate wealth scores, and to categorize households into different wealth index quintiles. In the first step, a wealth score in allotted to each household by making a list of household assets, which are then included in a principal components analysis (PCA). The first principal component is taken as the underlying index of wealth, and each household's position on it is calculated using the PCA weights. The PCA procedure produces an index that is "normalized" so that it has a mean value of zero and a standard deviation of one. The second step involves grouping households into different wealth index quintile based on their wealth scores. The wealth index does not provide information on absolute poverty, current income or expenditure levels, and the wealth scores calculated are applicable for only the particular data set they are based on (Rutstein and Johnson, 2004 and Filmer and Pritchett, 2001).

[27] The difference in the number of observations across areas is due to the unavailability of data on 6 rural and 3 urban tehsils in the DLR dataset.

areas. The mean level of salinity in rural areas in 1.95 ds/m, and 1.80 ds/m in urban areas.[28] In both areas the mean level of salinity is higher than the standard set by the DLR, which deems levels higher than 1.5 ds/m as unfit for drinking (DLR, 2008). In fact, in both rural and urban areas, almost half of the tehsils have unfit groundwater (40 tehsils in rural areas and 34 tehsils in urban areas have an average salinity greater than 1.5 ds/m).

The mean irrigated land area across rural tehsils is around 29 acres, and it is significantly much lower in urban areas where the average irrigated land area across tehsils is around 11 acres. This is not surprising since urban areas tend to have a higher population density making it difficult to have large agricultural plots.

As the dependent variable is binary, a logit model is used. The marginal effects implied by the logit estimates for the determinants of piped water placement are shown in Table 2.3.[29] For rural areas (column (1)) the coefficient of salinity is positive, and significant, indicating that if salinity increases by 1ds/m, the probability of a tehsil having a piped water connection increases, on average, by 17 percentage points. The coefficient of mean wealth index score is likewise positive and significant. The significant positive association between these two variables and piped water support the idea that wealth and salinity are contributory elements in piped water placement.

The coefficient of water table depth is negative but insignificant. Therefore there is no evidence to support water table depth as an important determinant of piped water placement. The coefficient of mean irrigated land is very small and positive, but also insignificant. This may be because the variable is weak in capturing agricultural clout. A better measure would exclude any privately irrigated land area, but data limitations prevented such an analysis.[30]

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[28] The DLR sets groundwater table and quality check posts in various locations within the rural and urban areas of a district. Since the water table and salinity levels vary slightly across different regions within a district, the averages for the values from rural check posts are slightly different from the averages from urban check posts. However, the variation within districts is not as large as the variation across districts (DLR, 2008).

[29] The logit analysis consists of 85 rural tehsils and 73 urban tehsils since tehsils with missing observations were omitted.

[30] Population density and household size were also added as explanatory variables but were found to be highly insignificant with variables signs; therefore they were dropped from the analysis. Other possible agricultural variables and combinations were also tried, including total land area/value, maximum land area/value, and sum

The marginal effects of the logit model for the determinants of piped water placement in urban areas are shown in column (2) of Table 2.3. The coefficient of salinity is positive, and significant (albeit much smaller than rural areas). This is consistent with the notion that indicating that salinity plays some role in government decisions on piped water placement in urban areas as well. The coefficient of mean wealth index score is positive, and significant at the 90 percent confidence level. As in the case of rural areas, neither of the coefficients on water table depth nor mean irrigated land were significant. Therefore there is no evidence supporting water table depth or irrigated land as an important determinant of piped water placement in urban areas either.[31]

In sum, these results are supportive of contentions that in both rural and urban areas policymakers base part of their decisions on piped water placement on the groundwater salinity of the region, and that they prioritize wealthier tehsils over others. In areas with highly brackish water, salinity levels make ground water inconsumable and therefore pumped water is frequently an unsuitable source of water. It is thus sensible that households in such areas, who are in need of alternative sources of water, be given priority in the placement of piped water *vis-à-vis* households in areas where groundwater is sweet and hence pumped water is a relatively more feasible alternative.

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of land area/value, as well as their quadratic terms. However all combinations yielded insignificant coefficients.

[31] As in the case of rural areas, population density, household size, as well as other measures of agricultural dominance were used, but all combinations yielded highly insignificant results, often times with variables signs.

Table 2.1: Comparison of the Incidence of Diarrhea in Children (<5 years) in MICS 2003-04 and MICS 2007-08

	Incidence of Diarrhea in Children (%)	
	MICS 2003-04	MICS 2007-08
Punjab	22.8	7.6
Rural	23.6	7.3
Urban	20.9	8.2

Table 2.2: Descriptive Statistics: Water Placement Variables

	Rural					Urban				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Any household with Piped Water (0=no household with piped water in tehsil, 1= at least 1 household with piped water in tehsil)	*91*	*0.80*	*0.4*	*0*	*1*	*76*	*0.86*	*0.4*	*0*	*1*
Ground water Salinity (EC)	*85*	1.95	1.1	1	5	*73*	1.80	1.0	1	5
Ground water depth (feet)	*85*	38.52	47.9	7	200	*73*	44.72	53.3	8	200
Mean wealth index score	*91*	-0.52	0.4	-1	1	*76*	0.48***	0.4	0	1
Mean irrigated land area (acres)	*91*	28.84	122.4	3	818	*76*	11.25***	10.3	0	66

*p<0.01, **p<0.05, ***p<0.1 for t-test of mean(rural)=mean(urban)

Table 2.3: Determinants of Piped-Water Connection

	Dependent Variable: Dummy for any household with piped water in tehsil	
	Average Marginal Effects	
	Rural Areas	**Urban Areas**
Variable	(1)	(2)
Ground water salinity	0.172***	0.028***
	(3.03)	(2.84)
Water table depth	-0.003	-0.004
	(-0.96)	(-1.20)
Mean wealth index score	0.376***	0.191*
	(3.63)	(1.89)
Mean irrigated land area	0.003	0.003
	(0.80)	(1.01)
(Constant)	0.383	0.083
	(0.39)	(0.08)
N	85	73
LR chi-squared	18.00	7.09
Pseudo R-squared	0.21	0.13

**p<0.1, **p<0.05, ***p<0.01*

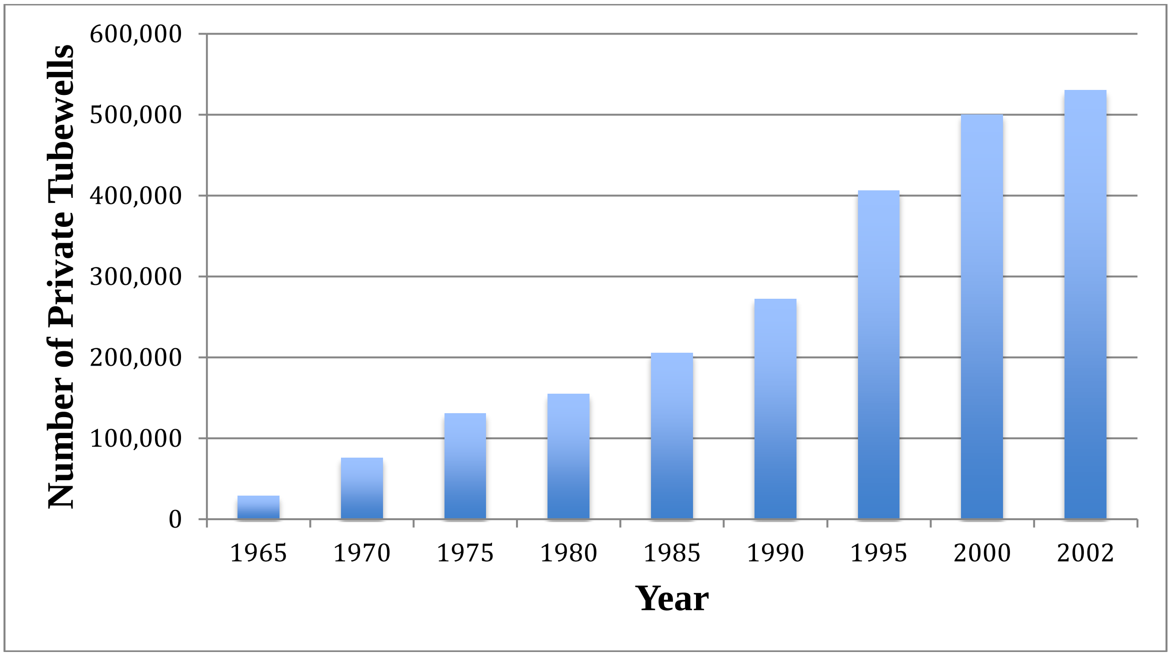
z-statistics in brackets

Source: Government of Pakistan

Figure 2.1: Map of Pakistan

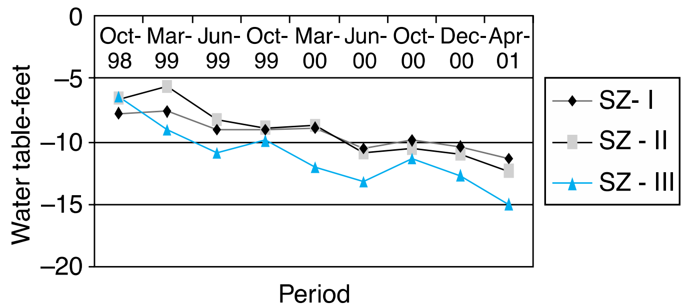
Source: Government of Pakistan

Figure 2.2: Map of Districts of Punjab



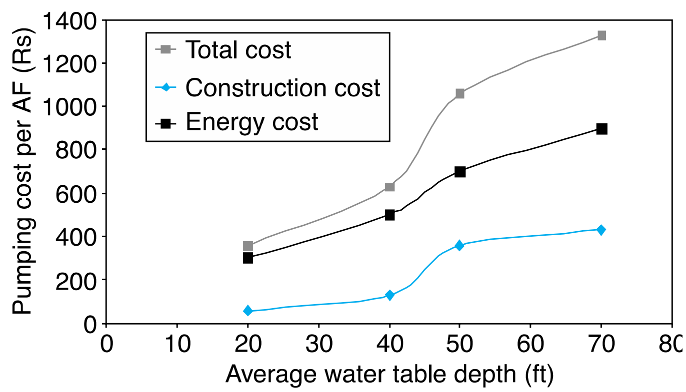
Source: Pakistan Water Partnership (PWP), 2003

Figure 2.3: Historical Development of Tubewells in Punjab



Source: Steenbergen and Gohar, 2005
**SZ = Saturated Zone*

Figure 2.4a: Declining Groundwater Table in Punjab



Source: Steenbergen and Gohar, 2005

Figure 2.4b: The Effect of Declining Water Table on the Cost of Pumping

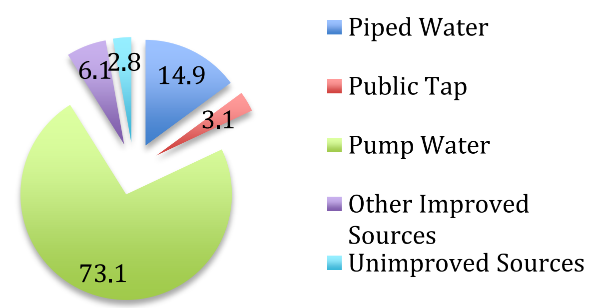


Figure 2.5a: Sources of Water in the Punjab - All Households

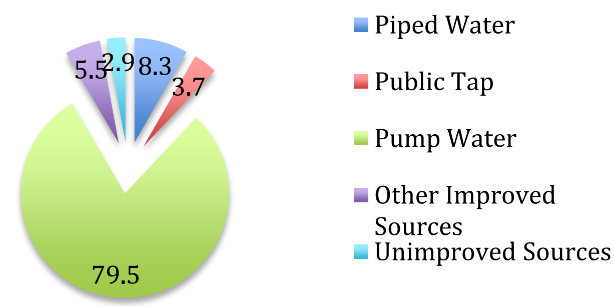


Figure 2.5b: Sources of Water in the Punjab - Rural Households

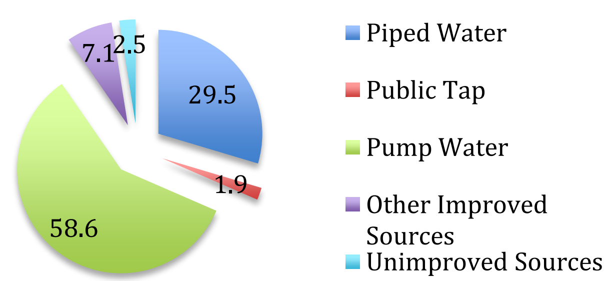


Figure 2.5c: Sources of Water in the Punjab - Urban Households

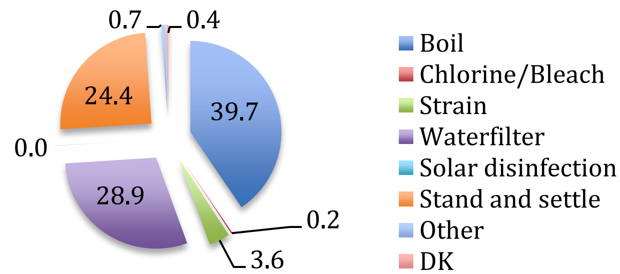


Figure 2.6a: Type of Water Treatment in the Punjab - All Households

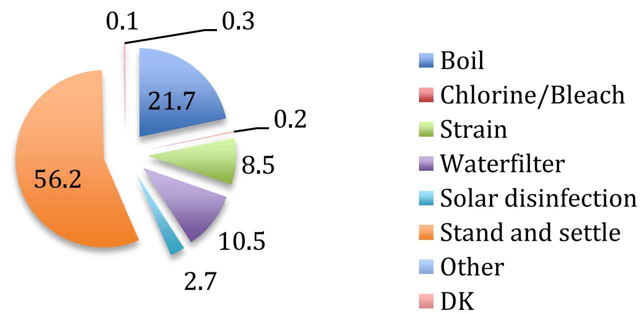


Figure 2.6b: Type of Water Treatment in the Punjab - Rural Households

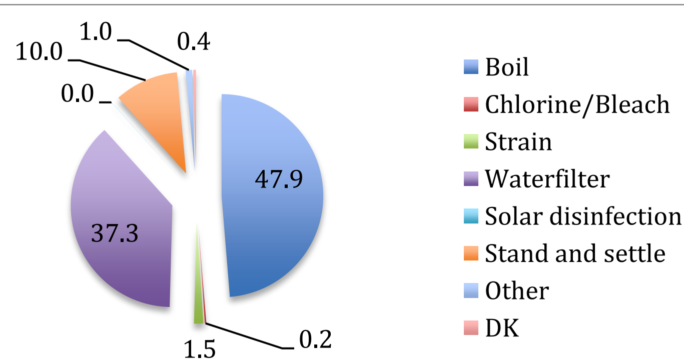
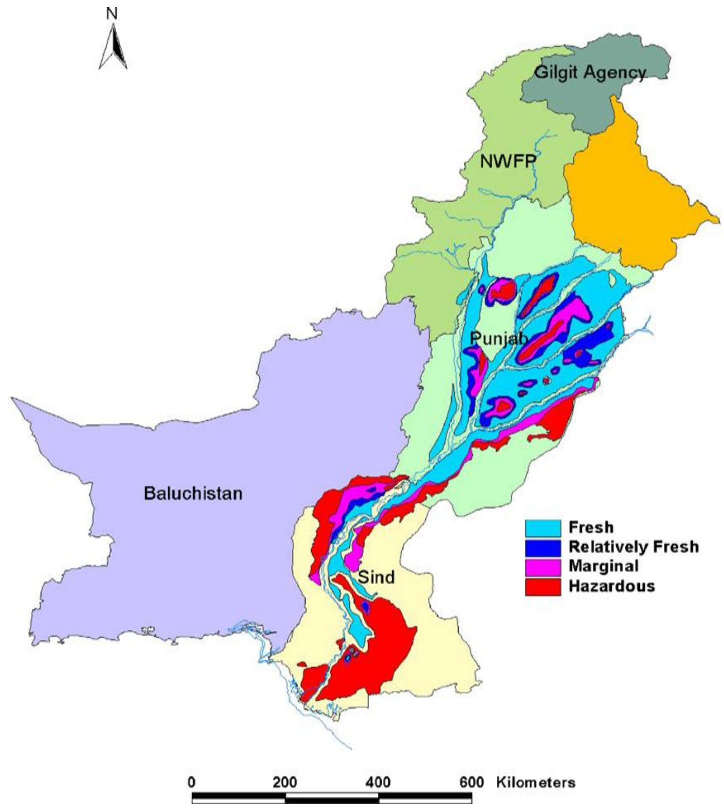


Figure 2.6c: Type of Water Treatment in the Punjab - Urban Households



Source: Qureshi et. al, 2004

Figure 2.7: Spatial Distribution of Groundwater Salinity in the Indus Basin of Pakistan

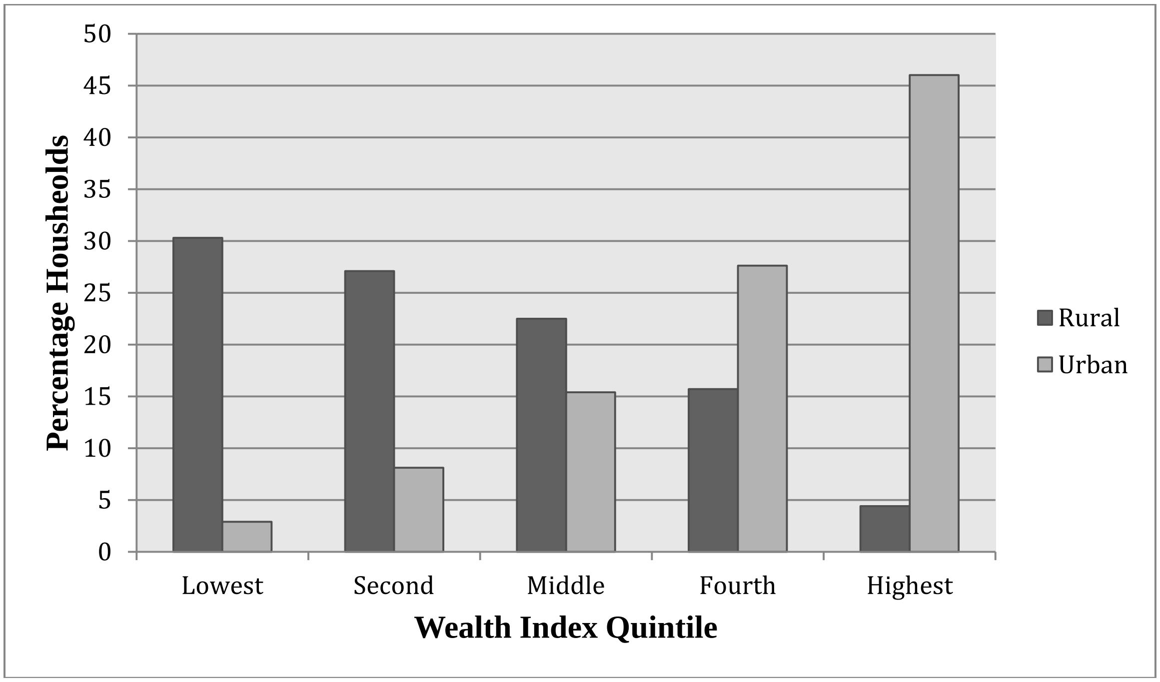


Figure 2.8: Distribution of Households by Wealth Index Quintiles in the Punjab

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CHAPTER 3
THE IMPACT OF PIPED WATER ON THE INCIDENCE OF DIARRHEA IN CHILDREN IN PUNJAB, PAKISTAN

3.1 INTRODUCTION

Diarrhea is the leading cause of child mortality in developing countries. About 90 per cent of cases of child diarrhea are caused by poor water quality and lack of sanitation (Black, Morris, and Bryce, 2003). Fink, Günther, and Hill (2011) estimated that access to clean water and adequate sanitation could prevent 2.2 million child deaths every year, while others estimate that almost 20 percent of diarrheal related mortality among under-5-year-old children in developing countries is due to contaminated drinking water (Kosek, et al., 2003). Consequently, the provision of clean drinking water is a high priority among policy makers, development banks and many bilateral donors. The World Bank alone reports an increase in water related lending by 55 percent between 1997 and 2007, reaching $8 billion per year, a third of which is spent on providing access to piped drinking water and sewage (World Bank, 2010).

Surprisingly, little is known about the actual health impacts of piped water schemes on diarrhea incidence in children. The empirical evidence is mixed at best, although most often no signs of improved health are found. Recent impact evaluations of interventions have shown that improved water and sanitation infrastructure, while showing positive outcomes in other dimensions, have rarely been found to translate into better health outcomes. For example, after reviewing several hundred World Bank funded water projects, the Bank's Independent Evaluation Group (IEG) concluded that "evidence of improved water quality is rare, as are indications of the improved health of project beneficiaries" (World Bank 2010, p.xiii). Indeed, most empirical studies only find limited health impacts from access to drinking water (some recent quasi-experimental examples include Gamper-Rabindran et al, 2010, and Devoto et al, 2012).

The reasons for this apparent lack of impact on health have only been partially identified (Waddington and Snilstvei, 2009). In many cases water is typically polluted at point-of-use despite access to clean piped water. In their review of 57 peer-reviewed publications, Wright et al. (2004) find that water pollution at point-of-use remains severe in more than half of the evaluated projects. However, water running through the pipelines may also be polluted before it reaches households for consumption (Lechtenfeld et al., 2012). In fact, as Figure 3.1 shows, there can be several factors that determine the transmission of diarrhea-causing pathogens. These include: a) hygiene standards and sanitation practices at the household level; b) availability of drinking water facilities, whether contaminated or not, and availability of a continuous or interrupted supply of water; and c) sanitation services and sewage facilities.

Most of the previous empirical work on the health impacts of public water services in developing countries focuses on rural projects, with only limited external validity to cities. In fact, urban and rural water supply and sanitation systems may differ considerably. In urban areas water sources are typically located more closely to dwellings, and delivery of water directly to the household doorstep is much more common. Rural-urban differences in sanitation practices also exist. Open defecation is less prevalent in urban areas. Instead, toilets and latrines are widely used with the associated wastewater being discharged into open sewers, underground cesspits, or piped sanitation systems. Finally, because urban areas tend to be more densely populated, pipelines are placed closer together. Likewise, maintenance of pipelines is more difficult in the more bustling urban areas than in rural villages (Government of Pakistan, 2008).

In Pakistan, diarrhea is the primary cause of child mortality (Government of Punjab, 2008). In the rural areas of Punjab province of Pakistan, 73 per 1000 children under 5 years of age were reported to have had a diarrhea incidence in a two-week period in 2008, and 82 per 1000 in the urban areas (Tables 3.3 and 3.4). In households that used piped water for drinking, the numbers were higher: 75 per 1000 children in rural areas and 100 per 1000 children in urban areas reported diarrhea in a preceding two-week period. In both areas almost 47 percent of household water samples contain bacteria, and in piped water samples over 50 percent were found to be contaminated (Tables 3.3 and 3.4).

In recent years, water availability and water quality concerns have been increasing in Pakistan. There are several sources for this concern, including the discharge of untreated industrial and agricultural effluents into unprotected water bodies; poor maintenance and leakages of water and sewage pipelines due to unavailability of maintenance funds; and widespread water rationing that creates a fertile environment for bacterial growth in pipelines (Chaudhry and Chaudhry, 2009). Contaminants seeping in from the ground can directly impact the quality of groundwater supply sources, or they can pollute water as it passes through pipes connecting those sources with final users. In either event, such contamination increases the probability of diarrhea. In fact, according to the Pakistan Environmental Protection Agency (EPA), the most imminent threat to drinking water is bacterial contamination through contact with sewage (Government of Pakistan 2008b).

Water quality issues are exacerbated by the Design Criteria codified in 1998[32] by the Punjab Health and Engineering Department (PHED) – the department responsible for most of the actual construction and partial maintenance of water pipelines (Table 3.1). The Design Criteria contains some 18 water quality parameters mostly related to aesthetic quality, but are silent on the limits for bacteriological contaminants, limits of toxic substances, and other water quality monitoring aspects. This is puzzling, given that microbial contamination is the most common and widespread health risk associated with drinking water. The PHED claims to follow World Health Organization (WHO) standards as far is bacteriological contamination is concerned, but as Table 3.2 shows, the PHED still lags behind those standards.

[32] The 1998 PHED Design Criteria is currently being used for the design of all Public Health Engineering structure for water supply, sewage, and drainage. The Design Criteria was reviewed in 2008 but no major changes were proposed.

In sum, bacteriological standards of water quality may not be met in Pakistan, and piped water may or may not be exacerbating this problem – in part because poor maintenance may lead to leakages and cross-contamination in pipelines. Moreover, there may be differences in the health effects of piped water across rural and urban areas, as well as across socioeconomic groups. Therefore, the objective of this chapter is to measure the health effects of piped water in both rural and urban areas and across socioeconomic groups. To do so, the effect of piped water consumption on the incidence of diarrhea in children under the age of 5 is analyzed.[33] The questions answered are:

- What is the impact of in-home piped water connection on diarrhea incidence in children in rural and urban areas?
- How do these impacts vary across different wealth strata and education levels?
- What is a possible cause of the health effects observed?

Using a logistic regression model of piped water and other explanatory variables on the incidence of diarrhea in children, the results show that piped water has no significant effect on diarrhea in children in rural areas, and that piped water actually has a significant association with adverse health effects in urban areas. In urban areas, piped water is associated with increasing the probability of diarrhea in children by an average of 2.2 percentage points; and although wealth and education lower this probability, the effect remains positive even for the richest and most educated households. Further analysis suggests that one possible explanation of the negative health effects of piped water is contamination of piped water with sewage water through cross-contamination of drinking water by sewage effluent.

This chapter makes two contributions to the existing literature. First, it analyzes the effect of piped water on the incidence of diarrhea in children in both rural and urban areas, and finds that the results differ across the two areas. This is particularly important for Pakistan since a comprehensive health analysis of piped water in urban areas seems to be

[33] The analysis is limited to children under the age of 5 due to data limitations. There is literature that shows that the effect of piped water in children and adults may be similar (ADB, 2008).

lacking.[34] Second, by using household-level variables on bacterial presence in water, it analyzes possible explanations of the adverse health effects of piped water by relating it to the presence or absence of bacteria in piped water. Such an analysis has not yet been carried out in Pakistan.

3.2 LITERATURE REVIEW

Large-scale investments in water and sanitation infrastructure are commonly advocated as a means of reducing diarrhea and child mortality. For example, the Millennium Development Goal 10 addresses this point by encouraging developing countries to reduce the share of people without access to improved water and sanitation by half. The *Task Force on Water and Sanitation* from the related UN Millennium Project asserts that massive investments would help to dramatically reduce the staggering number of 3900 children worldwide who die every day from a lack of proper water and sanitation (Bartram et al, 2005).

This notion that piped water supply will lead to improved health finds support in Galiani, Gertler and Schargrodsky (2005). Using data from Argentina, the authors investigated the impact of water utility privatization on the incidence of child mortality by exploiting the variation of public and private ownership of water utility across time and space. On average, the authors found reductions in urban child mortality by 8 percentage points in the areas that privatized their water services, and that this impact increases more than threefold for the poorest areas of the country.

Focusing on another middle-income country, Gamper-Rabindran, Khan and Timmins (2010) presented more heterogeneous findings. The marginal impact of piped water supply on infant mortality in Brazil was the largest in areas with high initial child mortality. Using a quintile regression approach for panel data, the authors addressed a series of potential

[34] In fact no comprehensive study is found on the analysis of the heath impact of piped water in the urban areas of Punjab, Pakistan.

measurement problems and unobserved heterogeneity.

This picture from Latin America is largely confirmed by a meta-analysis of the health impacts of water, sanitation, and hygiene interventions in urban and rural areas (Fewtrell et al., 2005). The meta-analysis covered 46 peer-reviewed studies, nearly all of them from South Asia and Sub-Saharan Africa, and found that the average intervention on water, sanitation, or hygiene helps to reduce the relative risk of diarrhea by somewhere between 25-37 percent. Importantly, water treatment at point-of-use (e.g. water boiling, use of water filters, etc.) was found to be the most effective intervention. The authors also caution that estimates of the impact of hygiene training (e.g. hand washing) are likely to be overstated because they suffer from publication bias.

In stark contrast to the positive impacts found in these studies, a recent World Bank review of its activities over the past decade concludes that it is exceptionally rare to find any health improvements among beneficiaries of piped water schemes (World Bank 2010). This less sanguine assessment is supported by a literature review of randomized control trials by Zwane and Kremer (2007). Zwane and Kremer assert that infrastructure projects in water and sanitation rarely translate into health improvements when effective hygiene training is lacking. Inadequate water storage and handling at the point-of-use can reverse potential positive health effects from improved water sources.

In a 2012 study using data from Tangiers, Morocco, Devoto et al. (2012) show that household willingness to pay for a private connection is high, not because a connection improves health but because it increases the time available for leisure and reduces inter- and intra-household conflicts on water matters, leading to sustained improvements in well-being.

While there is vast literature on the health effects of piped water, the empirical evidence is largely ambiguous and very often causal links are missing. For example, in an influential paper using propensity score matching to analyze the impact of piped water on diarrhea in children in Rural India, Jalan and Ravallion (2001) find that the prevalence of diarrhea is significantly lower on average for families with piped water than for observationally identical households without piped water. However, they find that the health gains largely bypass children in poor families, particularly when the mother is poorly educated. Their findings point to the importance of combining infrastructure investments with effective public action to promote health knowledge and income poverty reduction. While this finding underscores the importance of water handling at household level, the authors do not have any information on behavior or water quality. They are thus unable to sort out the extent to which positive health impacts are related to water quality *vis-à-vis* water handling.

A similar problem pertains to a recent study on in-yard water supply in rural China (Mangyo, 2008). Although the paper finds that health outcomes are conditional on maternal education, no data is available to show how maternal education translates into actual water handling, and how that affects water quality and subsequently child health.

In contrast, Semenza et al. (1998) quantified the effect of water handling at household level in Nukus, Uzbekistan (where drinking water quality is found to be suboptimal) by measuring chlorine residues at point-of use. To do this, the authors randomized water purification at home by providing half of the sample with free chlorine tablets. The results clearly showed the effectiveness of water pollution purification near the point-of-use (at least in the short run). The authors concluded that pipe pollution is a serious problem and that irregular water pressure and water rationing can sever the situation further, as rationing allows pollutants to spread in all directions of the piped network. The generality of this paper is somewhat limited due to the fairly small sample of connected households (N=120) and the lack of information is available on health outcomes.

A study by Zhang (2012) is the first to distinguish between access to chlorinated and non-chlorinated drinking water. Using longitudinal data covering 150 Chinese villages from 1989 to 2006, he presents evidence that the quality of water supply is of immense importance to health. In the long run, anthropometric outcomes improve substantially among children, as does the incidence of diarrheal diseases among adults. Unfortunately, there is a lack of water quality data that could further support the claim that these health improvements are solely due to water chlorination at purification plants. Indeed, causal evidence on the health impact of piped water and sanitation in this paper is very limited insofar as water contamination may be a result of broken pipes, changing water pressure and interruptions of piped water supply (i.e. rationing). In addition, unhygienic water storage and handling may cause additional pollution at household level. Irregular hand washing opens up additional routes of pathogen transmission.

More recently, using a unique mix of household data, microbiological test results and spatial information from urban Yemen, Lechtenfeld et al. (2012) are able to disentangle more thoroughly the causal links between piped water and health at the point of use and point of consumption. Their analysis consists of three parts. First, exogenous variation of pipe construction is used to quantify the health impact of access to piped water. Piped water is found to <u>increase</u> the risk of diarrhea in children by 4.6 percentage points. Second, by exploiting the spatial correlation of pollution among households connected to the same water pipe, they find that broken pipes and interruptions of water supply are responsible for most of the water pollution. Third, they find that unhygienic water storage and handling at household level additionally increases water pollution.

In Punjab, Pakistan, very little research has been done in analyzing the health impacts of piped water. Jensen et al (2004) conducted a year long study in southern Punjab to investigate the association between bacteriological drinking water quality and incidence of diarrhea. Diarrhea episodes, drinking water sources, and drinking water quality were monitored weekly among children younger than 5 years in 200 households. No association was found linking the incidence of childhood diarrhea and the number of E.coli in the public drinking water sources. Fecal contamination levels in household water containers are generally high even when the source water is of good quality. The authors argue that under conditions such as these, it is questionable whether public water treatment will have a significant impact on the incidence of endemic childhood diarrhea.

The Asian Development Bank has invested significant resources in two projects increasing coverage of piped water and sanitation in the rural areas of Punjab (the PRSSP and PCWSSP projects described in Chapter 2). However, an impact study of those two projects found no significant health impact of piped water (Asian Development Bank 2009). Using propensity score matching, the study estimated the welfare impacts of the projects on (i) health, (ii) education, and (iii) labor force participation rate and hours worked. The results show that the projects had clear and large influences on education, but that the time savings from not having to fetch water did not translate into increased income, greater workforce participation, or any significant increase in labor force hours worked. Perhaps most notably, no significant aggregate reduction in the incidence or severity of waterborne illness such as diarrhea was found, although a more disaggregated analysis revealed instances (e.g., among middle income groups) in which extending coverage of the water system gave rise to significant positive health impacts.

3.3 THEORETICAL MODEL

Jalan and Ravallion (2003b) use a utility maximizing framework to analyze the impacts of piped water on children's diarrheal outcomes in India. Here, I use their theoretical framework and assume, like they do, that the child's health function is additively separable in the parents' utility function. The objective is to estimate the impact of water variables on health, with parents as utility maximizers. Parents choose optimal health outcomes based on their input choices that minimize their costs of producing good health. In this setting, it is assumed that parents know the health production functions of their children.

The model shows that once one allows for privately provided health inputs, and assuming that parents care about more than just their children's health, the direction of the effect on children's health is theoretically ambiguous, and becomes an empirical question.

Following Jalan and Ravallion (2003b) the child health production function is described by:

$$h = h(w, s, z) \tag{1}$$

where w indicates different means of water access (piped, pumped, public tap., other improved and unimproved sources)[35]; s is expenditure by parents on their children's health; and z is a vector of child-specific and socioeconomic variables such as age, gender of the child, height of the child, education or awareness of the mother, and income of the household. The function h is assumed to be twice continuously differentiable, and that $h_w > 0, h_s > 0, h_{ww} < 0, h_{ss} < 0$ (and $h_z \lesseqgtr 0$ depending on the particular variable).[36]

Parents derive utility from improved access to water, from net income for non-health consumer goods, and from other factors embodied in z. Expenses, s, incurred by parents on their children's health and consumption c of non-health consumer goods together make up (exogenous) income y. Hence, $y - s = c$ is left for parents to spend on non-health consumption goods and forms the budget constraint. So in choosing the level of spending on child health, the parents' take account of the lost opportunity for consumption of other private goods. The parents' problem is described by the choice of s, which maximizes their utility:

$$\text{Max U} = U(w, y - s, z) + h\,(w, s, z)^{37} \qquad (2)$$

where U is assumed to be twice continuously differentiable in (y − s), strictly increasing in (y − s) and w, with diminishing marginal utility of disposable income (i.e., $U_w > 0$, $U_{y\text{-}s} > 0$, $U_{y\text{-}s,y\text{-}s} < 0$).

The solution to the maximization problem is defined by setting $U_s = 0^{38}$ which gives

$$U_y(w, y - s, z) = h_s(w, s, z) \qquad (3)$$

The solution equates the marginal utility of own consumption to the marginal impact of spending on child health.

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35 Following Jalan and Ravallion, water source is treated as a continuous variable instead of a discrete variable.
36 Throughout this discussion, subscripts indicate derivatives.
37 A more complete model would include time allocation variables. However, since data limitations prevent such an analysis, including them here would just add additional layers of (untestable) ambiguity.
38 The type of water source, denoted by w, is assumed to be exogenous and is therefore not one of the choice variables.

Optimal s is therefore given by $\hat{s} = s(w, y, z)$ which gives the maximum utility for parents (obtained through substitution in their utility function) and optimal child health:

$$v(w, y, z) \equiv u(w, y - s(w, y, z), z) + H(w, y, z)(\text{parent}) \quad (4)$$

$$H(w, y, z) = h(w, \hat{s}, z) = h(w, s(w, y, z), z) \ (\text{child}) \quad (5)$$

3.3.1 Effect of Water Access on Child Health

By the envelope theorem, v(w, y, z) must be increasing in w. However, this need not hold for both the components of parental utility. The effect of w on child health in a neighborhood of the equilibrium in which private inputs are optimal is given by:

$$H_w = h_w + h_s s_w \quad (6)$$

We can obtain s_w by totally differentiating the first order condition (equation 3):

$$U_{yw} - h_{sw} = h_{ss} s_w + U_{yy} s_w \quad (7)$$

Re-arranging terms:

$$s_w = \frac{U_{yw} - h_{sw}}{h_{ss} + U_{yy}} \quad (8)$$

Using $U_{yy} < 0, h_{ss} < 0,$ the denominator is negative. Less can be said about the numerator where a positive or negative outcome depends on the effects of U_{yw} and h_{sw}. The ambiguity of this means that the cumulative effect of water access on child health can only be sorted out empirically.

3.3.2 Effect of Income on Child Health

Totally differentiating H_w with respect to y yields the income effect of a health gain to children from access to water;

$$H_{wy} = h_{ws}s_y + h_{ss}s_ys_w + h_ss_{wy} = s_y(h_{ws} + h_{ss}s_w) + h_ss_{wy} \qquad (9)$$

Totally differentiating equation (3) with respect to y yields

$$U_{yy} - U_{yy}s_y = h_{ss}s_y \qquad (10)$$

Rearranging terms:

$$s_y = \frac{U_{yy}}{U_{yy} + h_{ss}} \qquad (11)$$

The numerator is negative as $U_{yy} < 0$. The denominator is also negative since $U_{yy} < 0$ and $h_{ss} < 0$. Therefore, $0 < s_y \leq 1$. However, as equation (9) shows, the total income effect of a health gain to children from access to water, H_{wy}, also depends on s_w and s_{wy}, the directions of which are unclear.

3.3.3 Effect of Socioeconomic Factors on Child Health

The socioeconomic effect of a health gain to children from access to water is given by:

$$H_{wz} = h_{wz} + h_{ws}s_z + h_{sz}s_w + h_{ss}s_zs_w + h_ss_{wz} \qquad (12)$$

Substituting for s_z from the first order conditions in equation (3)

$$U_{yz} - U_{yy}s_z = h_{sz} + h_{ss}s_z \qquad (13)$$

Collecting terms for s_z we get

$$s_z = \frac{U_{yz} - h_{sz}}{U_{yy} + h_{ss}} \tag{14}$$

The denominator is negative since $U_{yy} < 0$ and $h_{ss} < 0$. The sign of the numerator is ambiguous, however, so the direction of the interaction effect of the water source and socioeconomic variables on child health, H_{wz}, is unclear.

To sum up, combining a utility function for parents that is additively separable in child health with interaction effects between water access and socio-economic variables, the impact on child health of access to water and other socio-economic variables is theoretically ambiguous. An empirical analysis is therefore necessary to find the direction of the effects.

3.4 EMPIRICAL ESTIMATION

To empirically estimate the effect of piped water on the incidence of diarrhea in children under the age of 5 the following model is used:[39]

$$\begin{aligned} \text{Diarrhea}_i = {} & \beta_0 + \beta_1 \text{Piped water}_j + \beta_2 \text{Other water sources}_j + \beta_3 \text{Sanitation}_j \\ & + \beta_4 \text{Health practices}_j + \beta_5 \text{Health Awareness}_j + \beta_6 \text{Child characteristics}_i \\ & + \beta_7 \text{HH characteristics}_j + \beta_8 \text{Wealth}_j + \beta_9 \text{Education of hh head}_j \\ & + \beta_{10} \text{Mother's education}_j + \beta_{11} \text{ Month of interview}_j \\ & + \varepsilon, \qquad i = 1, .., N, j = 1, \ldots, M \end{aligned} \tag{15}$$

Variables in equation (15) are defined as follows:

"Diarrhea" is a dummy variable on whether the child (under the age of 5) is reported to

[39] Note that the subscript i refers to 1,..., N children whereas the subscript j pertains to 1,...,M households.

have diarrhea in a 2-week period;[40]

"Piped Water" is a dummy variable taking a value of 1 if the household's main method of obtaining drinking water is from an in-home pipe, and 0 otherwise;

"Other Water Sources" is a vector of four dummy variables, one each for other water sources that are reported to be the household's main source of drinking water. These include pumped water (hand pump, motorized pump), public tap water, other improved water sources (protected well, protected spring, bottled water, etc.), or unimproved sources (unprotected well, unprotected spring, water from a cart, puddle water)[41];

"Sanitation" is a dummy variable taking a value of 1 if the household has a toilet facility connected to a community sewer system or a septic tank, and 0 otherwise;

"Health Practices" is a set of four dummy variables indicating whether or not the household employs certain health improving measures. These include whether the household treats water; whether all members wash hands before a meal; or whether all members wash hands after using the bathroom. Also included is a dummy variable taking a value of 1 if there is a health facility within 30 minutes of the household, and zero otherwise;

"Health Awareness" measures the degree of awareness of good health practices and is proxied by dummy variables on the knowledge of iodized salt, access to media (TV, computer, radio, phone), and knowledge of symptoms that would require taking the child to a health center;

"Child characteristics" is a set of variables indicating variables on age, sex, and weight for height of child;

"HH characteristics" is a set of variables for household size, and dummy variables for sex of household head, and whether the household has an electricity, gas, or water filter connection;

"Wealth" includes dummy variables for whether the household is in the lowest, second, middle, fourth, or highest wealth index quintile (as described in Chapter 2);

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[40] The interview question was worded as: "Did the child have diarrhea in the last two weeks?"

[41] 99.5 percent households in rural areas and 95.7 percent households in urban areas reported to have only one source of water.

“Education of household head” is a set of dummy variables indicating educational attainment of the household head – no education, primary, middle, secondary, or higher education;

“Mother’s education” includes dummy variables for whether the mother has no education, or primary, middle, secondary, or higher education; and

“Survey month” are dummy variables indicating the month in which the household was surveyed. These account for seasonal differences in likelihood of diarrhea incidence.

3.5 DESCRIPTIVE STATISTICS

This section provides descriptive statistics for the key variables used in the empirical analysis. Rural and urban areas are considered separately.

3.5.1 Rural Areas

The descriptive statistics for rural areas are shown in Tables 3.3-3.6. Table 3.3 provides statistics by treatment, and Tables 3.4-3.6 provide statistics by wealth, education of household head, and mother’s education, respectively.

Table 3.3 shows that the mean incidence of diarrhea in children under the age of five in rural areas is 7.3 percent. For households with piped water the incidence of diarrhea is 7.5 percent, and for those without piped water the incidence of diarrhea is 7.1 percent. Table 3.4-3.6 show that, in rural areas, the incidence of diarrhea decreases with wealth, education of household head, and mother’s education (t-tests confirm that the means are significantly different at the 0.01 level). For households in the lowest wealth index quintiles (Table 3.4), or those where the household head has no education (Table 3.5), or the mother has no education (Table 3.6), the incidence of diarrhea is on average 8 percent. For the middle class households (i.e., those in the second and third quintiles), or households where the education of the household head is low (at most primary or middle schooling), or mother’s education is low, the mean incidence of diarrhea is 7 percent. For rich households (fourth or highest wealth index quintile) (Table 3.4), or households where the education of the household head is high (secondary or higher) (Table 3.5), or mother's education is high (Table 3.6), the mean incidence of diarrhea in children is lower at 6 percent.

Almost half of the households in rural areas have bacteria present in their water (47 percent). Interestingly, bacterial incidence is higher in piped water samples than samples obtained from other water sources. This difference is statistically significant at the .01 level.

The most common source of water in rural areas is pumped water (hand pump or motorized pump). Around 80 percent of rural households in rural areas use this source, as shown in Table 3.3. Only 8 percent of households use piped water, 4 percent use public taps, 6 percent use other improved sources such as covered well or bottled water, and 3 percent obtain their water from unimproved sources such as uncovered wells and surface water. Tables 3.4-3.6 show that the choice of water source seems to follow a consistent pattern across the different wealth and education strata: the percentage households with piped water and other improved sources of water rises as wealth and education increases, and the use of pumped water, public taps, and unimproved sources falls as wealth and education rises (t-tests confirm that the differences are all significant at the 0.01 level).

Table 3.3 shows that only 3 percent of rural households have a toilet facility that is connected to a mainline. Not surprisingly, households with piped water are more likely to have toilet facilities connected to a mainline than those without. 3 percent of households that use alternative water sources to piped water have a toilet facility connected to a main line and the value is higher for those households with piped water at 5 percent. 35 percent rural households have a toilet facility connected to a septic tank, and more than 60 percent of households have no covered toilet facilities, and dispose off waste in pits, fields, etc. Not surprisingly, Tables 3.4-3.6 show that the percentage of households with a toilet facility flushed to a mainline increases as wealth and education increases and the percentage of households using improper means of sanitation (pit, fields, buckets) decreases as wealth and education increases (t-tests confirm that the differences are significant at the 0.01 level).

Almost no household in the lowest wealth index quintile has a toilet connected to a mainline compared with 8 percent of households in the two top wealth quintiles; and 96 percent poor households use unimproved sanitation facilities versus only 15 percent rich households (Table 3.4).

Table 3.3 indicates that the treatment of water is quite limited in rural areas. Only 2.3 percent of households treat their water in any form (boiling, chlorinating, settling). Note that a higher percentage of households with piped water treat their water than those who use other sources. This may indicate that households are aware that piped water is unsafe (over alternative sources) and therefore requires some form of treatment before consumption; or may be due to differences in wealth and education between the two groups. In terms of hygienic practices, washing hands after using the bathroom is a more common practice than washing them before meals, 29 percent of households wash their hands before a meal, and 41 percent after using the bathroom, and the percentages of hand washing are higher for households with piped water than those without. Also, more than 60 percent of households have a health center within 30 minutes of their house. Also, as would be expected, Tables 3.4-3.6 show that as wealth and education increases, the percentage households that treat water, wash their hands after a meal or after using the bathroom, or have a health center within 30 minutes of the house increases (t-tests confirm that the differences are significant at the 0.01 level).

Table 3.3 shows that almost 50 percent of households in rural areas know about the benefits of using iodized salt, and 60 percent of households have some form of access to media (either a TV, radio, or computer). All households claim to know at least one symptom that would require taking the child to a health center.[42] The percentage of households with knowledge about iodized salt and access to media are higher for households with piped water than those without. This may be attributed to the different distribution of wealth and income strata between the two groups where households with piped water tend to be wealthier and

[42] Note, however, that this variable was rather vaguely stated, and hence responses most probably overstate health awareness.

educated; indeed, Tables 3.4-3.6 show that the percentage households with knowledge about iodized salt and access to media increase as wealth and education increases (t-tests show that these differences are significant at the 0.01 level).

The average household size in rural areas is around 8 members (Table 3.3). Only 3 percent of households have a female household head. Around 88 percent of households have electricity connections; this percentage is higher for households with piped water. Gas connections are not common and only 5 percent of households are connected to gas pipelines. Water filters are also not very common and only 1 percent of households in rural areas have water filters in both piped and non-piped households. Not surprisingly, Tables 3.4-3.6 show that the percentage of households with electricity, gas, and water filters, increases as wealth or education (mother’s or household head’s) increases (and the differences are significant at the 0.01 confidence level).

The majority of households in rural areas are towards the lower half of the wealth spectrum (Table 3.3). 32 percent of households are in the lowest wealth index quintile versus only 4 percent in the highest wealth index quintile. Also, rural households with piped water are generally wealthier than those using other sources of water, and the difference in means are significant. 34 percent of non-piped households are in the lowest wealth index quintile compared with only 12 percent of piped households. Similarly, 15 percent of non-piped households are in the fourth and fifth wealth index quintile as compared to 26 percent of the piped households.

More than half of the household heads have no education, 16 percent have primary education, 11 percent have middle education, and only 21 percent have secondary education or higher. Similar to the wealth pattern, household heads in piped households are generally more educated, and the differences are significant at the 0.01 level (except for household heads with education at primary level, which is not found to be significantly different between piped and non-piped groups). 53 percent of household heads in non-piped households have no education versus 43 percent in piped households; likewise, 20 percent of household heads have secondary education or higher in non-piped households versus 27 percent in piped households.

Striking gender differences in education exist. This can be seen by comparing the educational attainment levels of mothers with those of household heads (which tend to be overwhelmingly male). T-tests indicate the differences in average educational attainment of household heads and mothers are significant. 70 percent of mothers have no education, 14 percent have primary education and only 15 percent have middle education or higher. Again, mothers in piped households are generally more educated than their non-piped counterparts. 72 percent mothers in non-piped households have no education versus a lower 55 percent in piped households, and 9 percent mothers in non-piped households have secondary education of higher versus more than double the amount (19 percent) in piped households.

3.5.2 Urban Areas

The descriptive statistics for rural areas are shown in Tables 3.7-3.10. Table 3.7 provides statistics by treatment, and Tables 3.8-3.10 provide statistics by wealth, education of household head, and mother's education, respectively.

Table 3.7 shows that the mean incidence of diarrhea in children under the age of five in urban areas is 8.2 percent, higher than the 7.3 percent in rural areas (t-tests confirm that the difference in means are significant at the 0.01 level). As in rural areas, the incidence of diarrhea is significantly higher for households with piped water than for households obtaining water from other sources. Tables 3.8-3.10 reveal similar patterns in the incidence of diarrhea across different wealth and education strata in urban areas to those that were found in rural areas. The incidence of diarrhea declines from 10 percent for poor and middle-class households (lowest three wealth index quintiles) to 8 percent for richer households (from the upper two wealth quintiles (Table 3.8)), and the differences are significant at the 0.01 level. Similarly, reported incidence of diarrhea is 9 percent for households in which the household head (mother) have no or low education, falling to 7 percent for households in which the head or mother has a secondary or higher level of education (Tables 3.9 and 3.10).

As in the rural areas, almost half of the households in urban areas have bacteria present in their water (Table 3.7) and the levels are higher in piped water samples than samples obtained from other water sources.

Table 3.7 shows that, pumped water is the most common water source for the majority (59 percent) of urban households, although not to the same extent as rural households (80 percent of which rely on pumped water). However, a higher percentage of urban households (30 percent) rely on piped water than in rural areas (where the figure was 8 percent). 2 percent of urban households obtain water from public taps, 7 percent from other improved sources, and 2 percent from unimproved sources. Tables 3.8-3.10 show that the choice of water source seems to follow a consistent pattern across the different wealth and education strata where the percentage households with piped water and other improved sources of water rises as wealth and education increases, and the use of pumped water and public taps falls as wealth and education rises (t-tests confirm that the differences are significant at the 0.01 level).

Table 3.7 shows that almost 50 percent of households in urban areas have a toilet facility that is connected to a main line, and that households with piped water are more likely to have toilet facilities connected to a mainline than those without. 42 percent of non-piped households have a toilet facility connected to a main line versus 58 percent for piped households. 40 percent of households have a toilet facility that is connected to a septic tank, and only 13 percent of households use informal sanitation measures. Not surprisingly, Tables 3.8-3.10 show that the percentage of households with a toilet facility flushed to a mainline increases as wealth and education increases and the percentage of households using unimproved means of sanitation (pit, fields, buckets) decreases as wealth and education increases (t-tests confirm that the differences are significant at the 0.01 level). Only 7 percent poor households have a toilet facility connected to a mainline versus more than 50 percent rich households, and 78 percent poor households use unimproved toilet facilities versus only 6 percent rich households.

Table 3.7 indicates that 11 percent of households in urban areas treat their water before consumption, and a higher percentage of households with piped water treat their water than those who use other sources. As was the case for rural households, this may indicate that households are aware that piped water is unsafe (over alternative sources) and therefore requires some form of treatment before consumption; or it may reflect other variables (e.g. education, wealth) that are correlated with both reliance on piped water and propensity to treat. As in rural areas, washing hands after using the bathroom is a more common practice than washing them before meals. 58 percent wash their hands before meals and 72 percent after using the bathroom, and these percentages are higher for households with piped water than those without. 95 percent have a health center located within 30 minutes of the house. Also, as would be expected, the percentage households that treat water, wash their hands after a meal or after using the bathroom, or have a health center within 30 minutes increases with wealth and with education (t-tests confirm significance at the 0.01 level).

Table 3.7 indicates that 71 percent of households know about the benefits of using iodized salt, 85 percent of households have some form of access to media (either a TV, radio, or computer). As in rural areas, all sampled urban households claimed to know at least one symptom that would require taking the child to a health center (again with the caveat that since this variable is very subjective, the values are most probably overstated). The percentages of households with knowledge about iodized salt, and access to media are higher for households with piped water than those without. This may be attributed to the different distribution of wealth and education between the two groups: households with piped water tend to be wealthier and better educated, and the Tables 3.8-3.10 show that the percentage households with knowledge about iodized salt and access to media increase as wealth and education increases (t-tests confirm significance at the 0.01 level).

As in rural areas, the average household size is around 8 members, and only 4 percent of households have a female household head. 90 percent of households have electricity connections, and the percentages are higher for households with piped water in which all households have electricity. 60 percent of households have gas connections, and the percentages are also higher for households with piped water than those with other water sources. Water filters are not very common and only 6 percent of households have water filters, and a higher 10 percent in households with piped water. Not surprisingly, the percentage of households with electricity, gas, and water filters, increases as wealth or education (mother's or household head's) increases (t-tests confirm the differences are significant at the 0.01 level).

Urban households are generally richer than rural households.[43] As in rural areas, urban households relying on piped water are generally wealthier than urban households relying on different water sources. 16 percent of non-piped households are in the lowest and second wealth index quintiles, versus only 6 percent piped households, and 37 percent non-piped households are in the highest wealth index quintile versus a higher 56 percent piped households.

Urban households clearly are better educated, in general, than rural households. For example, Table 3.7 shows that almost 40 percent of household heads in urban areas have secondary education or higher – nearly double the fraction for rural areas; and 33 percent of urban household heads report no education (compared with 59 percent in rural areas). Table 3.7 also indicates that piped households tend to be better-educated: 35 percent of household heads in non-piped households have no education versus 30 percent in piped households; and 38 percent of household heads have secondary or higher education in non-piped households versus a larger 44 percent in piped households (t-tests confirm that the differences are significant at the 0.01 level).

As in rural areas, gender differences in educational attainment exist among urban households (and the differences are significant at the 0.01 level). This is reflected by a higher (lower) percentage of mothers with lower (higher) levels of education than household

[43] While most households in rural areas are poor (Table 3.3), the majority of households in urban areas are in the upper half of the wealth spectrum (Table 3.7). 43 percent of households in urban areas are in the higher wealth index quintile, and only 3 percent of households in are in the lowest wealth index quintile.

heads. And again, mothers in piped households tend to be are more educated than their non-piped counterparts.

3.6 RESULTS

This section presents econometric estimates of the impact of piped water on the incidence of diarrhea in children under five, based on the empirical model discussed above (equation (15)). Since the dependent variable is a binary variable – i.e., whether or not the child had had diarrhea within the past two weeks – a logistic regression model was used, and the tables present the average marginal effects of the logit estimates.

Results are presented separately for rural and urban areas. Two different models are estimated. One contains only the dummy variable for piped water, so the effect of piped water is compared to all other sources of water. The second contains dummies for all water sources, with “other improved sources” (covered well, covered spring, bottled water, tube well) as the omitted category. The idea of using other improved sources as the comparison category is to enable a comparison between the health effects of sources found on premises (piped and pumped water) to other improved sources that are located off-premises. If, for example, improved sources located off-premises are found to be healthier, this may justify (in the household decision maker’s eyes) the extra time it takes to fetch water from these sources.

Consideration was given to whether the piped water variable could be endogenous, for example if the public placement of water supply infrastructure were directed to locations in which the incidence of waterborne pathogens was relatively high. However, as the dependent variable was whether the child had diarrhea in the last two weeks, and given the extremely small likelihood that a particular household would have decided to install a piped connection during the two week prior to the survey, the endogeneity of piped water seems highly unlikely *a priori*.[44]

3.6.1 Rural Areas

The regression results for rural areas are found in Table 3.11. In column (1) of Table 3.11, the coefficient of piped water is small, positive, and not significant, indicating no meaningful effect of piped water on the incidence of diarrhea in children in rural areas. This is consistent with the findings of the Asian Development Bank's assessment of the Punjab Rural Water Supply and Sanitation (PRWSS) and Punjab Community Water Supply and Sanitation (PCRWSS) projects described in Chapter 2 (ADB, 2009). The ADB report found no statistically significant evidence of piped water reducing the incidence of diarrhea in children and adults.

When piped water is compared to other improved water sources (in column (2) of Table 3.11) the coefficient is positive and significant, as are the coefficients for pumped water and public taps. These results indicate a greater probability of diarrhea among children in households using these three water sources *vis-à-vis* households using the comparison water source (other improved water sources). In terms of magnitudes, the results suggest that on average, the probability of diarrhea is greater by 2.6 percentage points for households employing either of the two on-site sources (pumped and piped water), and 4.6 percentage points greater for households relying on public taps. Unexpectedly, the coefficient of unimproved water source is very small and statistically insignificant, indicating no difference in health impacts between "other improved" and "other unimproved" sources.

[44] It is possible, however, that placement of piped water in an area may be influenced by past incidence of diarrhea. To explore this possibility, an instrumental variable (IV) regression was estimated in which tehsil-level groundwater salinity was used as an instrument for piped water. If anything, the lack of beneficial health effects from piped water was more pronounced when using an IV. Specifically, the coefficient on piped water in rural areas was found to be small, positive and significant; and in urban areas the coefficients remained positive and significant (as in the non-instrumented regression), but the effects were larger. Wu-Hausman tests rejected the endogeneity in both areas. In sum, none of the models (either taking piped water as endogenous or not) indicated any beneficial health effects of piped water. This increases our confidence that piped water, at the very least, seems to have no effect on the probability of diarrhea.

Although it is hard to predict here whether households are aware of the relative unhealthiness of piped (and pumped) water, the higher percentage of piped and pumped households may indicate a preference for a timesaving in-home alternatives over sources located off-premises. If households are in fact aware of these health effects, this may indicate a higher preference for convenience over health. Household preferences are analyzed to some extent in the next chapter on the willingness to pay for piped water.

When it comes to sanitation, both having an improved toilet facility connected to main line or septic tank decreases the probability of diarrhea, all things constant, and toilet facilities connected to main lines have a stronger effect (decrease the average probability of diarrhea by around 2 percentage points versus around 1 percentage point with septic tanks (column (1)).

Surprisingly, the coefficient of treating water is positive and significant. This may be because more than half of the few households that do treat water do so by letting the water 'stand and settle.' This is not effective in killing bacteria and making water safer, and in fact the extra time that the water is let to stand may allow more bacteria and germs to enter therefore making the water more unsafe and therefore more prone to causing negative health effects. Or perhaps, the positive coefficient may be attributed to the fact that households experiencing a higher incidence of child diarrhea might be more inclined to treat their water. When it comes to washing hands as a good health practice, the results show that the coefficient of washing hands before a meal is negative and significant, so, this practice is successful in decreasing the probability of diarrhea, however the coefficient of washing hands after using the bathroom is positive and significant, indicating that this practice actually increases the probability of diarrhea, all things constant. It is not clear why washing hands after using the bathroom would cause negative health effects, and may be because hands are washed improperly or with water from containers that may have stagnant and therefore more bacteria-prone water. Having a health facility within 30 minutes of the house is not found to have any significant effect on the incidence of diarrhea.

Of the variables used to measure general awareness of health issues, knowledge of iodized salt is found to have an expected negative and significant effect on the incidence of diarrhea. Having access to any form of media is not found to have a significant effect. Knowledge about symptoms requiring taking a child to a health center has a positive and significant effect on diarrhea. This unexpected sign may be because the variable is a weak proxy of awareness and is subjective, and since almost 99 percent of households claim to have knowledge of the symptoms of poor health, it is probably an overstated and inaccurately measured variable in the first place. Another reason could be that perhaps households with unclean water are more cognizant of diarrhea, hence the positive association between knowledge and incidence.

All child characteristics variables are found to have negative and significant coefficients. These indicate that the older the child and the larger the weight for height of the child, the lower the probability of diarrhea. Interestingly if the child is a female the probability of diarrhea also decreases. This may be attributable to biological factors, or perhaps to the fact that rural male children are more likely to play outdoors and thus be exposed to more pathogens than females.

None of the household characteristic variables are found to be significant.

The empirical results regarding wealth are interesting in that they point to a significant inverse relationship between wealth and diarrhea incidence. Specifically, the coefficients indicate that on average, the probability of diarrhea incidence among children in households in the third and fourth wealth index quintiles is 2 percentage points lower than that of the two lowest quintiles. For the wealthiest quintile, the average probability of diarrhea incidence is 4 percentage points lower.

It is also interesting to note differences in the impact of the education of the household head (overwhelmingly males in this sample) versus education of the mother. Coefficients on the household head's education are generally insignificant (with the exception of the middle school education, which is small, negative, and significant at the 10% level). An F-test confirmed that the household head education variables are not jointly significant. In contrast, significant reductions of the probability of diarrhea are in evidence for households in which the mother has a secondary education or greater.

When looking at the effect of piped water on the incidence of diarrhea across different wealth and income strata, Table 3.12 shows that the piped water coefficients remain insignificant for all levels of wealth and education.

3.6.2 Urban Areas

Regression results for urban areas are shown in Table 3.13. In contrast to rural areas (where no significant relationship was found), children in households reliant on piped water experience, on average, a 2.2 percentage point greater probability of diarrhea. Comparing diarrheal outcomes for all water sources (column (2)), the coefficient on piped water is still positive and significant, and indicates that piped water increases the probability of diarrhea in children, on average, by 1.2 percentage points relative to other improved sources (the omitted category), all else constant. None of the coefficients on other water sources are significant.

Taken together, these results imply that for urban households the use of piped water is "unhealthy" relative to all other water sources – i.e., it increases the probability of child diarrhea – and that there is no statistically significant difference in the likelihood of child diarrhea among all other water sources. As in the case of rural areas, it is hard to predict here whether households are aware of the relative unhealthiness of piped water. But to the extent that they are aware, the relatively large percentage of urban households relying on piped water (30 percent) suggests that those piped urban households are willing to trade off that higher health risk for the convenience (and cost) of piped water. This issue is pursued further in Chapter 4.

Another finding that contrasts with what was observed in rural areas is that toilet facilities connected to a mainline have a positive and significant coefficient in urban areas, and increase the probability of diarrhea, on average, by as much as 1.5 percentage points. Toilet facilities connected to a septic tank are not found to have a significant effect.

Other health practices and awareness variables for urban households were found, for the most part, to have similar impacts on diarrhea probabilities as was the case for rural areas. Treating water has a positive and significant impact on the probability of diarrhea. Again, this may be attributed to inadequate treating methods, or perhaps to the fact that households experiencing a higher incidence of child diarrhea might be more inclined to treat their water. Washing hands before a meal decreases the probability of diarrhea in children by 2.2 percentage points on average, but washing hands after using the bathroom is found to have no significant effect. Having a health facility within 30 minutes is found to decrease the probability of diarrhea, on average, by 1.3 percentage points in the urban areas. The coefficient of knowledge of iodized salt is negative and significant, indicating that it decreases the probability of diarrhea. The coefficients of access to media and knowledge about symptoms that require taking the child to a health center are not significant.

Of child characteristics, age and weight for height have negative and significant coefficients. Therefore, the older the child and the more the weight for height, the lower the probability of diarrhea, all things constant. Although girls were found to have a reduced smaller probability of having had diarrhea than boys in rural areas, there is no support for this in urban areas. Perhaps in rural areas greater gender differentials exist and boys play outdoors and therefore come in contact with disease causing pathogens while girls stay home and therefore are less prone to diarrhea. In urban areas such gender differentials may not exist, or they may be less profound.

Regarding household characteristics, household size decreases the probability of diarrhea. Having a gas connection also decreases the probability of diarrhea– perhaps because having gas facilitates households better heating food and water killing disease-causing bacteria. In contrast, having an electricity connection has no significant effect on the probability of diarrhea in children. Interestingly, the coefficient of water filter is positive and significant indicating water filters increase the probability of diarrhea. It is not certain why this is so, but may be attributed to poor quality and rusty filters that actually add to the bacterial content rather than decreasing it, or perhaps to the fact that households experiencing a higher incidence of child diarrhea might be more inclined to filter their water.

As in rural areas, the results for urban areas suggest that wealthier households – at least those in the top three wealth index quintiles – have progressively a lower probability of diarrhea in children. Being in the highest wealth index quintile, on average, decreases the probability of diarrhea by about 3 percentage points.

Similar to wealth, the probability of child diarrhea falls as the education of either household heads or mother's increases. The results for mother's education are qualitatively similar to what was found in rural areas, although the magnitudes of the reduction in diarrhea probability is somewhat larger in magnitude for mothers having a secondary or higher education. The results for household head education are qualitatively different in urban areas, however, insofar as these too suggest a progressively greater reduction in diarrhea incidence as educational attainment increases.

When looking at the effect of piped water on the incidence of diarrhea across different wealth and income strata, Table 3.14 shows that point estimates of the probability of diarrhea are lower as wealth and education of the household head and mother progresses, the probability of diarrhea falls.[45] However, the probability remains positive and significant at the highest levels of wealth and education, indicating that even for the richest or most educated households piped water still increases the probability of diarrhea.

3.7 EXPLORING TRANSMISSION PATHWAYS BETWEEN PIPED WATER AND DIARRHEA

The previous section revealed that piped water has no significant effect on the probability of diarrhea in children in rural areas, but that it has a positive and significant effect in urban areas. This section explores one possible explanation for the lack of

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[45] Note, however, that as these point estimates are from separate regressions it is not possible to say whether these differences across wealth and education classes are statistically significant.

healthfulness of piped water – specifically, that leakages in the water and sanitation pipes might lead to cross-contamination of drinking water by sewage water. In Pakistan, as in many developing countries, water and sanitation pipelines are placed side by side (Government of Punjab, 2008), and has been noted earlier (in Chapter 2), maintenance of public water and sanitation infrastructure is spotty in Punjab.

To purse this issue, the following household-level model was estimated:

$$\mathrm{Bacteria_j} = \beta_1 + \beta_2 \mathrm{Water\ source_j} + \beta_3 \mathrm{Toilet\ facility_j} + \beta_4 \mathrm{Piped\ water_j} * \mathrm{Toilet\ facility_j} + \beta_5 \mathrm{Month\ of\ interview_j} + \varepsilon, \qquad j=1,..,M \qquad (16)$$

Where:

"Bacteria" is a dummy variable for the presence of bacteria in the water sample and is measured directly at the source of water (this variable was collected at the time of the household interview);

"Water source" is a vector of dummy variables for the source of water (piped water, pump water, public tap water, other improved sources, or unimproved sources);

"Toilet facility" is a set of dummy variables indicating whether or not the household has a toilet facility connected to some piped system underground (either to a public sewer system via a main line or to an on-premise septic tank); and

"Month of interview" denotes when the bacteria sample was taken (to account for seasonal differences in likelihood of diarrhea incidence).

Equation (16) was estimated for both rural and urban areas using a linear probability model. A linear probability model is used instead of a nonlinear (logit or probit) model to make interpretations easier with interaction terms. Since water samples are split nearly 50-50 in terms of bacteria present or not present, we can be fairly confident that the results of a linear probability model will be similar to a nonlinear model.[46]

[46] A logit model was estimated, and the results were almost identical to the linear probability model reported here.

Econometric results are presented in Table 3.15. Columns (1) and (2) present results for households in the rural areas, and columns (3) and (4) present results for households in the urban areas. As in the earlier analyses, the model was estimated using only the piped water dummy (columns 1 and 3) as well as for all of the water source dummies with Other Improved Sources as the omitted category (columns 2 and 4).

In both rural and urban areas, the positive coefficients on the piped water dummy indicates a significant positive impact of piped water on bacterial presence. Moreover, the positive and significant interaction terms between piped water and the toilet facilities dummies suggest that the joint presence of piped drinking water and piped sewage disposal confers an additional positive impact on bacteria incidence. Point estimates for rural areas suggest that this interaction effect is substantially larger if the toilet facility is connected to a septic tank than to a main line (this is confirmed by an F-test that rejects at the 0.01 level the equality of these two interactions terms). Point estimates for urban areas indicate that the interaction effect is somewhat larger if the toilet is connected to a mainline (an F-test rejects the equality of the interaction terms at the 0.1 level).

The implication of these results is that there appears to be substantial cross contamination between the water and sanitation pipelines, possible through leakages in the pipes. Since bacteria are ultimately responsible for causing diarrhea, the leakages and cross contamination between the water and sewage pipes may explain part of the absence of positive health effect of piped water in rural areas, and the negative effect in urban areas. In the more cramped urban areas, where pipelines are placed closer together and are more vulnerable to wear and tear and poor maintenance, the leakages and cross contamination may be much more widespread than in rural areas. This would in turn increase the prevalence (and probability of detection) of bacteria in piped water, therefore resulting in the positive and significant coefficients for piped water seen in the previous section.

Interestingly, the econometric results indicate that for households without piped water, toilet facilities connected to a mainline increase the probability of bacteria in water in rural areas (column (1)), but have no effect on the probability of bacteria in urban areas (column (3)); and septic tanks significantly decrease the probability of bacteria in water (the coefficients are negative and significant).

Finally, it is worth noting that in the absence of toilet facilities connected to main lines or septic tanks, the coefficients of piped water are still positive and significant in both rural and urban areas. This means that, although cross contamination with sewage lines may explain part of the problem, the water running through the pipelines may also be contaminated at the main source. Public water supply schemes use water obtained from surface (canal, dam) and groundwater (tubewells, springs) sources. Much of the wastewater from agriculture is drained off to surface water, or makes its way back in to the aquifer. According to the United Nations Water Activity Information System (2009), it is estimated that only 1 percent of all wastewater in urban areas of Pakistan is treated in municipal treatment plants, and none in rural areas. Although purification plants have been constructed across the Punjab through the Clean Water Drinking Water for All Program (2004), the facilities lack the capacity to treat most of the water that is piped through the network. Therefore, much of the water that is piped through the network is typically contaminated with bacteria.

3.8 IMPLICATIONS

The salient empirical results presented above are that piped water has no significant effect on diarrhea in children in rural areas; that piped water has an adverse health effect in urban areas, and is associated with increasing the probability of diarrhea in children by an average of 2.2 percentage points; and that in both areas proximity of piped drinking water and wastewater confers addition health risks, presumably due to cross-contamination. At the very least, then, the empirical findings offer no support to the view held by some that publicly provided water has beneficial health impacts. Indeed, for urban areas they implicate piped water as contributing to negative child health outcomes.

These findings have important policy implications. Public policy and donor funding has, in the past, been focused on increasing coverage of public water services in rural areas, with less attention on urban areas (ADB, 2009).[47]. The differing results for rural and urban areas suggest that adding focus to urban areas merits attention. The greater density of population, and hence the comingling of water and sewer lines, in urban areas cause greater difficulties in maintenance of pipes (World Bank, 2005), and likely underlays the increase incidence of bacterial contamination found here for urban households that rely on publicly provided water and sanitation systems.

More generally, the empirical analyses that have been presented in this chapter highlight three dimensions of public policy intervention for improving the health and safety components of public water services: a) improving education and awareness of society, b) reconsidering and improving the design criteria of public water services and sewage, and c) increasing efforts towards the maintenance of public water services and sanitation.

As far as the first area of focus is concerned, the results show that both education and awareness significantly improve the health effects of piped water in urban areas. Behaviors (e.g., washing hands before a meal) and health awareness (e.g. knowledge of iodized salt) were both found to significantly decrease the probability of diarrhea in both rural and urban areas. Therefore, government efforts towards increasing education and awareness of good health practices, particularly for mothers (who are the primary childcare givers), appear to yield significant public health benefits.[48]

Although increasing education is a step towards the right direction in decreasing the adverse effects of piped water on the incidence of diarrhea, it is only likely to be successful in improving the quality of water at the point of consumption. That is, it does not affect the

[47] For example, two of the biggest water projects in Punjab – the Punjab Rural Water Supply and Sanitation (PRWSS) and Punjab Community Water Supply and Sanitation (PCWSS) projects – have been focused in expanding and improving water services solely in rural areas, with no focus on urban areas. Both projects were funded by the Asian Development Bank.

[48] The Asian Development Bank included such efforts as part of their Punjab Community Water Supply and Sanitation Project (2002) by implementing a hygiene education program, but found that cultural barriers limited the full participation of women in the decision-making process at all stages of the project cycle.

quality of water at its source. The results show that although greater educational attainment by mothers and (in urban areas) household heads is associated with a decreased diarrhea incidence for piped households, the underlying link between piped water and negative health outcomes persists even among the most highly educated. Thus, although higher education may improve the quality of water at the point of consumption, the quality of water at the source is still poor, and no amount of handling by the household can change that.

This, in combination with the evidence drinking water seems to be contaminated by sewage water, suggests significant scope for improving the quality of piped water service through better construction and maintenance of pipelines. To date, the construction of water and sewage pipelines have followed an outdated and ill-advised 1998 Public Health and Engineering Department Design Criteria. According to these design criteria, water and sewage pipelines are placed almost equidistant from ground level (rather than placing sewage lines below water lines). The standard for water pipelines in the Design Criteria is to have 3 feet of earth cover (except for hilly areas, which have no cover) and for sewage pipelines to have 2.5 feet earth cover (except for hilly areas, which require no cover) (Government of Punjab, 2008). This increases the possibility of cross contamination of water and sewage pipelines, as they are placed too close to each other. Therefore, for future placement of pipelines, modifying the Design Criteria to follow better standards of construction and maintenance is warranted as a means of reducing possible cross contamination of sewage and water pipelines.[49]

Also, the PHED Design Criteria is mainly silent on bacteriological quality standards, and should be updated to follow World Health Organization (WHO) standards, requiring that no coliform be present in any water sample (WHO, 2004). This would require setting up

[49] Examples of such standards are the California Waterworks Standards. The California Waterworks Standards require the horizontal distance between water and sewage pipelines to be no less than 10 feet apart, and that sewage pipelines be placed at least 12 feet below water pipelines where the lines must cross. This design ensures that, in an event of a leak, sewage water does not contaminate the water running through water pipelines (California Department of Public Health, 2008).

quality check posts, and regularly evaluating the bacterial content of the water running through pipelines.[50]

Although a reevaluation of the Design Criteria is likely to be effective in improving the quality of future pipelines, current pipelines must be adequately maintained on a regular basis to fix and prevent future leakages. A pressing problem in Pakistan has been the lack of funds for Operation and Maintenance of public water services as a result of low tariffs, a lack of metered connections, and high staffing costs (World Bank, 2005). This subsequently led to the negligence of proper maintenance of the depreciating pipeline infrastructure, making it more vulnerable to leaks and contamination.[51]

What is needed, then, is to increase tariff payments, which in turn requires improved accountability and service of connections. Higher tariffs coupled with metered connections may provide the funds necessary for covering Operation and Maintenance costs, which would further increase consumer trust and user payments, and therefore making the system more self-sufficient. Of course, the potential for raising tariffs would be bounded by the willingness of households to pay for piped water (and sanitation) services. This issue will be explored further in the next chapter.

[50] In this effort, The Pakistan Council of Research in Water Resources (PCRWR) initiated the National Water Quality Monitoring Program (NWQMP) in 2001. The NWQMP generated the first detailed water quality profile of 23 major cities in the country. In 2004, the program was extended to rural areas. In Punjab, 12 districts were monitored. Since it's initiation, the coverage of the NWQMP has increased, but it still does not cover all districts.

[51] For example, a World Bank report (2005) on Pakistan's water economy states that Punjab's water economy is based on the "payment of heavily overstaffed bureaucracies, whose productivity is low and whose appetite leaves insufficient funds for system maintenance and operation. This reality gives rise to a vicious cycle, in which users are not willing to pay for poor and unaccountable services, which means that insufficient funds are available for operations and maintenance, which results in the decline of service quality and whereupon users are even less willing to pay, and so on."

Table 3.1: PHED Water Quality Standards 1998

Substance or Characteristics	Highest Desirable Level	Maximum Permissible Level
Color	5 Units	50 Units
Odor	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable
Turbidity	5 Units	5 Units
Total Solids	500 mg/l	1500 mg/l
pH range	7.0 to 8.5	6.5 to 9.2
Anionic detergents	0.2 mg/l	1.0 mg/l
Mineral oil	0.01 mg/l	0.3 mg/l
Copper	0.05mg/l	1.5 mg/l
Iron	0.1 mg/l	1.0 mg/l
Magnesium	30 mg/l	150 mg/l
Manganese	0.05 mg/l	0.5 mg/l
Sulphate	200 mg/l	400 mg/l
Zinc	5.0 mg/l	15 mg/l
Phenolic Compounds	0.001 mg/l	0.002 mg/l
Total Hardness	100 mg/l CaCO3	500 mg/l CaCO3
Calcium	75 mg/l	200 mg/l
Chloride	200 mg/l	600 mg/l

Source: Technical and Service Delivery Standards for Water Supply and Sanitation Service, Government of Punjab, 2008

Table 3.2: PHED versus WHO Bacteriological Standards

Standards PHED claims to follow	WHO standards
In 95% of samples examined throughout the year, coliform organisms should be absent in 100 ml of sample	Must not be detectable in any 100 ml sample
No sample should contain more than 10 coliform organisms per 100 ml in the remaining 5% samples	Must not be detectable in any 100 ml sample
No sample should contain E-Coli (Escherachia Coliform) in 100 ml sample	Must not be detectable in any 100 ml sample
Coliform organisms should not be detectable in 100 ml of any two consecutive samples	Must not be detectable in any 100 ml sample

Source: Technical and Service Delivery Standards for Water Supply and Sanitation Service, Government of Punjab, 2008

Table 3.3: Descriptive Statistics by Treatment: Health (Rural)

	Total			Piped water (in-home)					
				Comparison Group			Treatment Group		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*47931*	*0.073*	*0.3*	*43958*	*0.071*	*0.3*	*3973*	*0.075*	*0.3*
Bacteria present in sample (0=no, 1=yes)	*44401*	*0.47*	*0.5*	*40689*	*0.46*	*0.5*	*3712*	*0.51******	*0.5*
Water source (0=no, 1=yes):									
Piped Water in-home	49272	0.08	0.3	45206	0.00	0.0	4066	1.00	0.0
Public tap	49272	0.04	0.2	45206	0.04	0.2	4066	0.00	0.0
Pumped water	49272	0.80	0.4	45206	0.87	0.3	4066	0.00	0.0
Other improved water sources	49272	0.06	0.2	45206	0.06	0.2	4066	0.00	0.0
Unimproved water sources	49272	0.03	0.2	45206	0.03	0.2	4066	0.00	0.0
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	49272	0.03	0.2	45206	0.03	0.2	4066	0.05***	0.2
Toilet facility: Flushed to septic tank	49272	0.35	0.5	45206	0.35	0.5	4066	0.42***	0.5
Toilet facility: Other	49272	0.61	0.5	45206	0.62	0.5	4066	0.53***	0.5
Health Practices (0=no, 1=yes):									
Treat Water	49172	0.02	0.1	45109	0.02	0.1	4063	0.05***	0.2
All members wash hands before meal	49198	0.29	0.5	45143	0.28	0.5	4055	0.38***	0.5
All members wash hands after latrine	49194	0.41	0.5	45140	0.40	0.5	4054	0.50***	0.5
Health center within 30 mins	48999	0.64	0.5	44957	0.64	0.5	4042	0.67***	0.5
Awareness (0=no, 1=yes):									
Know about iodized salt	49232	0.49	0.5	45166	0.48	0.5	4066	0.57***	0.5
Access to media (tv, cable, radio, computer, internet)	49272	0.60	0.5	45206	0.59	0.5	4066	0.73***	0.4
Know any symptoms that would require taking child to health center	46932	1.00	0.1	43061	1.00	0.1	3871	1.00**	0.0
Child characteristics:									
Child's age (months)	48237	29.68	17.4	44254	29.71	17.4	3983	29.43	17.4
Child is female (0=no, 1=yes)	49272	0.49	0.5	45206	0.49	0.5	4066	0.49	0.5
Weight for height of child	47381	1.20	4.1	43449	1.25	4.1	3932	0.60***	3.7
Household characteristics:									
Number of HH members	49272	8.21	3.7	45206	8.22	3.7	4066	8.10**	3.7
Household head is female (0=no, 1=yes)	49272	0.03	0.2	45206	0.03	0.2	4066	0.04***	0.2
Electricity (0=no, 1=yes)	49245	0.88	0.3	45182	0.88	0.3	4063	0.96***	0.2
Gas (0=no, 1=yes)	49095	0.05	0.2	45045	0.04	0.2	4050	0.10***	0.3
Water Filter (0=no, 1=yes)	49113	0.01	0.1	45059	0.01	0.1	4054	0.01**	0.1

Table 3.3: (continued)

	Total			Piped water (in-home)					
				Comparison Group			Treatment Group		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Wealth index quintile (0=no, 1=yes):									
Lowest	49272	0.32	0.5	45206	0.34	0.5	4066	0.12***	0.3
Second	49272	0.27	0.4	45206	0.27	0.4	4066	0.25*	0.4
Middle	49272	0.22	0.4	45206	0.21	0.4	4066	0.27***	0.4
Fourth	49272	0.16	0.4	45206	0.15	0.4	4066	0.26***	0.4
Highest	49272	0.04	0.2	45206	0.03	0.2	4066	0.09***	0.3
Education of household head (0=no, 1=yes):									
None	49246	0.53	0.5	45183	0.53	0.5	4063	0.43***	0.5
Primary	49246	0.16	0.4	45183	0.16	0.4	4063	0.16	0.4
Middle	49246	0.11	0.3	45183	0.11	0.3	4063	0.13***	0.3
Secondary	49246	0.15	0.4	45183	0.14	0.3	4063	0.19***	0.4
Higher	49246	0.06	0.2	45183	0.06	0.2	4063	0.08***	0.3
Mother's education (0=no, 1=yes):									
None	49257	0.70	0.5	45192	0.72	0.5	4065	0.55***	0.5
Primary	49257	0.14	0.3	45192	0.14	0.3	4065	0.19***	0.4
Middle	49257	0.06	0.2	45192	0.06	0.2	4065	0.08***	0.3
Secondary	49257	0.06	0.2	45192	0.06	0.2	4065	0.11***	0.3
Higher	49257	0.03	0.2	45192	0.03	0.2	4065	0.08***	0.3
Month of interview (0=no, 1=yes):									
January	49272	0.16	0.4	4066	0.13	0.3	45206	0.16	0.4
February	49272	0.29	0.5	4066	0.31	0.5	45206	0.29	0.5
March	49272	0.45	0.5	4066	0.48	0.5	45206	0.45	0.5
April	49272	0.09	0.3	4066	0.06	0.2	45206	0.09	0.3
December	49272	0.02	0.1	4066	0.02	0.1	45206	0.02	0.1

*p<0.01, **p<0.05, ***p<0.1 for t-test of mean(comparison)=mean(treatment).

Table 3.4: Descriptive Statistics by Wealth Index Quintile: Health (Rural)

	WIQ: Poor (lowest)			WIQ: Middle-class (second or middle)			WIQ: Rich (fourth or highest)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*15454*	*0.08*	*0.3*	*23114*	*0.07*	*0.3*	*9363*	*0.06*	*0.2*
Water source (0=no, 1=yes):									
Piped water in-home	15862	0.03	0.2	23782	0.09	0.3	9628	0.15	0.4
Public tap	15862	0.06	0.2	23782	0.04	0.2	9628	0.01	0.1
Pumped water	15862	0.86	0.3	23782	0.78	0.4	9628	0.72	0.4
Other improved water sources	15862	0.02	0.1	23782	0.07	0.2	9628	0.09	0.3
Unimproved water sources	15862	0.03	0.2	23782	0.03	0.2	9628	0.02	0.2
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	15862	0.00	0.1	23782	0.04	0.2	9628	0.08	0.3
Toilet facility: Flushed to septic tank	15862	0.03	0.2	23782	0.39	0.5	9628	0.77	0.4
Toilet facility: Other	15862	0.96	0.1	23782	0.57	0.3	9628	0.15	0.3
Health practices (0=no, 1=yes):									
Treat Water	15819	0.01	0.1	23735	0.02	0.1	9618	0.04	0.2
All members wash hands before meal	15831	0.12	0.3	23747	0.29	0.5	9620	0.56	0.5
All members wash hands after latrine	15830	0.20	0.4	23744	0.43	0.5	9620	0.71	0.5
Health center within 30 mins	15763	0.48	0.5	23670	0.68	0.5	9566	0.80	0.4
Awareness (0=no, 1=yes):									
Know about the iodized salt	15853	0.29	0.5	23762	0.51	0.5	9617	0.76	0.4
Access to media (tv, cable, radio, computer, internet)	15862	0.24	0.4	23782	0.69	0.5	9628	0.96	0.2
Know any symptoms that would require taking child to health center	15145	0.99	0.1	22618	1.00	0.1	9169	1.00	0.1
Household characteristics:									
Number of HH members	15862	7.55	3.0	23782	8.22	3.7	9628	9.28	4.5
Female household head (0=no, 1=yes)	15862	0.02	0.1	23782	0.03	0.2	9628	0.05	0.2
Electricity (0=no, 1=yes)	15856	0.65	0.5	23765	0.99	0.1	9624	1.00	0.0
Gas (0=no, 1=yes)	15840	0.00	0.0	23690	0.02	0.1	9565	0.19	0.4
Water Filter (0=no, 1=yes)	15846	0.00	0.0	23679	0.01	0.1	9588	0.03	0.2

Table 3.4: (continued)

	WIQ: Poor (lowest)			WIQ: Middle-class (second or middle)			WIQ: Rich (fourth or highest)		
	N	Mean	SD	N	Mean	SD	N	Mea n	SD
Education of household head (0=no, 1=yes):									
None	15859	0.73	0.4	23764	0.49	0.5	9623	0.29	0.5
Primary	15859	0.14	0.3	23764	0.17	0.4	9623	0.15	0.4
Middle	15859	0.07	0.3	23764	0.13	0.3	9623	0.14	0.3
Secondary	15859	0.05	0.2	23764	0.16	0.4	9623	0.27	0.4
Higher	15859	0.01	0.1	23764	0.05	0.2	9623	0.16	0.4
Mother's education (0=no, 1=yes):									
None	15861	0.94	0.2	23768	0.70	0.5	9628	0.31	0.5
Primary	15861	0.05	0.2	23768	0.17	0.4	9628	0.23	0.4
Middle	15861	0.01	0.1	23768	0.06	0.2	9628	0.13	0.3
Secondary	15861	0.00	0.1	23768	0.05	0.2	9628	0.19	0.4
Higher	15861	0.00	0.0	23768	0.01	0.1	9628	0.14	0.3

Table 3.5: Descriptive Statistics by Education of Household Head: Health (Rural)

	Educ of hh head: None			Educ of hh head: Low (pri or mid)			Educ of hh head: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*25220*	*0.08*	*0.3*	*12874*	*0.07*	*0.3*	*9811*	*0.06*	*0.2*
Water source (0=no, 1=yes):									
Piped water in-home	25964	0.07	0.3	13232	0.09	0.3	10050	0.11	0.3
Public tap	25964	0.04	0.2	13232	0.03	0.2	10050	0.03	0.2
Pumped water	25964	0.81	0.4	13232	0.79	0.4	10050	0.76	0.4
Other improved water sources	25964	0.05	0.2	13232	0.06	0.2	10050	0.07	0.3
Unimproved water sources	25964	0.03	0.2	13232	0.03	0.2	10050	0.03	0.2
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	25964	0.03	0.2	13232	0.03	0.2	10050	0.05	0.2
Toilet facility: Flushed to septic tank	25964	0.26	0.4	13232	0.40	0.5	10050	0.54	0.5
Toilet facility: Other	25964	0.72	0.3	13232	0.57	0.3	10050	0.41	0.4
Health practices (0=no, 1=yes):									
Treat Water	25910	0.02	0.1	13205	0.02	0.1	10032	0.04	0.2
All members wash hands before meal	25920	0.22	0.4	13211	0.31	0.5	10041	0.46	0.5
All members wash hands after latrine	25913	0.34	0.5	13211	0.43	0.5	10044	0.58	0.5
Health center within 30 mins	25814	0.60	0.5	13156	0.66	0.5	10003	0.71	0.5
Awareness (0=no, 1=yes):									
Know about the iodized salt	25938	0.39	0.5	13224	0.53	0.5	10044	0.67	0.5
Access to media (tv, cable, radio, computer, internet)	25964	0.51	0.5	13232	0.64	0.5	10050	0.77	0.4
Know any symptoms that would require taking child to health center	24677	1.00	0.1	12610	1.00	0.1	9622	1.00	0.1
Household characteristics:									
Number of HH members	25964	8.39	3.8	13232	8.08	3.7	10050	7.93	3.7
Female household head (0=no, 1=yes)	25964	0.04	0.2	13232	0.02	0.1	10050	0.01	0.1
Electricity (0=no, 1=yes)	25950	0.83	0.4	13224	0.92	0.3	10045	0.96	0.2
Gas (0=no, 1=yes)	25886	0.03	0.2	13181	0.05	0.2	10002	0.08	0.3
Water Filter (0=no, 1=yes)	25884	0.01	0.1	13184	0.01	0.1	10019	0.02	0.1

Table 3.5: (continued)

	Educ of hh head: None			Educ of hh head: Low (pri or mid)			Educ of hh head: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Wealth index quintile (0=no, 1=yes):									
Lowest	25964	0.45	0.5	13232	0.25	0.4	10050	0.10	0.3
Second	25964	0.28	0.4	13232	0.30	0.5	10050	0.20	0.4
Middle	25964	0.17	0.4	13232	0.25	0.4	10050	0.29	0.5
Fourth	25964	0.09	0.3	13232	0.17	0.4	10050	0.30	0.5
Highest	25964	0.01	0.1	13232	0.03	0.2	10050	0.11	0.3
Mother's education (0=no, 1=yes):									
None	25955	0.84	0.4	13231	0.65	0.5	10050	0.41	0.5
Primary	25955	0.09	0.3	13231	0.20	0.4	10050	0.21	0.4
Middle	25955	0.03	0.2	13231	0.07	0.3	10050	0.11	0.3
Secondary	25955	0.03	0.2	13231	0.06	0.2	10050	0.16	0.4
Higher	25955	0.01	0.1	13231	0.02	0.2	10050	0.11	0.3

Table 3.6: Descriptive Statistics by Mother's Education: Health (Rural)

	Mother's education: None			Mother's education: Low (pri or mid)			Mother's education: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*33722*	*0.08*	*0.3*	*9523*	*0.07*	*0.3*	*4671*	*0.06*	*0.2*
Water source (0=no, 1=yes):									
Piped water in-home	34626	0.06	0.2	9827	0.11	0.3	4804	0.15	0.4
Public tap	34626	0.04	0.2	9827	0.03	0.2	4804	0.02	0.1
Pumped water	34626	0.82	0.4	9827	0.76	0.4	4804	0.72	0.4
Other improved water sources	34626	0.05	0.2	9827	0.07	0.3	4804	0.08	0.3
Unimproved water sources	34626	0.03	0.2	9827	0.03	0.2	4804	0.03	0.2
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	34626	0.03	0.2	9827	0.05	0.2	4804	0.07	0.2
Toilet facility: Flushed to septic tank	34626	0.25	0.4	9827	0.55	0.5	4804	0.68	0.5
Toilet facility: Other	34626	0.73	0.3	9827	0.40	0.4	4804	0.25	0.4
Health practices (0=no, 1=yes):									
Treat Water	34544	0.02	0.1	9817	0.03	0.2	4796	0.06	0.2
All members wash hands before meal	34574	0.21	0.4	9808	0.41	0.5	4801	0.62	0.5
All members wash hands after latrine	34568	0.32	0.5	9810	0.56	0.5	4801	0.75	0.4
Health center within 30 mins	34459	0.60	0.5	9765	0.73	0.4	4760	0.77	0.4
Awareness (0=no, 1=yes):									
Know about the iodized salt	34606	0.40	0.5	9816	0.64	0.5	4795	0.81	0.4
Access to media (tv, cable, radio, computer, internet)	34626	0.51	0.5	9827	0.76	0.4	4804	0.88	0.3
Know any symptoms that would require taking child to health center	33038	1.00	0.1	9318	1.00	0.1	4562	1.00	0.0
Household characteristics:									
Number of HH members	34626	8.20	3.7	9827	8.28	3.7	4804	8.20	3.6
Female household head (0=no, 1=yes)	34626	0.02	0.2	9827	0.04	0.2	4804	0.05	0.2
Electricity (0=no, 1=yes)	34603	0.84	0.4	9825	0.97	0.2	4802	0.99	0.1
Gas (0=no, 1=yes)	34514	0.02	0.2	9789	0.07	0.3	4777	0.15	0.4
Water Filter (0=no, 1=yes)	34516	0.01	0.1	9798	0.01	0.1	4784	0.03	0.2

Table 3.6: (continued)

	Mother's education: None			Mother's education: Low (pri or mid)			Mother's education: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Wealth index quintile (0=no, 1=yes):									
Lowest	34626	0.43	0.5	9827	0.09	0.3	4804	0.02	0.1
Second	34626	0.30	0.5	9827	0.22	0.4	4804	0.09	0.3
Middle	34626	0.18	0.4	9827	0.34	0.5	4804	0.23	0.4
Fourth	34626	0.08	0.3	9827	0.29	0.5	4804	0.45	0.5
Highest	34626	0.01	0.1	9827	0.06	0.2	4804	0.22	0.4
Education of household head (0=no, 1=yes):									
None	34606	0.63	0.5	9826	0.32	0.5	4804	0.21	0.4
Primary	34606	0.16	0.4	9826	0.19	0.4	4804	0.09	0.3
Middle	34606	0.09	0.3	9826	0.17	0.4	4804	0.13	0.3
Secondary	34606	0.09	0.3	9826	0.24	0.4	4804	0.33	0.5
Higher	34606	0.03	0.2	9826	0.08	0.3	4804	0.23	0.4

Table 3.7: Descriptive Statistics by Treatment: Health (Urban)

	Total			Piped water (in-home)					
				Comparison Group			Treatment Group		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*21581*	*0.082*	*0.3*	*15217*	*0.080*	*0.3*	*6364*	*0.100******	*0.3*
Bacteria present in sample (0=no, 1=yes)	*20527*	*0.46*	*0.5*	*14565*	*0.44*	*0.5*	*5962*	*0.52******	*0.5*
Water source (0=no, 1=yes):									
Piped water in-home	22235	0.30	0.5	15673	0.00	0.0	6562	1.00	0.0
Public tap	22235	0.02	0.1	15673	0.03	0.2	6562	0.00	0.0
Pumped water	22235	0.59	0.5	15673	0.83	0.4	6562	0.00	0.0
Other improved water sources	22235	0.07	0.3	15673	0.10	0.3	6562	0.00	0.0
Unimproved water sources	22235	0.02	0.2	15673	0.03	0.2	6562	0.00	0.0
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	22235	0.47	0.5	15673	0.42	0.5	6562	0.58***	0.5
Toilet facility: Flushed to septic tank	22235	0.40	0.5	15673	0.42	0.5	6562	0.33***	0.5
Toilet facility: Other	22235	0.13	0.5	15673	0.15	0.5	6562	0.09***	0.5
Health practices (0=no, 1=yes):									
Treat Water	22154	0.11	0.3	15596	0.07	0.3	6558	0.20***	0.4
All members wash hands before meal	22155	0.58	0.5	15608	0.55	0.5	6547	0.64***	0.5
All members wash hands after latrine	22162	0.72	0.4	15610	0.70	0.5	6552	0.77***	0.4
Health center within 30 mins	22117	0.95	0.2	15585	0.95	0.2	6532	0.95	0.2
Awareness (0=no, 1=yes):									
Know about the iodized salt	22172	0.71	0.5	15620	0.70	0.5	6552	0.74***	0.4
Access to media (tv, cable, radio, computer, internet)	22235	0.85	0.4	15673	0.83	0.4	6562	0.89***	0.3
Know any symptoms that would require taking child to health center	21093	1.00	0.1	14858	1.00	0.1	6235	1.00**	0.0
Child characteristics:									
Child's age (months)	21835	29.36	17.4	15396	29.46	17.4	6439	29.12	17.2
Female Child (0=no, 1=yes)	22235	0.49	0.5	15673	0.49	0.5	6562	0.50	0.5
Weight for height of child	21280	1.02	3.8	14975	1.05	3.8	6305	0.94*	3.7

Table 3.7: (continued)

	Total			Piped water (in-home)					
				Comparison Group			Treatment Group		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Household characteristics:									
Number of HH members	22235	8.27	3.8	15673	8.26	3.8	6562	8.27	3.9
Female household head (0=no, 1=yes)	22235	0.04	0.2	15673	0.04	0.2	6562	0.04**	0.2
Electricity (0=no, 1=yes)	22217	0.90	0.1	15665	0.90	0.1	6552	1.00***	0.1
Gas (0=no, 1=yes)	22163	0.60	0.5	15618	0.56	0.5	6545	0.70***	0.5
Water Filter (0=no, 1=yes)	22119	0.06	0.2	15604	0.05	0.2	6515	0.10***	0.3
Wealth index quintile (0=no, 1=yes):									
Lowest	22235	0.03	0.2	15673	0.05	0.2	6562	0.01***	0.1
Second	22235	0.09	0.3	15673	0.11	0.3	6562	0.05***	0.2
Middle	22235	0.17	0.4	15673	0.18	0.4	6562	0.13***	0.3
Fourth	22235	0.28	0.4	15673	0.30	0.5	6562	0.25***	0.4
Highest	22235	0.43	0.5	15673	0.37	0.5	6562	0.56***	0.5
Education of household head (0=no, 1=yes):									
None	22215	0.33	0.5	15660	0.35	0.5	6555	0.30***	0.5
Primary	22215	0.15	0.4	15660	0.15	0.4	6555	0.15	0.4
Middle	22215	0.12	0.3	15660	0.13	0.3	6555	0.12**	0.3
Secondary	22215	0.22	0.4	15660	0.22	0.4	6555	0.24***	0.4
Higher	22215	0.17	0.4	15660	0.16	0.4	6555	0.20***	0.4
Mother's education (0=no, 1=yes):									
None	22221	0.39	0.5	15661	0.41	0.5	6560	0.33***	0.5
Primary	22221	0.16	0.4	15661	0.16	0.4	6560	0.14***	0.4
Middle	22221	0.11	0.3	15661	0.10	0.3	6560	0.11*	0.3
Secondary	22221	0.18	0.4	15661	0.16	0.4	6560	0.21***	0.4
Higher	22221	0.17	0.4	15661	0.16	0.4	6560	0.20***	0.4
Month of interview (0=no, 1=yes):									
January	22235	0.28	0.4	15673	0.29	0.5	6562	0.25	0.4
February	22235	0.28	0.4	15673	0.29	0.5	6562	0.26	0.4
March	22235	0.32	0.5	15673	0.32	0.5	6562	0.33	0.5
April	22235	0.07	0.2	15673	0.05	0.2	6562	0.10	0.3
December	22235	0.05	0.2	15673	0.05	0.2	6562	0.05	0.2

*p<0.01, **p<0.05, ***p<0.1 for t-test of mean(comparison)=mean(treatment).

Table 3.8: Descriptive Statistics by Wealth Index Quintile: Health (Urban)

	WIQ: Poor (lowest)			WIQ: Middle-class (second or middle)			WIQ: Rich (fourth or highest)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*737*	*0.10*	*0.3*	*5494*	*0.10*	*0.3*	*15350*	*0.08*	*0.3*
Water source (0=no, 1=yes):									
Piped water in-home	763	0.07	0.2	5673	0.21	0.4	15799	0.34	0.5
Public tap	763	0.08	0.3	5673	0.03	0.2	15799	0.01	0.1
Pumped water	763	0.81	0.4	5673	0.71	0.5	15799	0.53	0.5
Other improved water sources	763	0.01	0.1	5673	0.03	0.2	15799	0.09	0.3
Unimproved water sources	763	0.02	0.2	5673	0.01	0.1	15799	0.03	0.2
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	763	0.07	0.3	5673	0.31	0.5	15799	0.55	0.5
Toilet facility: Flushed to septic tank	763	0.14	0.4	5673	0.44	0.5	15799	0.39	0.5
Toilet facility: Other	763	0.78	0.3	5673	0.26	0.5	15799	0.06	0.5
Health practices (0=no, 1=yes):									
Treat Water	754	0.02	0.1	5629	0.03	0.2	15771	0.14	0.4
All members wash hands before meal	743	0.15	0.4	5639	0.36	0.5	15773	0.68	0.5
All members wash hands after latrine	745	0.27	0.4	5640	0.53	0.5	15777	0.81	0.4
Health center within 30 mins	754	0.84	0.4	5628	0.92	0.3	15735	0.97	0.2
Awareness (0=no, 1=yes):									
Know about the iodized salt	756	0.35	0.5	5648	0.52	0.5	15768	0.79	0.4
Access to media (tv, cable, radio, computer, internet)	763	0.26	0.4	5673	0.65	0.5	15799	0.95	0.2
Know any symptoms that would require taking child to health center	712	0.99	0.1	5347	1.00	0.1	15034	1.00	0.0
Household characteristics:									
Number of HH members	763	7.20	2.6	5673	7.90	3.4	15799	8.45	4.0
Female household head (0=no, 1=yes)	763	0.01	0.1	5673	0.02	0.2	15799	0.04	0.2
Electricity (0=no, 1=yes)	763	0.80	0.4	5662	0.99	0.1	15792	1.00	0.0
Gas (0=no, 1=yes)	759	0.01	0.1	5636	0.19	0.4	15768	0.78	0.4
Water Filter (0=no, 1=yes)	763	0.01	0.1	5644	0.01	0.1	15712	0.09	0.3

Table 3.8: (continued)

	WIQ: Poor (lowest)			WIQ: Middle-class (second or middle)			WIQ: Rich (fourth or highest)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Education of household head (0=no, 1=yes):									
None	763	0.76	0.4	5664	0.53	0.5	15788	0.24	0.4
Primary	763	0.13	0.3	5664	0.17	0.4	15788	0.14	0.3
Middle	763	0.05	0.2	5664	0.12	0.3	15788	0.13	0.3
Secondary	763	0.06	0.2	5664	0.14	0.3	15788	0.26	0.4
Higher	763	0.01	0.1	5664	0.05	0.2	15788	0.23	0.4
Mother's education (0=no, 1=yes):									
None	763	0.91	0.3	5670	0.69	0.5	15788	0.25	0.4
Primary	763	0.07	0.2	5670	0.17	0.4	15788	0.16	0.4
Middle	763	0.02	0.1	5670	0.06	0.2	15788	0.13	0.3
Secondary	763	0.01	0.1	5670	0.06	0.2	15788	0.23	0.4
Higher	763	0.00	0.0	5670	0.02	0.1	15788	0.23	0.4

Table 3.9: Descriptive Statistics by Education of Household Head: Health (Urban)

	Education of hh head: None			Education of hh head: Low (pri or mid)			Education of hh head: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*7180*	*0.09*	*0.3*	*5811*	*0.09*	*0.3*	*8573*	*0.07*	*0.3*
Water source (0=no, 1=yes):									
Piped water in-home	7406	0.27	0.4	5977	0.29	0.5	8832	0.32	0.5
Public tap	7406	0.03	0.2	5977	0.02	0.1	8832	0.01	0.1
Pumped water	7406	0.63	0.5	5977	0.59	0.5	8832	0.55	0.5
Other improved water sources	7406	0.05	0.2	5977	0.07	0.3	8832	0.09	0.3
Unimproved water sources	7406	0.02	0.1	5977	0.02	0.1	8832	0.03	0.2
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	7406	0.41	0.5	5977	0.45	0.5	8832	0.53	0.5
Toilet facility: Flushed to septic tank	7406	0.38	0.5	5977	0.42	0.5	8832	0.40	0.5
Toilet facility: Other	7406	0.21	0.5	5977	0.13	0.5	8832	0.07	0.5
Health practices (0=no, 1=yes):									
Treat Water	7358	0.05	0.2	5958	0.09	0.3	8818	0.18	0.4
All members wash hands before meal	7365	0.44	0.5	5956	0.55	0.5	8814	0.72	0.4
All members wash hands after latrine	7370	0.60	0.5	5958	0.71	0.5	8814	0.83	0.4
Health center within 30 mins	7366	0.93	0.3	5940	0.95	0.2	8791	0.96	0.2
Awareness (0=no, 1=yes):									
Know about the iodized salt	7381	0.58	0.5	5957	0.71	0.5	8814	0.82	0.4
Access to media (tv, cable, radio, computer, internet)	7406	0.78	0.4	5977	0.84	0.4	8832	0.91	0.3
Know any symptoms that would require taking child to health center	7026	1.00	0.1	5660	1.00	0.1	8389	1.00	0.1
Household characteristics:									
Number of HH members	7406	8.73	3.8	5977	8.45	3.9	8832	7.76	3.7
Female household head (0=no, 1=yes)	7406	0.07	0.3	5977	0.03	0.2	8832	0.01	0.1
Electricity (0=no, 1=yes)	7402	0.98	0.1	5970	0.99	0.1	8825	1.00	0.0
Gas (0=no, 1=yes)	7382	0.48	0.5	5952	0.60	0.5	8809	0.71	0.5
Water Filter (0=no, 1=yes)	7374	0.02	0.2	5938	0.04	0.2	8787	0.11	0.3

Table 3.9: (continued)

	Education of hh head: None			Education of hh head: Low (pri or mid)			Education of hh head: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Wealth index quintile (0=no, 1=yes):									
Lowest	7406	0.08	0.3	5977	0.02	0.1	8832	0.01	0.1
Second	7406	0.16	0.4	5977	0.09	0.3	8832	0.03	0.2
Middle	7406	0.25	0.4	5977	0.18	0.4	8832	0.09	0.3
Fourth	7406	0.28	0.4	5977	0.33	0.5	8832	0.25	0.4
Highest	7406	0.24	0.4	5977	0.37	0.5	8832	0.63	0.5
Mother's education (0=no, 1=yes):									
None	7403	0.65	0.5	5975	0.38	0.5	8827	0.17	0.4
Primary	7403	0.15	0.4	5975	0.23	0.4	8827	0.12	0.3
Middle	7403	0.07	0.3	5975	0.14	0.3	8827	0.11	0.3
Secondary	7403	0.09	0.3	5975	0.15	0.4	8827	0.27	0.4
Higher	7403	0.04	0.2	5975	0.10	0.3	8827	0.33	0.5

Table 3.10: Descriptive Statistics by Mother's Education: Health (Urban)

	Mother's education: None			Mother's education: Low (pri or mid)			Mother's education: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Child had diarrhea in last 2 weeks (0=no, 1=yes)	*8418*	*0.09*	*0.3*	*5638*	*0.09*	*0.3*	*7511*	*0.07*	*0.3*
Water source (0=no, 1=yes):									
Piped water in-home	8648	0.25	0.4	5829	0.29	0.5	7744	0.35	0.5
Public tap	8648	0.03	0.2	5829	0.01	0.1	7744	0.01	0.1
Pumped water	8648	0.64	0.5	5829	0.61	0.5	7744	0.51	0.5
Other improved water sources	8648	0.05	0.2	5829	0.07	0.3	7744	0.10	0.3
Unimproved water sources	8648	0.02	0.1	5829	0.02	0.1	7744	0.03	0.2
Sanitation (0=no, 1=yes):									
Toilet facility: Flushed to pipe system	8648	0.40	0.5	5829	0.46	0.5	7744	0.56	0.5
Toilet facility: Flushed to septic tank	8648	0.38	0.5	5829	0.43	0.5	7744	0.39	0.5
Toilet facility: Other	8648	0.22	0.5	5829	0.11	0.5	7744	0.05	0.5
Health practices (0=no, 1=yes):									
Treat Water	8589	0.04	0.2	5818	0.08	0.3	7733	0.22	0.4
All members wash hands before meal	8597	0.40	0.5	5807	0.58	0.5	7737	0.78	0.4
All members wash hands after latrine	8601	0.56	0.5	5811	0.75	0.4	7736	0.88	0.3
Health center within 30 mins	8591	0.93	0.3	5808	0.96	0.2	7704	0.97	0.2
Awareness (0=no, 1=yes):									
Know about the iodized salt	8614	0.56	0.5	5816	0.73	0.4	7728	0.86	0.3
Access to media (tv, cable, radio, computer, internet)	8648	0.74	0.4	5829	0.87	0.3	7744	0.95	0.2
Know any symptoms that would require taking child to health center	8233	1.00	0.1	5492	1.00	0.0	7357	1.00	0.0
Household characteristics:									
Number of HH members	8648	8.44	3.7	5829	8.48	4.1	7744	7.91	3.7
Female household head (0=no, 1=yes)	8648	0.03	0.2	5829	0.04	0.2	7744	0.05	0.2
Electricity (0=no, 1=yes)	8647	0.98	0.1	5827	1.00	0.1	7729	1.00	0.0
Gas (0=no, 1=yes)	8613	0.44	0.5	5811	0.63	0.5	7725	0.77	0.4
Water Filter (0=no, 1=yes)	8621	0.02	0.1	5804	0.04	0.2	7680	0.14	0.3

Table 3.10: (continued)

	Mother's education: None			Mother's education: Low (pri or mid)			Mother's education: High (sec or higher)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Wealth index quintile (0=no, 1=yes):									
Lowest	8648	0.08	0.3	5829	0.01	0.1	7744	0.00	0.0
Second	8648	0.18	0.4	5829	0.05	0.2	7744	0.01	0.1
Middle	8648	0.27	0.4	5829	0.17	0.4	7744	0.05	0.2
Fourth	8648	0.29	0.5	5829	0.37	0.5	7744	0.20	0.4
Highest	8648	0.17	0.4	5829	0.40	0.5	7744	0.74	0.4
Education of household head (0=no, 1=yes):									
None	8640	0.56	0.5	5825	0.28	0.4	7740	0.12	0.3
Primary	8640	0.16	0.4	5825	0.20	0.4	7740	0.09	0.3
Middle	8640	0.10	0.3	5825	0.18	0.4	7740	0.10	0.3
Secondary	8640	0.13	0.3	5825	0.24	0.4	7740	0.31	0.5
Higher	8640	0.04	0.2	5825	0.11	0.3	7740	0.37	0.5

Table 3.11: Effect of In-Home Piped Water on the Incidence of Diarrhea in Children (<5 yos.) – Rural

	Dependent Variable: Incidence of Diarrhea in Children<5 years old	
	Pipe vs. All^	**Pipe vs. Other Improved Sources^^**
Variable	(1) Average Marginal Effects	(2) Average Marginal Effects
Piped water in-home	0.002	0.026***
	(0.51)	(3.37)
Public tap		0.046***
		(5.37)
Pumped water		0.026***
		(3.84)
Unimproved water source		-0.002
		(-0.15)
Sanitation:		
Toilet facility: flushed to main line	-0.017***	-0.015*
	(-2.07)	(-1.85)
Toilet facility: flushed to septic tank	-0.009***	-0.009***
	(-2.64)	(-2.65)
Health Practices:		
Treat water	0.026***	0.028***
	(3.53)	(3.74)
HH members wash hands before meal	-0.014***	-0.013***
	(-3.51)	(-3.13)
HH members wash hands after using toilet	0.013***	0.013***
	(3.58)	(3.48)
Health facility within 30 mins	0.002	0.002
	(0.81)	(0.57)
Health Awareness:		
Know about iodized salt	-0.011***	-0.010***
	(-3.94)	(-3.91)
Access to media	0.005	0.005
	(1.61)	(1.54)
Know about symptoms of sickness	0.081**	0.081**
	(2.37)	(2.36)
Wealth:		
Wealth Index Quintile: Second	-0.006	-0.004
	(-1.57)	(-1.19)
Wealth Index Quintile: Middle	-0.021***	-0.019***
	(-4.43)	(-3.96)
Wealth Index Quintile: Fourth	-0.021***	-0.018***
	(-3.50)	(-3.05)
Wealth Index Quintile: Highest	-0.043***	-0.040***
	(-3.95)	(-3.73)
Education of Household Head:		
Education of household head: Primary	-0.004	-0.003
	(-0.99)	(-0.93)
Education of household head: Middle	-0.008*	-0.008*
	(1.85)	(-1.84)
Education of household head: Secondary	-0.001	-0.001
	(-0.26)	(-0.20)
Education of household head: Higher	-0.010	-0.010
	(-1.47)	(-1.54)

Table 3.11: (continued)

	Dependent Variable: Incidence of Diarrhea in Children<5 years old	
	Pipe vs. All^	**Pipe vs. Other Improved Sources^^**
Variable	(1) Average Marginal Effects	(2)Average Marginal Effects
Mother's Education:		
Mother's education: Primary	-0.000	-0.001
	(-0.11)	(-0.15)
Mother's education: Middle	-0.010	-0.010
	(-1.65)	(-1.62)
Mother's education: Secondary	-0.018***	-0.018***
	(-2.75)	(-2.82)
Mother's education: Higher	-0.014*	-0.014*
	(-1.67)	(-1.66)
Child Characteristics:		
Child's age (months)	-0.002***	-0.002***
	(-23.11)	(-23.12)
Child is female	-0.010***	-0.010***
	(3.91)	(-3.87)
Weight for height of child	-0.002***	-0.002***
	(-6.36)	(-6.38)
Household Characteristics:		
Household size	-0.000	-0.002
	(-0.46)	(-0.55)
Female household head	-0.001	-0.030
	(-0.06)	(-0.04)
Electricity	-0.007	-0.006
	(-1.55)	(-1.42)
Gas	-0.001	-0.001
	(-0.19)	(-0.18)
Water filter	0.012	0.012
	(0.75)	(0.79)
Month of Interview:		
Month of interview: January	-0.034***	-0.033***
	(-4.09)	(-4.02)
Month of interview: February	-0.063***	-0.062***
	(-7.75)	(-7.63)
Month of interview: March	-0.058***	-0.057***
	(-7.22)	(7.09)
Month of interview: April	-0.039***	-0.038***
	(-4.52)	(-4.37)
(constant)	-1.922***	-2.328***
	(-2.59)	(-3.11)
N	43901	43901
LR chi-squared	952.76	993.01
Pseudo R-squared	0.04	0.04

Omitted Variables: ^Water source: All other sources (public tap, pumped, other improved and unimproved sources)
^^Water source: Other improved sources (protected well, protected spring, tubewell, bottled water)
Toilet facility: Other (flushed to pit, buckets, field, etc.)
Month of interview: December
Wealth Index Quintile: Lowest
Education of household head: None
Mother's education: None

**p<0.1, **p<0.05, ***p<0.001; z-statistics in brackets*

Table 3.12: Effect of Piped Water on Diarrhea by Wealth and Education – Rural

Wealth	
Lowest	0.001
	(0.06)
Middle-class (second or middle)	0.000
	(0.07)
Rich (fourth or highest)	0.003
	(0.38)

Education	Household head	Mother
None	-0.003	-0.002
	(-0.43)	(-0.24)
Low (primary or middle)	0.003	0.003
	(0.39)	(0.38)
High (secondary or higher)	0.007	0.013
	(0.87)	(1.35)

Results are from separate regressions by wealth class and education levels, respectively
Values are average marginal effects
z-statistics in brackets
Omitted category: All other water sources

Table 3.13: Effect of In-Home Piped Water on the Incidence of Diarrhea in Children (<5 yos.) – Urban

	Dependent Variable: Incidence of Diarrhea in Children<5 years old	
	Pipe vs. All^	**Pipe vs. Other Improved Sources^^**
Variable	(1) Average Marginal Effects	(2) Average Marginal Effects
Piped water in-home	0.022***	0.012*
	(5.12)	(1.70)
Public tap		-0.012
		(-0.72)
Pumped water		-0.012
		(-1.42)
Unimproved water source		0.002
		(0.11)
Sanitation:		
Toilet facility: flushed to main line	0.015**	0.015**
	(2.21)	(2.24)
Toilet facility: flushed to septic tank	-0.007	-0.006
	(-1.00)	(-0.95)
Health Practices:		
Treat water	0.020***	0.020***
	(2.80)	(0.86)
HH members wash hands before meal	-0.022***	-0.022***
	(-3.99)	(-3.96)
HH members wash hands after using toilet	0.002	0.002
	(0.36)	(0.38)
Health facility within 30 mins	-0.013*	-0.012
	(-1.66)	(-1.48)
Health Awareness:		
Know about iodized salt	-0.016***	-0.016***
	(-3.42)	(-3.42)
Access to media	0.008	0.008
	(1.24)	(1.27)
Know about symptoms of sickness	0.035	0.034
	(0.89)	(0.88)
Wealth:		
Wealth Index Quintile: Second	0.001	0.000
	(0.04)	(-0.02)
Wealth Index Quintile: Middle	-0.008*	-0.009*
	(-1.68)	(-1.70)
Wealth Index Quintile: Fourth	-0.023*	-0.024*
	(-1.71)	(-1.74)
Wealth Index Quintile: Highest	-0.028*	-0.031**
	(-1.87)	(-2.02)
Education of Household Head:		
Education of household head: Primary	0.004	0.004
	(0.61)	(0.62)
Education of household head: Middle	-0.012*	-0.012*
	(-1.83)	(-1.82)
Education of household head: Secondary	-0.013**	-0.012**
	(-2.06)	(-2.05)
Education of household head: Higher	-0.014**	-0.014**
	(-2.10)	(-2.11)

Table 3.13: (continued)

	Dependent Variable: Incidence of Diarrhea in Children<5 years old	
	Pipe vs. All^	**Pipe vs. Other Improved Sources^^**
Variable	(1)	(2)
Mother's Education:		
Mother's education: Primary	0.000	0.000
	(0.05)	(0.06)
Mother's education: Middle	-0.005*	-0.005*
	(-1.72)	(-1.73)
Mother's education: Secondary	-0.015**	-0.015**
	(-2.26)	(-2.26)
Mother's education: Higher	-0.029***	-0.030***
	(-3.73)	(-3.79)
Child Characteristics:		
Child's age (months)	-0.002***	-0.002***
	(-14.31)	(-14.32)
Child is female	-0.001	-0.001
	(-0.36)	(-0.36)
Weight for height of child	-0.003***	-0.003***
	(-5.24)	(-5.24)
Household Characteristics:		
Household size	-0.001*	-0.001*
	(-1.91)	(-1.92)
Female household head	-0.015	-0.015
	(-1.30)	(-1.33)
Electricity	0.031	0.029
	(1.64)	(1.55)
Gas	-0.014***	-0.014***
	(-2.67)	(-2.60)
Water filter	0.017*	0.017*
	(1.73)	(1.72)
Month of Interview:		
Month of interview: January	-0.015*	-0.015*
	(-1.76)	(-1.72)
Month of interview: February	-0.052***	-0.052***
	(-5.91)	(-5.94)
Month of interview: March	-0.059***	-0.058***
	(-6.72)	(-6.69)
Month of interview: April	-0.038***	-0.038**
	(-3.48)	(-3.50)
(constant)	-1.498**	-1.333*
	(-2.07)	(-1.82)
N	19506	19506
LR chi-squared	508.77	511.50
Pseudo R-squared	0.05	0.05

Omitted Variables: ^Water source: All other sources (public tap, pumped, other improved and unimproved sources)
^^Water source: Other improved sources (protected well, protected spring, tubewell, bottled water)
Toilet facility: Other (flushed to pit, buckets, field, etc.)
Month of interview: December
Wealth Index Quintile: Lowest
Education of household head: None
Mother's education: None

**p<0.1, **p<0.05, ***p<0.01; z-statistics in brackets*

Table 3.14: Effect of Piped Water on Diarrhea by Wealth and Education – Urban

Wealth	
Lowest	0.0289**
	(2.29)
Middle-class (second or middle)	0.021*
	(1.89)
Rich (fourth or highest)	0.018***
	(5.99)

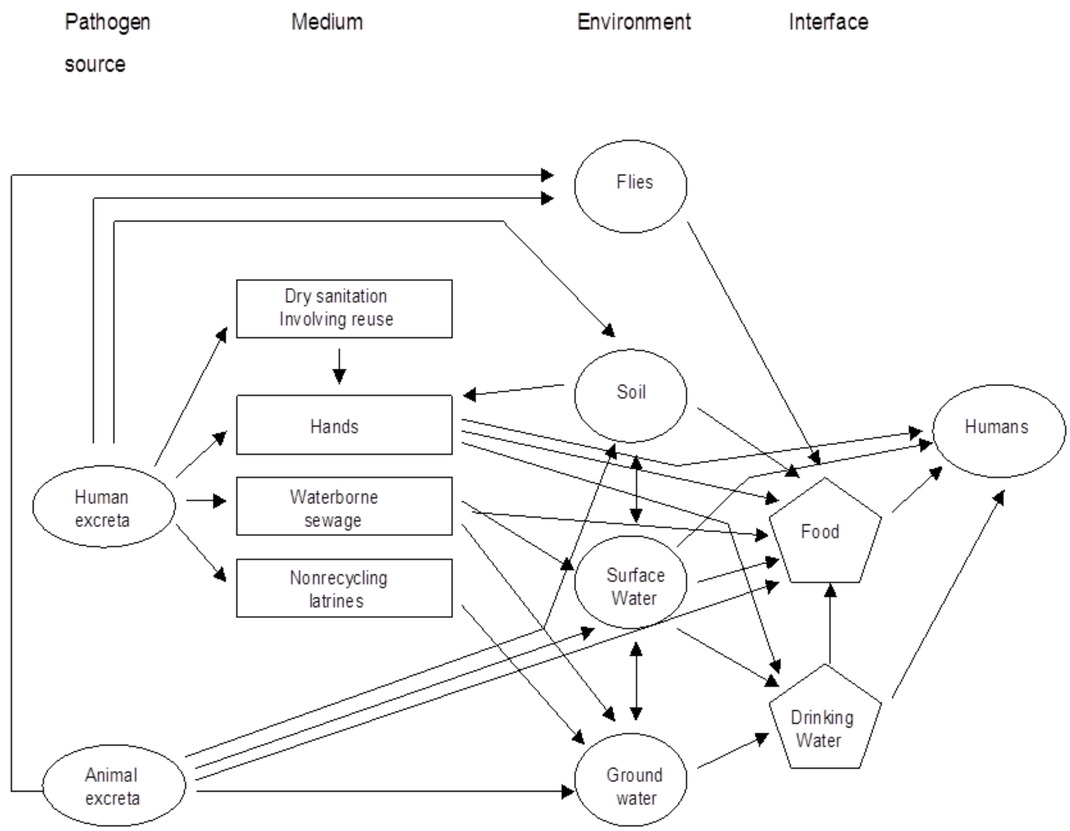
Education	Household head	Mother
None	0.025***	0.029***
	(2.62)	(3.91)
Low (primary or middle)	0.021*	0.021**
	(1.80)	(2.41)
High (secondary or higher)	0.019**	0.014**
	(2.89)	(2.25)

Results are from separate regressions by wealth class and education levels, respectively
Values are average marginal effects
**p<0.1, **p<0.05, ***p<0.01*
z-statistics in brackets
Omitted category: All other water sources

Table 3.15: Determinants of Presence of Bacteria in Water Source

	Dependent Variable: Bacteria Present in Water Sample			
	Rural		**Urban**	
	Pipe vs. All	Pipe vs. Other Improved Sources	Pipe vs. All	Pipe vs. Other Improved Sources
Variable	(1)	(2)	(3)	(4)
Piped water in-home	0.134***	0.099***	0.150***	0.121***
	(12.32)	(6.95)	(6.75)	(4.87)
Public tap		0.054***		0.005
		(3.62)		(0.18)
Pumped water		-0.044***		-0.032***
		(-4.60)		(-2.65)
Unimproved water source		0.026		-0.037
		(1.62)		(-1.60)
Toilet facility: flushed to main line	0.089**	0.089**	-0.035	-0.035
	(2.55)	(2.54)	(-1.64)	(-1.60)
Toilet facility: flushed to septic tank	-0.159***	-0.159***	-0.211***	-0.211***
	(-10.12)	(-10.14)	(-9.36)	(-9.38)
Pipe*Toilet main line	0.085**	0.084**	0.145***	0.144***
	(2.27)	(2.25)	(5.99)	(5.94)
Pipe*Toilet septic tank	0.139***	0.140***	0.122***	0.122***
	(8.41)	(8.52)	(4.84)	(4.85)
(constant)	0.330***	0.369***	0.175***	0.201***
	(17.84)	(17.77)	(10.70)	(10.27)
N	44401	44401	20527	20527
F-statistic	794.62	606.52	522.79	392.99
R-squared	0.14	0.14	0.19	0.19
Omitted variables: ^Water Source: All other sources (public tap, pump, other improved and unimproved sources) ^^Water source: Other improved sources (protected well, protected spring, bottled, etc.) Toilet facility: Other (flushed to pit, buckets, field, etc.)				

**p<0.1, **p<0.05, ***p<0.001*
t-statistics in brackets
Dummy variables for month of interview were included in the regression, but results are not reported here.



Adapted from Prüss et al. (2002)

<u>Figure 3.1: Transmission Pathways of Fecal Diseases</u>

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CHAPTER 4
THE WILLINGNESS TO PAY FOR PIPED WATER: A HEDONIC ANALYSIS OF HOUSE PRICES IN PUNJAB, PAKISTAN

4.1 INTRODUCTION

The literature on the economics of public infrastructure management suggests that in a financially well-structured water system users pay for operations, maintenance, and replacement of the assets that provide their services, while the government pays the interest on debt accumulated in the past. Such an idealized system (depicted in part (a) of Figure 4.1) is simple and the incentives right (for the users to demand efficient operations and maintenance (O&M), and replacement only of essential assets and that at least cost). The typical Pakistani system is much more complex (see part (b) in Figure 4.1). First, there is an extra ‘block of payment’ to be made for the extra costs incurred by having large numbers of unnecessary workers. Staffing and energy costs represent an overwhelming portion of O&M costs, leaving little cash for maintenance of Water Supply and Sanitation (WSS) infrastructure (World Bank, 2005). Second, the user payments represent only a small fraction of the total money required for O&M (including salaries). Tariffs are low; Table 4.1 shows that even at the maximum, the average monthly tariff rates in Pakistan for a connection are lower than those of other low-income countries. Moreover, only about 75% of WSS bills issued are collected, and this ratio is often much lower in smaller towns (World Bank, 2006).

In addition to these organizational inefficiencies, physical losses in Pakistani water systems are also substantial. An average 40% of the water injected in the distribution network is lost to leaks and illegal connections (referred to as Non-Revenue Tariffs), but in the absence of bulk and residential metering this is merely an estimate (World Bank, 2006). Table 4.2 shows that the average leakage ratio in the 9 largest urban cities of Punjab is around 40 percent; that collection ratios are low, particularly in Multan, Bahawalpur, and

Sargodha; and that staffing and energy costs make up the bulk of the operating costs, with very little going into maintenance.

Table 4.3 shows the tariff rates and costs of piped water service in the nine urban cities (estimated by the World Bank for the period 2004-05).[52] Tariffs do not cover operation and maintenance costs in all nine cities. Even when Urban Immovable Property Tax Revenues are added, seven of the nine cities still show a deficit.[53]

What this means is that there is a yawning gap between revenues and expenses that is paid for neither by users nor taxpayers. Service providers respond to such financial gaps by reducing service quality (e.g., by reducing hours of service to reduce electricity costs). This means that maintenance is inadequate and—since maintenance is last in the queue—there is no investment in replacing aging assets. Poor maintenance and poor operating efficiency thus contribute to a vicious circle of poor performance, poor service, poor collection rates, and insufficient funding.

The contrast between globally accepted good maintenance-and-replacement practice and that pursued by water authorities in Pakistan—described by the World Bank (2005) as 'Build-Neglect-Rebuild'—is represented schematically in Figure 4.2. In the 'good practice' case, the stock of infrastructure grows fast in 'Stage 1' and then tails off in Stages 2 and 3. But as this stock grows, so the financial demands for maintaining and replacing it increase. In the Pakistan case—which arguably is at Stage 2—the stock is still growing, but the finance available for maintaining and replacing that stock has fallen rather than risen. Much of what is built is not being maintained, and that which does still function, delivers services of a low quality. This in turn reinforces the vicious cycle—users refuse to pay for poor services, meaning that revenues decline still further, and the maintenance and replacement gaps widen still further.

Breaking this vicious cycle thus requires an increase in both user costs and collection

[52] Revenue/Cost figures for the period covered by the econometric analysis (2007-08) were unavailable due to poor bookkeeping, low collection rates, and unmetered connections.
[53] According to the Punjab Urban Immovable Property Tax Act (1958) the UIP Tax is levied on all urban plots of land (with several exemptions) at 20% of their annual value as determined and notified by the government.

rates to improve the financial stability of the Water Supply and Sanitation (WSS) system and thereby the ability to pay for O&M costs. However, empirical evidence shows that starting with the idea of increasing charges (for bad services provided by inefficient agencies) will quite reasonably be resisted (World Bank, 2005). Many users want to have a higher level of service than is provided; and when consumers do not get the desired level or quality of service, they tend to stop paying their water bills. For this reason, the idea of bringing tariffs into balance with costs must come after improving services first, and providing those services in an efficient and accountable manner. In order to do this, accountancy and transparency are key to restoring users' trust.

A comprehensive analysis of consumer's willingness to pay for publicly provided water services at prevailing service levels is needed to begin the process of restoring the fiscal solvency of public water systems in the Punjab. This chapter uses a hedonic approach to measure households' willingness to pay (WTP) for piped water in both rural and urban areas of the Punjab, and analyze the response in WTP to public policy changes that improve the quality and service of piped water systems – i.e., by eliminating bacteria present in piped water, and by increasing the duration of flow of piped water.

The results show that piped connections add a positive and significant value to the imputed house rental price in both rural and urban areas; that the value of piped water increases as water table depth, groundwater salinity, and duration of piped water flow per day increases; and that it falls as the percentage of households in a district with bacteria present in their piped water increases. Taken together, these findings suggest that improving both the quantity (i.e., increased the duration of flow daily) and water quality have a significant effect in increasing the willingness to pay for piped water. The results also indicate that households are willing to pay more for an improvement in quality of piped water than for an increase in the duration of flow (based on ideal 24-hour service standards and zero bacterial contamination), and that the response is higher in areas where alternatives to piped water are harder or more costly to find.

4.2 HEDONIC VALUATION

The most common revealed preference approach to valuing a piped water connection is the hedonic property valuation method. This approach infers the value of water connection from differences in property values for houses with and without a connection. In hedonic models, dwelling unit prices represent the sum of expenditures on a bundle of characteristics that can be priced separately. If $z = (z_1, \ldots, z_n)$ is a set of characteristics of the house, the price of the house is determined by some hedonic function, p(z), according to prevailing market clearing conditions. The set of characteristics that determine home values consists of the structural attributes of the house itself, such as the floor area, lot size, and construction material, as well as the availability of public services such as water supply or electricity. Such models have been used in developing countries to determine the optimum housing characteristics for low-income groups (Follain and Jimemez, 1985) and for valuation of access to specific services (North and Griffin, 1993; Crane et. al., 1997, among others).

Two assumptions are necessary when using a hedonic pricing approach. First, supply is assumed to consist of a continuum of goods with different quantities of attributes. Households choose to consume a unique combination of these attributes that maximize their utility, given their budget constraints. Second, the market is assumed to be perfectly competitive and in equilibrium. This might not be a reasonable assumption in a developing region; however, without having more information about the housing markets in each district, this assumption is necessary (Megbolugbe, 1989; Yusuf and Resosudarmo, 2009).

Following Rosen (1974), households maximize utility from consuming a vector of n housing attributes $z = (z_1, \ldots, z_n)$ and a numeraire consumption bundle x, subject to a budget constraint. Letting y denote household income and p(z*)* denote housing price as a function of housing attributes, the household's constrained optimization problem can be written as:

$$\max_{x,z} U(x, z_1, \ldots, z_n) \tag{1}$$
$$\text{subject to } y = x + p(z)$$

The indirect utility function can be written as:

$$U(y - \theta, z_1, \dots, z_n) \quad (2)$$

The bid function $\theta(z; u, y)$ is what a household is willing to pay for combinations of housing attributes at given utility and income levels; it is increasing in z_i at a decreasing rate. Household utility is maximized when $\theta(z^*;\ u^*, y) = p(z^*)$. Households with similar bid functions will purchase housing with similar attributes, and this leads to an observed spatial distribution of households.

On the supply side, sellers maximize profits from selling M units of housing. Each house has a unique combination of housing attributes $(z_1, \dots, z_n)$ given production costs $C(M, z;\ \beta)$, where β denotes costs of inputs and production parameters:

$$\pi = Mp(z) - C(M, Z;\ \beta) \quad (3)$$

Profits are maximized when marginal revenue equals marginal cost. The first order conditions are:

$$p(z) = C_M(M, z;\ \beta) \quad (4)$$

$$Mp_z(z) = C_z(M, z;\ \beta)$$

The offer function, $\phi(z^*;\ \pi^*, \beta)$ is defined as the price that a seller is willing to accept for each housing unit at a given profit and cost levels. Then, (4) can be rewritten as:

$$\phi(z^*;\ \pi^*, \beta) = C_M(M, z;\ \beta) \quad (5)$$

$$M\phi_z = C_z(M, z; \beta)$$

to solve for ϕ. In equation (5), ϕ is increasing in z.

In equilibrium, each household (as the consumer) maximizes utility and each seller maximizes profits. The market clears, quantity supplied equals quantity demanded such that:

$$p(z^*) = \theta(z^*;\ u^*, y) \tag{6}$$

$$p(z^*) = \phi(z^*;\ u^*, \beta)$$

Using the first order conditions, the marginal price of each housing attribute can be computed as follows:

$$\frac{\partial p(z_i)}{\partial z_i} = \frac{\partial U / \partial z_i}{\partial U / \partial x} = \frac{\partial \theta}{\partial z_i}, i = 1, \ldots, n \tag{7}$$

In empirical implementation, the estimated hedonic price function, $p(z)$, cannot identify demand and/or supply, rather, it identifies the market price in an assumed competitive equilibrium.

4.3 EMPIRICAL APPLICATIONS OF THE HEDONIC APPROACH

The full empirical estimation of the hedonic model consists of two steps. The first step estimates the hedonic price function, which results in the estimated coefficients of each housing attribute. Using these coefficients, the marginal willingness to pay for a change in a housing attribute - also known as the implicit price of a housing attribute - can be estimated. In the second step, these estimated marginal prices are used to estimate the demand for each attribute given the offer and bid functions (which contain household characteristics and firms' factor costs and/or production parameters).

Most hedonic analyses use only the first step of the estimation. The second step is usually not done due to a lack of consumer and/or seller data, difficulty in identifying the bid and/or offer functions that are different from the hedonic price function estimated in the first step, and endogeneity between marginal prices and the housing attributes (Palmquist 1999). Nevertheless, hedonic estimation using only the first step is quite useful in measuring the WTP of public services, especially in developing countries where access to such services is less than complete.

4.3.1 Previous Studies Evaluating the Willingness to Pay for Piped Water in Developing Countries

Table 4.4 presents a summary of previous studies evaluating the willingness to pay for piped water in developing countries. Details of the studies are as follows.

North and Griffin (1993) used the hedonic model to estimate households' willingness to pay for private water sources in the Bicol region of the Philippines. They divided households into three income groups based on imputed income: low income, middle income, and high income. The hedonic estimation was done separately for each household group with imputed monthly rent as the dependent variable. They found that households' willingness to pay for a tap water connection was 50 percent of the imputed monthly rent in all income groups, while middle-income households were willing to pay 18 percent of the imputed rent to have a private well. However, this study also included water for agricultural purposes, which complicates interpretation of the estimation results because there are a multitude of differences between (derived) water demand for agricultural purposes and water demand for domestic purposes.

Yusuf and Koundouri (2005) used a hedonic analysis to study households' willingness to pay for various water sources in Indonesia. Separate regressions were estimated for urban and rural regions to avoid bias in sample selection. They found that, on average, urban households are willing to pay 25 percent of imputed monthly rent for a tap water connection, while rural households are willing to pay 14 percent. The study was restricted to households' domestic water use, further subdivided into two groups: 'main use' (drinking and cooking) and 'other use' (laundry and personal hygiene). Yusuf and Koundouri included distance to water source for each use and controlled for neighborhood characteristics (distance to center of the district and median per capita expenditure) and regional fixed effects.

Berg and Nauges (2012) used a hedonic house price analysis to value connection to the piped water network in Southwest Sri Lanka based on a household survey that was conducted in 2003-04. They found that the willingness to pay for a piped water connection was on average about 5 percent of monthly household expenditure, which is at the lower end of the range from estimates obtained in the two case studies described above. In addition, the willingness to pay for piped water was found to decrease as a proportion of income when income goes up. An important policy conclusion they reached was that connection to the piped water system should be considered in relation to the availability and quality of alternative water sources. If alternative sources with good water quality are available, the need for a piped water connection is less urgent.

Lumbantobing (2010) used data from 3 districts in Sri Lanka to study how tap water network availability in a neighborhood influenced household location decisions. Preliminary results based on the hedonic model indicated that in each district, availability of a tap water network in a neighborhood led to higher housing prices, and the price increase was the highest in the district in which tap water networks were the least available. Lumbantobing's study also compared estimates of households' marginal willingness to pay (MWTP) for availability of a tap water network with MWTP estimates computed from an equilibrium sorting model. This comparison found that the hedonic analysis tended to overstate households' willingness to pay measures.

In the Punjab province of Pakistan, however, relatively little work has been done in the past in calculating the willingness to pay for piped water. A first willingness to pay survey in Punjab was conducted by Wardrop-Acres, Co-water International and National

Engineering Services Pakistan (NESPAK) as part of the Strategic Investment Plan and Project Preparation for Rural Water Supply, Sanitation, and Health in 1989.[54]

Also in 1989, a more comprehensive study was carried out for the World Bank by Mir Anjum Altaf and Haroon Jamal of the Applied Economic Research Centre (AERC), University of Karachi. Altaf and Jamal then went on to publish a series of papers on the willingness to pay for piped water in rural Punjab (along with Dale Whittington and Kerry Smith) using the 1989 World Bank dataset. Using contingent valuation the authors found that household willingness to pay for reliable improved services was much higher than had been assumed by policy makers. They divided rural areas into different zones based on groundwater quality, and then studied one city from each zone (Sheikhupura from the sweet water zone, Faisalabad from the brackish zone, and Rawalpindi from the Arid zone). This method allowed them to measure geographical differences in willingness to pay. They argued that the WTP depends on the alternatives available, specifically that households in the sweet water zone were willing to pay less for publicly supplied water than households in the brackish and arid zones because of the availability of a relatively less costly alternative (hand pumps). Perhaps most importantly, they found that the reliability of water supply is the key to customer satisfaction (and correspondingly, the proportion of households choosing to connect to public water systems). They found that households were willing to pay as much as 40 percent more per month for reliable service than for unreliable service.[55] They therefore recommended that reliability be improved and that private connections be metered to cover the costs of increasing reliability.

In 2005, The World Bank carried out a study on the financial situation of the Water and Sanitation Sector (WSS) of urban Punjab as part of the Punjab Urban Water Supply and Sewerage Reform Strategy. One task of this project – that produced the data discussed earlier

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[54] Details of the Wardrop-Acres study is unavailable. Some information is reported in Hasan (1993), where the author says that the findings of the Wardrop-Acres study are "identical" to the AERC study (without providing any further details).

[55] "Unreliable service" is defined as service that unexpectedly has no running water for a few hours a day, or one in which water unexpectedly runs at low pressure. "Reliable service" is defined as as possessing flows at expected times and pressure.

in Tables 4.2 and 4.3 – was to review the tariff structures of the WSS Service providers in eight cities of Punjab and to propose a tariff adjustment.[56] Based on the analysis, a revised tariff system was proposed that would allow the WSS service providers to recover their cost. The revised tariffs were based on a number of measures to increase service quality (and presumably consumers' willingness to pay as well). In the study, it was found that almost all (98 percent) households surveyed wished to have a water connection; and only 2 percent still prefer to use a well and a motorized pump. Interestingly enough, households expressed a stronger interest in improved water quality than an increased number of hours of service. The amount households were willing to pay for a 24/7 service of water of guaranteed quality was, on average, Rs.160/month (US$2.7/month[57]). This was not significantly higher than the then-current average water bill of Rs.135/month during the study period (2005).

More recently, Akram and Olmstead (2010) used contingent valuation to estimate willingness to pay for improved piped water quality and reduction in supply interruptions among a sample of 193 households in Lahore. The distribution of WTP was estimated using parametric and non-parametric models. Their results indicated that households in Lahore are willing to pay about Rs.630 ($7.50[58]) to Rs.756 ($9.00) per month for piped water supply that is clean and drinkable from the tap – comparable to the monthly cost of in-home water treatment, and about three to four times the average monthly water bill for sample households using piped water. Estimates of WTP for reducing supply interruptions are both smaller and more difficult to interpret, since a significant fraction of the estimated WTP distribution for supply improvements is negative.

[56] The eight cities were: Faisalabad, Gujranwala, Multan, Rawalpindi, Bahawalpur, DG Khan, Sargodha, and Sialkot.
[57] Based on exchange rate in 2005: $1=Rs. 60
[58] Based on exchange rate in 2010: $1=Rs.84

4.4 EMPIRICAL ESTIMATION

Following the work of Altaf, Jamal, Smith, and Whittington (1993), the 35 districts of the Punjab are divided into geological zones based on groundwater quality. However, instead of dividing them into three zones like they did, here they are divided into two broad categories labeled as the "Sweet Water Zone" and the "Other Zone".[59] The "Other Zone" includes the "arid zone" which contains districts that have little or no groundwater or groundwater is hard to reach at deeper water table depths (such as the northernmost districts of the Punjab); and the "brackish zone" where ground water is easy to reach but is highly saline (such as the southern districts of Punjab). In the analysis, there are 14 districts in the Sweet Water Zone and 21 districts in the Other Zone (see Figure 4.3 for a map of the Sweet Water and Other zones).[60]

This characterization of districts is made in accordance with the alternative sources of water available in the absence of piped water. In the Sweet Water Zone groundwater is sweet and at a shallow water table depth. As such, on-premise alternatives to piped water (hand pumps or low-depth motor pumps) may be accessed relatively. In the Other Zone the on-site alternative to piped water is the use of expensive motorized pumps or the procurement of water off premises (from public taps, wells, springs, or bottled water), which would come at a time – and possibly monetary – cost.

The willingness to pay for piped water is calculated by measuring how much value a piped connection adds to the imputed monthly rent using the following equation:

$$\ln(\text{Imputed Monthy Rent}) = \beta_0 + \beta_1 \text{source of water} + \beta_2 \text{ house attributes} + \beta_3 \text{neighborhood variables} + + \beta_4 \text{district variables} + \beta_5 \text{district variables} * \text{piped water} + \varepsilon \qquad (8)$$

[59] The zones are divided into two categories instead of three to make the analysis simpler, however, the main concept of dividing zones based on the ease of access to alternative sources of water to piped water still remains.

[60] Gujrat is included in the Sweet Water Zone because it has low salinity and water table depth.

The variables are defined as follows:

The dependent variable is the natural log of the imputed monthly rent, which is calculated by using 1 percent of the house value and then dividing it by 12 to get a monthly rate (i.e. imputed monthly rent = house value (Rs.)* 0.01* 1/12) (North and Griffin, 1993).[61]

"Source of water" is vector of (0,1) categorical variables indicating whether or not the household's main source of water is a piped water connection, motorized pump, hand pump, public tap, other improved sources (bottled water, covered well, covered spring, or tubewell), or unimproved sources (surface water, unprotected well, unprotected spring, or cart water)[62],

"House attributes" is a vector of variables that includes sanitation (whether the house has a toilet facility connected to a public sewer system), the house area in marlas,[63] number of rooms, whether or not the house has a cemented roof and floor, the type of fuel used for cooking (electric or gas), and electricity connection.

"Neighborhood characteristics" include categorical (0,1) variables indicating whether a health center is located within 30 minutes of the house, and whether a primary school is located within 2 kilometers of the house.

"District variables" include district-level averages[64] of the water table depth in feet from the ground level, salinity in ds/m, duration of piped water flow per day (in hours)[65], and

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[61] The question in the survey was: "House Value (estimate of house value according to local market)". Hedonic price models are usually based on actual sales or rents. In developing countries, however, actual sales may be affected by high transaction costs, while data on transactions may be incomplete. Moreover, housing markets are often not perfectly competitive, sales transactions are often infrequent, and regulatory control can result in artificially low rent values (Nauges and Berg, 2009). Therefore, owner stated values, obtained from household surveys, are typically used instead. The literature shows that the discrepancy between actual and estimated value is relatively modest- from -2 percent to up to 6 percent (Goodman and Ittner, 1992).

[62] Since the variable used is the "main source of water", the possibility of multiple sources was considered. The dataset includes a variable on the second main source of drinking water. Only 0.5 percent houses in rural areas and 4.3 percent houses in urban areas have a second source of water. Of the households that have a second source of water, the vast majority (close to 100 percent) are those that have listed bottled water as their main source. If a household listed bottled water as the main source and piped water as the second source, the household was included as one with piped water, similarly for pumped water and all other sources. None of the households that have piped or pumped water as their main source reported having a second source.

[63] 1 marla= 30.25 sq. yards

[64] District averages are used instead of household-level values due to the unavailability of data at household level.

the percentage of households with bacteria in piped water (divided by 10, so that a one unit increase would equal an increase in 10 percent of households with bacteria[66]).

Finally, interaction terms are included in the empirical analysis in order to capture the relationship between piped water and the district level variables. These are useful in analyzing cross-sectional differences in the effect of improving piped water service and quality on the willingness to pay for piped water.

Household i's Marginal Willingness to Pay (MWTP) for piped water is given by

$$\mathrm{MWTP_i} = (e^{\hat{\beta}} - 1) * \bar{p}_i \tag{9}$$

where $\bar{p}_i$ = imputed rent for household i, and $\hat{\beta}$ is the coefficient on piped water.

4.5 DESCRIPTIVE STATISTICS

4.5.1 All Zones

The descriptive statistics for All Zones are shown in Table 4.4. In the pooled data, the mean imputed monthly rent is Rs.154.32 ($2.49[67]) in rural areas and Rs.600.64 ($9.67) in urban areas.

Hand pumps are the most common water source in rural areas, used by 46 percent of households. Motorized pumps are the second most common source, and are used by 34 percent of households. Only 8 percent households in rural areas have piped water, and the remaining 12 percent are divided between public taps and other improved or unimproved sources. In urban areas, motorized pumps are the most common water source; 46 percent households use this source for water. The second most common source of water in urban

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[65] Data for the average duration of water supply per day is obtained from the Pakistan Council of Research in Water Resources, Ministry of Science and technology.
[66] The percentage of bacteria is divided by 10 to make the interpretation of results easier.
[67] Based on exchange rate in 2008: $1=Rs.62

areas is piped water (used by 30 percent of households), 12 percent households have hand pumps and the remaining 12 percent use public taps or other improved or unimproved sources.

In rural areas only 3 percent of houses have toilet facilities that are connected to sewer lines. The majority of houses have informal sanitation facilities that are either connected to septic tanks, pits, or just disposed of (via buckets) in nearby fields. In urban areas the percentage of houses with toilet facilities connected to a sewer line is much higher: almost 50 percent of households have toilet facilities connected to a sewer line.

Houses in rural areas are, on average, almost double the size of houses in urban areas – (11.23 marlas (approx. 3060 sq. ft) versus 6.35 marlas (approx. 1726 sq. ft). Houses in both rural and urban areas have 2 rooms on average. Not surprisingly, a higher percentage of households in urban areas have a cemented roof, cemented floor, electric or gas fuel source, and electricity. In both rural and urban areas more than 90 percent households are within 2 kilometers of a primary school. Approximately 65 percent of rural households and 95 percent urban households are located within thirty minutes of a health center.

Turning to the district level variables, population density in rural areas is about 381 individuals per square kilometer, while in urban areas it is 588 individuals per square kilometers The average district water table depth, salinity, hours of piped water flow per day, and percentage of households with bacteria in piped water is higher in urban areas than rural areas. The water table depth is on average 39 feet below ground level in rural areas and 45 feet below ground level in urban areas. Salinity is slightly below 2 ds/m in both areas, average duration of piped water flow is around 7 hours per day, and more than half (51 percent) of the households have bacteria present in their piped water.

4.5.2 Sweet Water Zone and Other Zone

Tables 4.5 and 4.6 provide descriptive statistics for the Sweet Water and Other Zones, respectively.

The average imputed monthly rent is higher in the rural areas of Sweet Water Zone at Rs.184.34 ($2.97) than in the Other Zone at Rs.143.41 ($2.31), but lower in the urban areas (Rs.566.46 ($9.14) versus Rs.613.39 ($9.89) in the Other Zone) (t-tests confirm that the difference in means is significant at the 0.01 level).

In both zones the most common means of accessing water is via on-premise pumps – hand pumps in rural areas and motorized pumps in urban areas. Comparison across the two zones indicates that reliance on on-premise pumps is greater in the Sweet Water Zone (t-tests confirm that the difference in means is significant at the 0.01 level). More than 50 percent households in the rural areas of the Sweet Water Zone use hand pumps, and more than 50 percent households in the urban areas use motorized pumps. In the Other Zone 41 percent households in rural areas use hand pumps versus only around 9 percent in urban areas, and 34 percent households in rural areas use motorized pumps and 45 percent in urban areas.

This is not surprising. In the Sweet Water Zone groundwater is low in salinity and water table depth is shallow; therefore pumping represents a relatively convenient and low cost means of accessing water. In contrast, groundwater in the Other Zone is either more brackish or deeper which increases the cost (and lowers the quality) of pumped water. That pumped water is still the most common source of water in the Other Zone suggests that people there may be spending high costs to pump water from lower depths (for lack of better alternatives) or are consuming brackish water after treatment (for example by letting salts settle). That said, piped water is more prevalent in the Other Zone than in the Sweet Water Zone (t-tests confirm that the difference is means is significant at the 0.01 level). Only 7 percent households rely on piped water in the rural areas of the Sweet Water Zone versus 10 percent in the Other Zone, and 22 percent rely on piped water in the urban areas of the Sweet Water Zone versus 34 percent in the Other Zone.

Other house characteristics are relatively similar across zones. A higher percentage of households in both rural and urban areas of the Other Zone have toilet facilities connected to a sewer line than in the Sweet Water Zone, but a lower percentage of toilet facilities connected to a septic tank (confirmed by t-tests at the 0.01 level). In both zones, sealed toilets are much more common in urban areas than in rural areas.

The average house size and number of rooms is similar in both zones, and the other attributes (cemented roof, floor, electricity, fuel, proximity to school and health center) are slightly higher in the Sweet Water Zone.

The average population density for both rural and urban areas is higher in the Other Zone than in the Sweet Water Zone, despite the fact that the Sweet Water Zone includes Lahore district with a high population density of 3566 individuals per square kilometer. Water table depth and salinity is lower in the Sweet Water Zone than in the Other Zone (by construction). The average water table depth ranges between 12 and 13 feet in the Sweet Water Zone and 50 to 56 feet in the Other Zone (t-tests confirm that the difference in means across zones is significant at the 0.01 level).

Average salinity levels are around 1.2 Electrical Current (EC) in the Sweet Water Zone and above 2 EC in the Other Zone. The average duration of piped water flow per day is higher in the Sweet Water Zone at around 8 hours a day than in the Other Zone at around 6 hours a day. Finally, a higher percentage of households have bacteria present in piped water in the Other Zone than in the Sweet Water Zone (t-tests confirm the difference in means at the 0.01 level). In the rural areas of the Sweet Water Zone around 40 percent of households on average have bacteria present in piped water and 38 percent in urban areas, whereas in the Other Zone around 54 percent of households have bacteria present in water in the rural areas and 51 percent in the urban areas.

4.6 RESULTS

This section presents the results of the hedonic analysis of the willingness to pay for in-home piped water connections. Results for the pooled data are presented first, followed by separate analyses of the Sweet Water and Other Zones. In all cases, separate regressions were run for urban and rural areas. In addition, two models were estimated – one in which only piped water was used as the water source variable (effectively comparing piped water to all other water sources), and one in which the entire set of water source dummies (save for hand pumps[68]) was included. All results include the respective robust t-statistics clustered at the district level.

4.6.1 All Zones:

The regression results for the pooled sample (across both zones) are shown in Table 4.8. The fit of the regressions is reasonable for a cross-sectional analysis ($R^2 \approx 0.40$), nearly all variables are statistically significant (in most cases at the .05 level or better), and most possess the expected sign. Thus, house characteristics (e.g., area, number of rooms, building materials, etc.) and neighborhood characteristics (proximity to schools and health centers) contribute positively to house prices. Population density, which is a proxy for local housing market demand conditions, has a markedly greater impact in urban house prices than rural house prices. This too is plausible given that the greater level of economic activity and mobility of workers in urban areas *vis-à-vis* rural areas.

Turning to the impact of piped water, it is clear that piped water has a substantial positive impact on house prices in both rural and urban areas. This is the case regardless of whether piped water's impact on housing prices is compared against all other water sources, or against only hand pumped water. Moreover, the interaction terms indicate that the contribution of piped water to housing prices is conditioned in a plausible manner by other covariates: Piped water is more valuable where the water table is deeper (hence more costly to pump); where groundwater salinity is higher (hence pumped water is of lower quality); and where duration of daily piped water flow is greater (hence the quality of piped water service is higher). And piped water is less valuable where bacteria loads at the tap are higher (i.e., where piped water is of lower quality).

[68] Hand pumps were chosen as the omitted category because they are a common water source.

The significance of the multiple interaction terms in Table 4.8 makes it clear that the total impact of piped water on housing prices depends on the nature of groundwater resources and the quality of piped water service. To this end, Table 4.9 presents estimates of the total effect of piped water on imputed rents by evaluating water table depth, salinity, duration, and bacteria at their means. These indicate that when compared with all other water sources, piped water increases house prices by 11.5 percent in rural areas and 26.6 percent in urban areas. When piped water is compared with hand pumps, its contribution to house prices is even greater (21.4 percent and 30.2 percent in rural and urban areas, respectively) – a reflection of the relative undesirability of hand pumps to alternative water sources.

The greater contribution of piped water to urban house prices is striking, but also quite plausible. It no doubt reflects two things. First, the relatively cramped urban environment, both in terms of population and buildings, renders more difficult (and more costly) the drilling of wells for on-premise water access. This applies to both hand pumped and electrically pumped well water (for electrically pumped water, electricity service variability would add an additional level of uncertainty and cost). Second, off-premise sources of water are generally more difficult to access in urban areas as well. Again, this is likely due to greater urban population density.

Table 4.9 also presents the cumulative impact on housing prices of the other covariates interacted with piped water. All are statistically significant and of the expected sign, although the result for water table depth is so small as to be economically trivial. Importantly, the average duration of piped water flow and mean bacteria present in piped water – two variables which are amenable to management and policy interventions by local water supply agencies, at least in principle – can be seen to have substantial impacts on house prices. These impacts are greater in urban areas, especially with respect to bacterial contamination. The implication here is that making piped water available for more hours per day, as well as improving water quality (perhaps by reducing water and sewer leakages and hence cross contamination), would have substantial welfare benefits to consumers of that water.

4.6.2 Sweet Water Zone versus Other Zone

The regression results for the Sweet Water Zone are shown in Table 4.10, and the results for the Other Zone are shown in Table 4.11. As in the case of the pooled sample, nearly all variables are statistically significant in both zones and most possess the expected sign. Thus, house characteristics (e.g., area, number of rooms, building materials, etc.) and neighborhood characteristics (proximity to schools and health centers) contribute positively to house prices.[69]

In both zones, piped water has a substantial positive impact on house prices in both rural and urban areas, and across zones. However, piped water is much more valuable in the Other Zone than the Sweet Water Zone. Moreover, the interaction terms indicate that in both zones piped water is more valuable where the water table is deeper (hence more costly to pump); groundwater salinity is higher (hence pumped water is of lower quality); and duration of piped water flow is greater (hence the quality of piped water service is higher). Also, piped water is less valuable where bacteria loads at the tap are higher (i.e., where piped water is of lower quality).

For convenience, Table 4.12 summarizes the total effect of piped water on imputed rents in both zones by evaluating water table depth, salinity, duration, and bacteria at their means. A snapshot of the full effects is also illustrated in Figure 4.4. These indicate that piped water is more valuable in the Other zone, and in both zones the impact is greater in urban areas. When compared with all other water sources, piped water increases house prices by 7.1 percent in rural areas and 14.2 percent in urban areas of the Sweet Zone, and by a larger 20.1 percent in rural areas and 40.2 percent in urban areas of the Other Zone.

The greater contribution of piped water in the Other Zone is reasonable since alternative sources of water are more difficult or more costly to obtain due to the high levels of salinity and/or greater water table depth. In the Sweet Water Zone, however, salinity levels

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[69] An exception is the result for “Toilet facility flushed to main line” variable in the rural areas of the Sweet Water Zone, which is not statistically significant.

and water tables depths are much lower, and households have the option of obtaining water at relatively low cost through hand pumps and motor pumps.

Turning to the cumulative impact on housing prices of the other covariates interacted with piped water, Table 4.12 shows that all coefficients are statistically significant and most of them have an expected sign. The impact on housing values of duration and bacteria is greater in the Other Zone than in the Sweet Water Zone. An exception is that water table depth is found to have a positive impact on housing values in the Other Zone; however it so small as to be economically trivial. The impact is negative in the Sweet Water Zone. The result for the Sweet Water Zone is reasonable since pumped water is an important source of water in this zone and deeper water tables make pumping water more costly. Similarly, the effect of salinity is substantially greater in the Sweet Zone. Salinity has a substantially smaller impact on house prices in the Other Zone, perhaps because the base levels of salinity in that zone are above consumable amounts and any levels beyond that are not likely to affect house prices by much.

The overall results imply that actions that would improve piped water service (by increasing the number of hours of piped water service or improving water quality) are likely to be more highly valued (i.e., capitalized into housing prices) in the Other Zone than in the Sweet Water zone.

4.6.3 The Impact of Improving Quality and Duration of Piped Water on the Marginal Willingness to Pay for Piped Water

This section presents estimates of the marginal willingness to pay (MWTP) for piped water. Benchmark estimates are presented for MWTP evaluated at mean levels of water table depth, salinity, duration, and bacteria. Estimates of MWTP are also presented for increased levels of daily piped water service and for improvements in the quality of piped water (i.e., reduced levels of bacterial contamination). All estimates are based on sample means for imputed monthly rent.

Table 4.13 presents the MWTP for piped water in the rural and urban areas of the pooled sample (across both zones). These estimates were calculated using the formula presented in equation (8). The top row uses the marginal effects implied by the coefficient estimates from columns (2) and (6) of Table 4.8, evaluated at sample means for water table depth, salinity, duration, and bacterial presence. Note that the "marginal effects" in the top row are identical to the "full effects" presented in columns (1) and (3) of Table 4.9.

At sample averages for depth, salinity, duration and bacteria the MWTP for piped water in rural areas is Rs. 18.72 ($0.30[70]), approximately 12 percent of average monthly rent. In urban areas the comparable figure is Rs. 183.19 ($2.95), or about 30 percent of the average monthly rent. These figures suggest that urban housing markets value piped water substantially more than rural housing markets, both in absolute and relative terms.

The other rows of Table 4.13 indicate that MWTP for piped water increases from these benchmarks when duration or bacteria levels are improved (relative to their mean values). Thus, the MWTP of piped water increases by Rs. 4.35 (Rs. 38.13) in rural (urban areas) when evaluated at duration levels one hour greater than the sample mean. Likewise, the MWTP of piped water is roughly doubled when bacteria loads are decreased by 10 percent from mean levels. Finally, computed MWTP for achieving ideal levels of duration or healthfulness – i.e., 24-hour availability or complete elimination of bacteria – are very large in both rural and urban areas.

Two interesting points emerge from these estimates that echo the findings discussed in the previous section. First, the MWTP for piped water, both in absolute terms and as a fraction of imputed monthly rent, is greater in urban areas than in rural areas. Second, in both areas the MWTP for reducing bacterial contamination exceeds the MWTP for increased duration of service.

Finally, Table 4.14 presents separate MWTP estimates for the Sweet Water Zone and the Other Zone. Across the board, comparable MWTP estimates are larger for the Other Zone than for the Sweet Water Zone. As was noted in the discussion of the hedonic regressions,

[70] Using exchange rate (2008): $1=Rs.62

this is reasonable. Households in the Sweet Water Zone have access to easy and low cost in-home alternatives to piped water (in the form of pumped water) and therefore are not reliant on piped water. On the other hand, in the Other Zone alternatives may be more difficult, inconvenient, and costly to find. Thus, the welfare impacts of comparable improvements in the quality of piped water service are likely to be substantially larger in the Other Zone than in the Sweet Water Zone.

4.7 IMPLICATIONS

The results that have been presented in this chapter provide interesting insights for shaping public policy. They indicate substantial willingness to pay for both improving the daily service duration and health quality of piped water – particularly in urban areas. This translates into greater scope for collecting higher water tariffs that would be required to cover the increased costs of providing these improvements. Moreover, the results indicate that in both rural and (especially) urban areas the willingness to pay for reducing bacterial contamination in piped water is greater than the willingness to pay for achieving ideal piped water service standards by increasing the duration of piped water service to 24-hours. This is consistent with the findings of the World Bank (2005) study of 8 cities of the Punjab, in which households expressed a stronger interest in improved water quality than an increase in the number of hours of service. It also echoes the findings of Akram and Olmstead (2010), which found that households are willing to pay more for improved quality than for increased duration in Lahore.

Overall, the results suggest that households recognize the negative health effects of piped water. The analysis in Chapter 3 found that piped water is associated with an increased incidence of diarrhea in children (particularly in urban areas). The results presented in this chapter indicate that households are willing to pay for better water quality. An implication of this is that the key to breaking away from the vicious cycle of low quality piped water translating to low payments, declining revenues further, and further widening the gap between maintenance and replacement, is to first improve the quality and service of piped water.

The results also show that water system managers are likely to be more successful in enforcing higher tariffs due to service improvements (thereby covering the increased cost of service) in the Brackish and Arid districts than in Sweet Water districts. This applies to both increasing the daily duration of piped water flow and reducing bacterial loads of piped water. The reason for this is that in the Sweet Water Zone alternative water sources are more easily available and therefore piped water is not valued as highly (consistent with the findings of Berg and Nauges (2012). Recall that in Chapter 2 it was found that salinity is an important determinant in the public placement of piped water networks, the results in chapter suggest that prioritizing water system investments in areas with higher salinity levels is indeed reasonable.

However, there is no simple way to do this. Rather, it will require dramatic increases in the efficiency of the providers of the public services, as well as transition plans so that improved services can induce greater confidence in local water services (and hence willingness to pay for them by water system subscribers). Presumably, external funds would be needed to cover operational deficits in the first years as quality and service is improved, in the hopes that cost recovery will be achieved later through higher tariffs (justified by the willingness to pay for improved services).

Furthermore, all this is only possible if customers recognize the service providers' efforts to improve services. Although increased duration is easy to recognize by the increased hours of flow, improved quality may not be as readily apparent. For this reason, combining a service quality improvement program with customer dialogue and public awareness campaigns is recommended for improving the collection rates. For example, the results of independently certified water quality testing can be posted in newspapers or on billboards at public taps.

Table 4.1: Comparison of Tariffs of Selected Low Income Countries 2005-06

Country	GDP (US$/capita)	Average Tariff (US$/connection/month)
Benin	1100	8.4
Burkina Faso	1300	32.5
Cote d'Ivoire	1600	10.4
Morocco	4200	26.1
Namibia	7000	18.4
Nigeria	1400	4.3
Senegal	1800	17.0
Togo	1700	23.4
Pakistan (min)	2400	0.7
Pakistan (max)	2400	3.5

Source: World Bank (2005) Tehsil Municipal Authority (TMA)/ Water and Sanitation Authority (WASA), Punjab, Pakistan

Table 4.2: Efficiency Indicators – Urban Areas of Selected Districts

					Costs (% of Operating Expenditure)		
	Leakage Ratio (%)	Metering Ratio (%)	Collection Ratio (%)	Staff per 1000 connections	Staff Costs	Energy Costs	Maintenance Costs
Lahore	40	30	85	14.0	25	55	20
Faisalabad	35	0	45	6.5	36	53	11
Gujranwala	35	0	32	4.5	37	46	17
Multan	35	0	18	19.0	41	59	0
Rawalpindi	40	0	74	6.0	25	42	33
Bahawalpur	40	0	19	8.0	60	35	5
DG Khan	40	0	31	5.0	35	60	5
Sargodha	40	0	20	7.0	30	70	0
Sialkot	55	0	86	5.0	17	79	4

Source: The World Bank, Urban and Water Unit, South Asia Region, 2004-05

Table 4.3: Financial Indicators – Urban Areas of Selected Districts

	Sales (million m^3/yr)	Avg. tariff (Rs. per m^3)	Estimated Billing (million Rs.)	Collection ratio (million)	O&M costs (million Rs.)	Deficit (million Rs.)	Urban Immovable Property (UIP) tax (million Rs.)	Deficit (million Rs.)
Lahore	270	5.8	1565	85	1580	-250	360	110
Faisalabad	36	8.9	320	45	272	-131	53	-78
Gujranwala	11	6.3	69	32	133	-111	5	-106
Multan	18	4.6	83	18	217	-202	40	-162
Rawalpindi	33	2.7	89	74	228	-162	62	-100
Bahawalpur	1	3.6	4	19	9	-8	10	2
DG Khan	7	0.6	5	31	31	-30	0	-30
Sargodha	7	1.0	7	20	54	-53	0	-53
Sialkot	22	1.7	37	86	114	-82	23	-60
Total	405	5.4	2178	74	2641	-1029	553	-476

Source: The World Bank, Urban and Water Unit, South Asia Region, 2004-05

<u>Table 4.4: Summary of Previous Studies on the Willingness to Pay (WTP) for Piped Water</u>

Author	**Yr**	**Location**	**Findings**
North and Griffin	1993	Bicol Region, Philippines	Households' WTP for a tap water connection was 50 percent of the imputed monthly rent in all income groups.
Yusuf and Koundouri	2005	Indonesia	On average, urban households are willing to pay 25 percent of imputed monthly rent for a tap water connection, while rural households are willing to pay 14 percent.
Berg and Nauges	2012	Southwest Sri Lanka	(a) WTP for a piped water connection was on average about 5 percent of monthly household expenditure, and the WTP decreases as a proportion of income when income goes up. (b) If alternative sources with good water quality are available, the need for a piped water connection is less urgent.
Lumbantobing	2010	Gampaha, Kalutara, and Galle districts in SW Sri Lanka	(a) In each district, availability of a tap water network in a neighborhood leads to higher housing prices. (b) The price increase was the highest in the district in which tap water networks were the least available.
Altaf and Jamal	1989	Rural Punjab, Pakistan	WTP depends on the alternatives available: households in the sweet water zone were willing to pay less for publicly supplied water than households in the brackish and arid zones because of the availability of a relatively less costly alternative (hand pumps). Furthermore reliability of water supply is the key to customer satisfaction. Households were willing to pay as much as 40 percent more per month for reliable service than for unreliable service
World Bank	2005	Urban Punjab, Pakistan	(a) Almost all households surveyed wished to have a water connection (only 2 percent prefer to use a well and a motorized pump). (b) Households expressed a stronger interest in improved water quality than an increased number of hours of service. (c) The amount households were willing to pay for a 24/7 service of water of guaranteed quality was, on average, Rs.160/month (US$2.67/month).
Akram and Olmstead	2010	Lahore, Pakistan	Households in Lahore were willing to pay between Rs.630 ($7.50) to Rs.756 ($9.00) per month for piped water that is clean and drinkable from the tap.

Table 4.5: Descriptive Statistics: Willingness to Pay for Piped water – All Zones

	Rural					Urban				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Monthly Imputed Rent	*49272*	*154.32*	*2.6*	*3*	*83283*	*22235*	*600.64****	*3.1*	*4*	*83283*
Water Source (0=no, 1=yes)										
Piped in-home water	49272	0.08	0.3	0	1	22235	0.30***	0.5	0	1
Hand pump	49272	0.46	0.5	0	1	22235	0.12***	0.3	0	1
Motorized pump	49272	0.34	0.5	0	1	22235	0.46***	0.5	0	1
Public tap	49272	0.04	0.2	0	1	22235	0.02***	0.1	0	1
Other improved sources	49272	0.06	0.2	0	1	22235	0.07***	0.3	0	1
Unimproved sources	49272	0.03	0.2	0	1	22235	0.02***	0.2	0	1
House attributes										
Toilet facility: Flushed to pipe system (0=no, 1=yes)	49272	0.03	0.2	0	1	22235	0.47***	0.5	0	1
Toilet facility: Flushed to septic system (0=no, 1=yes)	49272	0.35	0.5	0	1	22235	0.40***	0.5	0	1
House area in marlas (1 marla=30.25 sq.yards)	49272	11.23	11.4	0	900	22235	6.35***	11.5	0	1500
Number of rooms for sleeping	49272	2.02	1.0	0	12	22235	2.17***	1.1	0	12
Main material of roof - improved (0=no, 1=yes)	49272	0.78	0.4	0	1	22235	0.95***	0.2	0	1
Main material of floor - improved (0=no, 1=yes)	49272	0.43	0.5	0	1	22235	0.87***	0.3	0	1
Fuel used - electric or gas (0=no, 1=yes)	49272	0.07	0.3	0	1	22235	0.69***	0.5	0	1
Electricity (0=no, 1=yes)	49272	0.89	0.3	0	1	22235	0.99***	0.1	0	1
Neighborhood characteristics (0=no, 1=yes)										
Primary school within 2km	49272	0.93	0.3	0	1	22235	0.99***	0.1	0	1
Health center within 30 mins	49272	0.65	0.5	0	1	22235	0.95***	0.2	0	1
District characteristics										
Population density (persons/sq.km)	35	381.40	184.1	90	800	35	587.90***	198.8	100	3566
Water table depth (feet)	35	38.52	47.9	7	200	35	44.72	53.3	8	200
Salinity (ds/m)	35	1.95	1.1	1	5	35	1.80	1.0	1	5
Duration of piped water flow (per day)	30	6.81	2.0	3	11	30	7.29***	2.2	3	11
Bacteria present (percentage households)	35	51.20	50.0	0	100	35	51.60**	50.0	0	96

Sources: Punjab Multiple Indicator Survey 2007-08; Directorate of Land Reclamation 2008; Punjab Development Statistics 2008; Punjab Council of Research and Water Resources 2008

*p<0.01, **p<0.05, ***p<0.1 for t-test of mean(rural)=mean(urban)

Table 4.6: Descriptive Statistics: Willingness to Pay for Piped water – Sweet Water Zone

	Rural					Urban				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Monthly Imputed Rent	*14387*	*184.34*	*2.7*	*3*	*66836*	*5826*	*566.46****	*2.8*	*4*	*41773*
Water Source (0=no, 1=yes)										
Piped in-home water	14387	0.07	0.2	0	1	5826	0.22***	0.4	0	1
Hand pump	14387	0.51	0.5	0	1	5826	0.18***	0.4	0	1
Motorized pump	14387	0.35	0.5	0	1	5826	0.51***	0.5	0	1
Public tap	14387	0.02	0.1	0	1	5826	0.02***	0.1	0	1
Other improved sources	14387	0.02	0.2	0	1	5826	0.05***	0.2	0	1
Unimproved sources	14387	0.03	0.2	0	1	5826	0.01***	0.1	0	1
House attributes										
Toilet facility: Flushed to pipe system (0=no, 1=yes)	14387	0.02	0.1	0	1	5826	0.36***	0.5	0	1
Toilet facility: Flushed to septic system (0=no, 1=yes)	14387	0.49	0.5	0	1	5826	0.50***	0.5	0	1
House area in marlas (1 marla=30.25 sq.yards)	14387	11.09	13.5	0	900	5826	6.32***	6.9	0	250
Number of rooms for sleeping	14387	2.04	1.1	0	12	5826	2.19***	1.1	1	12
Main material of roof - improved (0=no, 1=yes)	14387	0.82	0.4	0	1	5826	0.95***	0.2	0	1
Main material of floor - improved (0=no, 1=yes)	14387	0.48	0.5	0	1	5826	0.85***	0.4	0	1
Fuel used - electric or gas (0=no, 1=yes)	14387	0.09	0.3	0	1	5826	0.70***	0.5	0	1
Electricity (0=no, 1=yes)	14387	0.93	0.3	0	1	5826	0.99***	0.1	0	1
Neighborhood characteristics (0=no, 1=yes)										
Primary school within 2km	14387	0.93	0.3	0	1	5826	0.99***	0.1	0	1
Health center within 30 mins	14387	0.74	0.4	0	1	5826	0.96***	0.2	0	1
District characteristics										
Population density (persons/sq. km)	14	259.80	126.2	90	800	14	415.60***	178.8	100	3566
Water table depth (feet)	14	11.98	2.7	7	16	14	12.79	2.8	8	16
Salinity (ds/m)	14	1.26	0.4	1	2	14	1.17	0.4	1	2
Duration of piped water flow (per day)	12	8.13	1.9	5	11	12	8.64***	1.8	5	11
Bacteria present (percentage households)	14	39.90	26.4	0	79	14	38.40**	23.6	0	69

Sources: Punjab Multiple Indicator Survey 2007-08; Directorate of Land Reclamation 2008; Punjab Development Statistics 2008; PCRWR 2008

*p<0.01, **p<0.05, ***p<0.1 for t-test of mean(rural)=mean(urban)

Table 4.7: Descriptive Statistics: Willingness to Pay for Piped water – Other Zone

	Rural					Urban				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Monthly Imputed Rent	*34885*	*143.41*	*2.6*	*3*	*83283*	*16409*	*613.39****	*3.2*	*8*	*83283*
Water Source (0=no, 1=yes)										
Piped in-home water	34885	0.10	0.3	0	1	16409	0.34***	0.5	0	1
Hand pump	34885	0.41	0.5	0	1	16409	0.09***	0.3	0	1
Motorized pump	34885	0.34	0.5	0	1	16409	0.45***	0.5	0	1
Public tap	34885	0.04	0.2	0	1	16409	0.02***	0.1	0	1
Other improved sources	34885	0.07	0.3	0	1	16409	0.08***	0.3	0	1
Unimproved sources	34885	0.04	0.2	0	1	16409	0.03***	0.2	0	1
House attributes										
Toilet facility: Flushed to pipe system (0=no, 1=yes)	34885	0.05	0.2	0	1	16409	0.54***	0.5	0	1
Toilet facility: Flushed to pipe system (0=no, 1=yes)	34885	0.32	0.5	0	1	16409	0.35***	0.5	0	1
House area in marlas (1 marla=30.25 sq.yards)	34885	11.29	10.4	1	400	16409	6.36***	12.8	0	1500
Number of rooms for sleeping	34885	2.01	1.0	0	12	16409	2.17***	1.1	0	12
Main material of roof - improved (0=no, 1=yes)	34885	0.76	0.4	0	1	16409	0.95***	0.2	0	1
Main material of floor - improved (0=no, 1=yes)	34885	0.41	0.5	0	1	16409	0.88***	0.3	0	1
Fuel used - electric or gas (0=no, 1=yes)	34885	0.06	0.2	0	1	16409	0.69***	0.5	0	1
Electricity (0=no, 1=yes)	34885	0.87	0.3	0	1	16409	0.99***	0.1	0	1
Neighborhood characteristics (0=no, 1=yes)										
Primary school within 2km	34885	0.93	0.3	0	1	16409	0.99***	0.1	0	1
Health center within 30 mins	34885	0.61	0.5	0	1	16409	0.95***	0.2	0	1
District characteristics										
Population density (persons/sq. km)	21	367.20	184.4	90	590	21	704.50***	216.5	100	927
Water table depth (feet)	21	49.48	53.2	14	200	21	56.08	57.9	14	200
Salinity (ds/m)	21	2.24	1.1	1	5	21	2.03	1.0	1	5
Duration of piped water flow (per day)	18	5.97	1.6	3	10	18	6.47***	2.0	3	10
Bacteria present (percentage households)	21	53.90	27.6	0	100	21	51.10**	23.6	0	96

Sources: Punjab Multiple Indicator Survey 2007-08; Directorate of Land Reclamation; Punjab Development Statistics 2008; Punjab Council of Research and Water Resources 2008

*p<0.01, **p<0.05, ***p<0.1 for t-test mean(rural)=mean(urban)

Table 4.8: All Zones: Hedonic Estimation Results

	Dependent Variable: Ln(Monthly imputed rent)							
	Rural				**Urban**			
	Pipe vs. All^		Pipe vs. Hand pump^^		Pipe vs. All^		Pipe vs. Hand pump^^	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Piped water in-home	0.090***	0.250**	0.193***	0.245***	0.221***	0.653***	0.295***	0.754**
	(6.07)	(2.47)	(11.63)	(2.90)	(6.56)	(2.93)	(7.54)	(2.49)
Interaction terms								
Water table depth * Pipe		0.003***		0.003***		0.004*		0.004**
		(4.02)		(4.45)		(1.76)		(2.12)
Salinity * Pipe		0.110***		0.136***		0.070**		0.062***
		(3.38)		(3.93)		(2.29)		(3.76)
Duration * Pipe		0.025*		0.029**		0.048***		0.043***
		(1.67)		(2.28)		(5.86)		(6.59)
Bacteria * Pipe		-0.123***		-0.120***		-0.204***		-0.204***
		(-3.91)		(-4.52)		(-3.46)		(-4.17)
Other water sources								
Motorized Pump			0.207***	0.210***			0.138***	0.154***
			(18.81)	(19.03)			(5.88)	(6.55)
Public Tap			0.043	0.039			0.019	0.031
			(1.64)	(1.46)			(0.36)	(0.59)
Other improved sources			0.021	0.004			0.307***	0.341***
			(1.18)	(0.22)			(9.18)	(10.02)
Unimproved sources			0.108***	0.090***			0.362***	0.391***
			(4.72)	(3.91)			(8.12)	(8.70)
District Variables								
Population density	0.090***	0.089***	0.093***	0.091***	0.140***	0.140***	0.149***	0.150***
	(13.86)	(14.37)	(12.65)	(13.17)	(15.33)	(14.95)	(13.86)	(13.17)
Avg. water table depth of district	0.002***	-0.001***	0.001***	-0.002***	0.002***	-0.003***	0.002***	-0.002***
	(25.38)	(-25.60)	(24.98)	(-25.43)	(28.05)	(-22.86)	(26.83)	(-20.59)
Avg. salinity level of district	-0.042***	-0.151***	-0.032***	-0.170***	-0.100***	-0.168***	-0.111***	-0.180***
	(-4.08)	(-3.77)	(-3.10)	(-2.91)	(-6.08)	(-6.54)	(-6.74)	(-7.71)
Duration of piped water flow in district (per day)	0.038***	0.017***	0.035***	0.010***	0.055***	0.003***	0.059***	0.004*
	(16.32)	(14.76)	(15.00)	(13.34)	(3.63)	(3.73)	(4.04)	(1.75)
Mean bacteria present in piped water (district)	-0.124**	-0.002*	-0.129**	-0.005*	-0.202**	-0.003*	-0.210**	-0.004*
	(-2.14)	(-1.78)	(-2.61)	(-1.81)	(-2.57)	(-1.78)	(-2.55)	(-1.73)

Table 4.8: (continued)

	Dependent Variable: Ln(Monthly imputed rent)							
	Rural				**Urban**			
	Pipe vs. All^		Pipe vs. Hand pump^^		Pipe vs. All^		Pipe vs. Hand pump^^	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
House attributes								
Toilet facility: flushed to main line	0.093***	0.094***	0.075***	0.075***	0.361***	0.361***	0.334***	0.335***
	(3.76)	(3.76)	(2.98)	(2.98)	(14.64)	(14.64)	(13.41)	(13.41)
Toilet facility: flushed to septic tank	0.253***	0.253***	0.224***	0.225***	0.245***	0.246***	0.233***	0.233***
	(25.35)	(25.35)	(22.06)	(22.06)	(10.47)	(10.47)	(9.80)	(9.80)
House area (marlas^)	0.015***	0.015***	0.015***	0.015***	0.039***	0.039***	0.039***	0.039***
	(36.11)	(36.01)	(36.21)	(36.05)	(37.28)	(37.32)	(37.34)	(37.47)
Number of rooms	0.226***	0.226***	0.217***	0.218***	0.243***	0.242***	0.239***	0.238***
	(52.18)	(52.32)	(50.24)	(50.37)	(38.39)	(38.35)	(37.86)	(37.47)
Main material of roof- improved	0.443***	0.439***	0.401***	0.396***	0.386***	0.385***	0.352***	0.348***
	(45.14)	(44.70)	(40.10)	(39.62)	(16.15)	(16.11)	(14.46)	(14.33)
Main material of floor- improved	0.266***	0.266***	0.245***	0.245***	0.181***	0.185***	0.169***	0.173***
	(19.57)	(19.55)	(18.06)	(18.05)	(5.01)	(5.14)	(4.70)	(4.81)
Fuel used- good	0.594***	0.595***	0.570***	0.569***	0.495***	0.498***	0.469***	0.472***
	(39.49)	(39.50)	(38.01)	(37.97)	(27.84)	(28.01)	(26.22)	(26.39)
Electricity	0.247***	0.252***	0.194***	0.199***	0.215**	0.226**	0.203**	0.215**
	(12.04)	(12.28)	(9.44)	(9.69)	(2.08)	(2.19)	(1.96)	(2.08)
Neighborhood variables								
Primary school within 2 km	0.082***	0.079***	0.080***	0.076***	0.123*	0.128*	0.132**	0.137**
	(3.35)	(3.24)	(3.28)	(3.13)	(1.84)	(1.85)	(1.98)	(2.07)
Health center within 30 mins	0.168***	0.169***	0.161***	0.162***	0.194***	0.191***	0.197***	0.193***
	(16.30)	(16.42)	(15.74)	(15.84)	(5.23)	(5.15)	(5.33)	(5.23)
(constant)	3.266***	3.268***	3.321***	3.326***	3.732***	3.848***	3.693***	3.841***
	(87.95)	(86.23)	(89.53)	(87.82)	(28.28)	(28.85)	(28.04)	(28.89)
N	29901	29901	29901	29901	14419	14419	14419	14419
F-statistic	1289.24	1023.90	1051.78	875.56	677.83	539.21	545.58	455.43
R-squared	0.39	0.39	0.40	0.40	0.41	0.41	0.42	0.42

**p<0.1, **p<0.05, ***p<0.01, t-statistics in brackets*

^ Omitted category: all other sources of water, ^^Omitted category: Hand pumps

Table 4.9: All Zones: Full Effects of Models with Interactions (at Means)

Variable	Rural		Urban	
	Pipe vs. All^	Pipe vs. Hand pump^^	Pipe vs. All^	Pipe vs. Hand pump^^
Piped water	0.115**	0.214***	0.266**	0.302**
	(2.06)	(2.92)	(2.22)	(2.52)
Avg. water table depth of district	0.001***	0.002***	0.002***	0.002***
	(5.88)	(5.62)	(6.12)	(6.00)
Avg. salinity of district	-0.041***	-0.034**	-0.100**	-0.117**
	(-2.11)	(-1.91)	(-2.55)	(-2.65)
Duration of piped water flow in district (per day)	0.041***	0.039***	0.051**	0.047**
	(4.61)	(4.55)	(2.01)	(1.95)
Mean bacteria present in piped water (district)	-0.125*	-0.125*	-0.207*	-0.208*
	(-1.79)	(-1.80)	(1.81)	(-1.79)

**p<0.1, **p<0.05, ***p<0.01*

t-statistics in brackets

^ Omitted category: all other sources of water, ^^Omitted category: Hand pumps

Table 4.10: Sweet Water Zone: Hedonic Estimation Results

Dependent Variable: Ln(Monthly imputed rent)								
	Rural				**Urban**			
	Pipe vs. All^		Pipe vs. Hand pump^^		Pipe vs. All^		Pipe vs. Hand pump^^	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Piped water in-home	0.070***	0.036***	0.133***	-0.099**	0.143***	0.261**	0.202***	0.274***
	(4.33)	(3.00)	(8.23)	(-2.44)	(3.91)	(2.43)	(3.91)	(2.93)
Interaction terms								
Water table depth * Pipe		0.021*		0.025**		0.008*		0.007*
		(1.87)		(2.26)		(1.73)		(1.67)
Salinity * Pipe		0.117*		0.239***		0.142*		0.205**
		(1.84)		(3.76)		(1.65)		(2.38)
Duration * Pipe		0.002*		0.002**		0.012**		0.011**
		(1.79)		(2.00)		(2.53)		(2.39)
Bacteria * Pipe		-0.096**		-0.097**		-0.127**		-0.129**
		(-2.16)		(-2.19)		(-2.53)		(-2.64)
Other water sources								
Motorized Pump			0.245***	0.257***			0.237***	0.242***
			(13.74)	(14.24)			(7.12)	(7.12)
Public Tap			0.070	0.061			0.222***	0.222***
			(1.47)	(1.27)			(2.84)	(2.84)
Other improved sources			-0.039	-0.040			0.154**	0.164**
			(-0.86)	(-0.80)			(2.04)	(2.17)
Unimproved sources			0.230***	0.232***			0.166*	0.192*
			(4.54)	(4.58)			(1.75)	(1.77)
District variables								
Population density	0.091***	0.090***	0.091***	0.090***	0.154***	0.156***	0.155***	0.155***
	(8.60)	(5.74)	(9.10)	(6.19)	(7.02)	(4.62)	(10.31)	(5.62)
Avg. water table depth of district	-0.036***	-0.058***	-0.033***	-0.060***	-0.036***	-0.046***	-0.038***	-0.046***
	(-9.98)	(-8.85)	(-9.09)	(-7.69)	(-5.27)	(-4.62)	(-5.18)	(-4.73)
Avg. salinity level of district	-0.301***	-0.420***	-0.311***	-0.551***	-0.430***	-0.580***	-0.470***	-0.681***
	(-20.30)	(-18.74)	(-19.56)	(-17.53)	(-13.92)	(-11.62)	(-13.59)	(-10.73)
Duration of piped water flow in district (per day)	0.035***	0.035***	0.031***	0.028***	0.042***	0.030*	0.054***	0.039***
	(9.36)	(8.88)	(11.54)	(11.10)	(3.23)	(1.93)	(4.02)	(2.59)
Mean bacteria present in piped water (district)	-0.097**	-0.001*	-0.097**	-0.001*	-0.127**	-0.002*	-0.128**	-0.003*
	(-2.38)	(-1.80)	(-2.42)	(-1.72)	(-2.10)	(-1.67)	(-2.00)	(-1.67)

Table 4.10: (continued)

Dependent Variable: Ln(Monthly imputed rent)								
	Rural				**Urban**			
	Pipe vs. All^		Pipe vs. Hand pump^^		Pipe vs. All^		Pipe vs. Hand pump^^	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
House attributes								
Toilet facility: flushed to main line	0.026	0.027	0.014	0.014	0.434***	0.435***	0.409***	0.409***
	(0.41)	(0.41)	(0.23)	(0.23)	(12.02)	(12.02)	(11.33)	(11.33)
Toilet facility: flushed to septic tank	0.205***	0.205***	0.163***	0.164***	0.265***	0.265***	0.244***	0.245***
	(12.10)	(12.10)	(9.50)	(9.50)	(7.69)	(7.69)	(7.10)	(7.10)
House area (marlas^)	0.014***	0.014***	0.014***	0.013***	0.037***	0.037***	0.037***	0.037***
	(24.38)	(24.31)	(24.11)	(24.00)	(22.74)	(22.75)	(22.59)	(22.59)
Number of rooms	0.245***	0.245***	0.234***	0.234***	0.241***	0.240***	0.235***	0.235***
	(36.74)	(36.75)	(35.17)	(35.10)	(25.51)	(25.45)	(24.99)	(24.96)
Main material of roof- improved	0.392***	0.392***	0.328***	0.326***	0.358***	0.357***	0.298***	0.297***
	(24.49)	(24.52)	(19.86)	(19.74)	(10.49)	(10.49)	(8.53)	(8.49)
Main material of floor- improved	0.204***	0.204***	0.186***	0.185***	0.124**	0.119**	0.112*	0.106*
	(7.76)	(7.75)	(7.12)	(7.07)	(2.07)	(1.99)	(1.87)	(1.77)
Fuel used- good	0.567***	0.564***	0.539***	0.532***	0.366***	0.360***	0.336***	0.330***
	(24.79)	(24.60)	(23.69)	(23.29)	(13.38)	(13.13)	(12.14)	(11.91)
Electricity	0.200***	0.206***	0.174***	0.182***	0.247**	0.249**	0.219**	0.230**
	(4.51)	(4.63)	(3.94)	(4.12)	(2.52)	(2.53)	(2.35)	(2.42)
Neighborhood variables								
Primary school within 2 km	0.150***	0.149***	0.147***	0.145***	0.209*	0.219*	0.233*	0.241**
	(3.02)	(3.00)	(2.99)	(2.96)	(1.74)	(1.82)	(1.94)	(2.01)
Health center within 30 mins	0.116***	0.114***	0.106***	0.103***	0.273***	0.273***	0.271***	0.268***
	(6.04)	(5.94)	(5.57)	(5.39)	(5.05)	(5.04)	(5.03)	(4.98)
(constant)	5.856***	5.800***	5.969***	5.893***	5.101***	4.995***	5.077***	4.951***
	(48.56)	(47.25)	(49.80)	(48.36)	(21.99)	(21.18)	(21.89)	(21.00)
N	11010	11010	11010	11010	5486	5486	5486	5486
F-statistic	517.40	409.13	427.24	354.55	245.80	194.70	198.48	164.51
R-squared	0.41	0.41	0.42	0.43	0.40	0.40	0.41	0.41

*p<0.1, **p<0.05, ***p<0.01, t-statistics in brackets

^ Omitted category: all other sources of water, ^^Omitted category: Hand pumps

Table 4.11: Other Zone: Hedonic Estimation Results

	Dependent Variable: Ln(Monthly imputed rent)							
	Rural				**Urban**			
	Pipe vs. All^		Pipe vs. Hand pump^^		Pipe vs. All^		Pipe vs. Hand pump^^	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Piped water in-home	0.201***	0.682**	0.231***	0.709**	0.401***	1.023***	0.435***	1.047***
	(5.31)	(2.41)	(6.61)	(2.24)	(5.99)	(3.19)	(5.37)	(3.44)
Interaction terms								
Water table depth * Pipe		0.001***		0.001***		0.002***		0.001***
		(3.65)		(3.86)		(3.38)		(2.85)
Salinity * Pipe		0.038**		0.035*		0.028**		0.042**
		(1.81)		(1.74)		(2.18)		(1.84)
Duration * Pipe		0.037***		0.038***		0.057***		0.057***
		(4.23)		(4.32)		(8.27)		(9.36)
Bacteria * Pipe		-0.152**		-0.153**		-0.222**		-0.224**
		(-2.03)		(-2.34)		(-2.13)		(-2.31)
Other water sources								
Motorized Pump			0.181***	0.187***			0.110***	0.121***
			(13.12)	(13.53)			(3.33)	(3.64)
Public Tap			0.008	0.008			-0.149**	-0.129*
			(0.26)	(0.26)			(-2.10)	(-1.82)
Other improved sources			0.051***	0.049***			0.302***	0.349***
			(2.64)	(2.73)			(7.24)	(8.27)
Unimproved sources			0.039	0.031			0.342***	0.369***
			(1.57)	(1.23)			(6.48)	(6.98)
District variables								
Population	0.090***	0.090***	0.091***	0.090***	0.138***	0.140***	0.139***	0.140***
	(10.05)	(6.44)	(7.55)	(5.11)	(12.87)	(11.56)	(11.44)	(9.86)
Avg. water table depth of district	0.004***	0.003***	0.004***	0.003***	0.004***	0.002***	0.004***	0.003***
	(35.05)	(35.25)	(34.78)	(35.10)	(18.79)	(18.13)	(18.65)	(17.73)
Avg. salinity level of district	0.016***	-0.054***	-0.018***	-0.052***	-0.054**	-0.082*	-0.066***	-0.106**
	(-8.93)	(-8.39)	(-8.29)	(-7.64)	(-2.37)	(-1.70)	(-2.89)	(-2.55)
Duration of piped water flow in district (per day)	0.042***	0.006***	0.037***	0.001***	0.079***	0.020**	0.079***	0.023*
	(6.53)	(3.43)	(6.48)	(3.28)	(4.63)	(2.38)	(4.78)	(2.00)
Mean bacteria present in piped water (district)	-0.153**	-0.000*	-0.155**	-0.001*	-0.226**	-0.002*	-0.228*	-0.003*
	(-2.47)	(-1.69)	(-2.31)	(-1.84)	(-2.07)	(-1.78)	(-1.75)	(-1.78)

Table 4.11: (continued)

	Dependent Variable: Ln(Monthly imputed rent)							
	Rural				**Urban**			
	Pipe vs. All^		Pipe vs. Hand pump^^		Pipe vs. All^		Pipe vs. Hand pump^^	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
House attributes								
Toilet facility: flushed to main line	0.465***	0.466***	0.431***	0.432***	0.283***	0.284***	0.272**	0.273**
	(25.29)	(25.29)	(23.30)	(23.30)	(8.46)	(8.46)	(8.10)	(8.10)
Toilet facility: flushed to septic tank	0.222***	0.223***	0.191***	0.191***	0.151***	0.152***	0.152***	0.153***
	(15.37)	(15.37)	(13.07)	(13.07)	(4.65)	(4.65)	(4.72)	(4.72)
House area (marlas^)	0.021***	0.021***	0.021***	0.021***	0.042***	0.042***	0.042***	0.042***
	(36.95)	(37.03)	(36.55)	(36.59)	(30.83)	(31.07)	(30.80)	(31.08)
Number of rooms	0.205***	0.205***	0.198***	0.198***	0.244***	0.242***	0.239***	0.236***
	(37.59)	(37.61)	(36.41)	(36.41)	(29.26)	(29.11)	(28.81)	(28.54)
Main material of roof- improved	0.373***	0.369***	0.345***	0.339***	0.374***	0.374***	0.350***	0.349***
	(31.13)	(30.77)	(28.45)	(27.96)	(11.44)	(11.46)	(10.59)	(10.61)
Main material of floor- improved	0.210***	0.210***	0.186***	0.185***	0.141***	0.144***	0.126***	0.129***
	(13.74)	(13.77)	(12.11)	(12.11)	(3.12)	(3.19)	(2.90)	(2.88)
Fuel used- good	0.514***	0.509***	0.501***	0.496***	0.514***	0.509***	0.488***	0.479***
	(26.8)	(26.40)	(26.19)	(25.79)	(21.20)	(21.05)	(20.05)	(19.73)
Electricity	0.199***	0.204***	0.146***	0.150***	0.197**	0.207**	0.191**	0.207**
	(9.01)	(9.25)	(6.54)	(6.74)	(2.49)	(2.47)	(2.45)	(2.58)
Neighborhood variables								
Primary school within 2 km	0.090***	0.087***	0.086***	0.083***	0.089*	0.103*	0.096*	0.112*
	(3.36)	(3.28)	(3.25)	(3.14)	(1.71)	(1.69)	(1.69)	(1.68)
Health center within 30 mins	0.154***	0.155***	0.148***	0.149***	0.141***	0.135***	0.150***	0.144***
	(13.21)	(13.20)	(12.68)	(12.72)	(2.82)	(2.70)	(3.01)	(2.90)
(constant)	3.066***	3.117***	3.105***	3.160***	3.559***	3.701***	3.497***	3.682***
	(77.08)	(75.30)	(77.88)	(75.99)	(21.52)	(22.14)	(21.19)	(22.13)
N	18891	18891	18891	18891	8933	8933	8933	8933
F-statistic	973.49	773.18	786.54	654.76	458.28	368.06	370.81	313.09
R-squared	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.45

**p<0.1, **p<0.05, ***p<0.01, t-statistics in brackets*

^ Omitted category: all other sources of water, ^^Omitted category: Hand pumps

Table 4.12: Sweet Water Zone and Other Zone: Full Effects of Models with Interactions (at Means)

Sweet Water Zone

	Rural		**Urban**	
Variable	Pipe vs. All^	Pipe vs. Hand pump^^	Pipe vs. All^	Pipe vs. Hand pump^^
Piped water	0.071*	0.134**	0.142*	0.205**
	(1.71)	(2.42)	(1.87)	(2.17)
Avg. water table depth of district	-0.037***	-0.035***	-0.038***	-0.039***
	(4.42)	(4.12)	(-3.41)	(-3.29)
Avg. salinity of district	-0.304***	-0.312***	-0.438***	-0.476***
	(-5.61)	(-5.56)	(-4.92)	(-4.89)
Duration of piped water flow in district (per day)	0.037***	0.030***	0.042**	0.049**
	(3.33)	(3.61)	(2.12)	(2.50)
Mean bacteria present in piped water (district)	-0.097**	-0.098**	-0.129*	-0.132*
	(-1.91)	(1.93)	(-1.77)	(-1.75)

Other Zone

	Rural		**Urban**	
Variable	Pipe vs. All^	Pipe vs. Hand pump^^	Pipe vs. All^	Pipe vs. Hand pump^^
Piped water	0.201**	0.228**	0.402***	0.428***
	(2.40)	(2.25)	(2.81)	(2.79)
Avg. water table depth of district	0.004***	0.004***	0.004***	0.004***
	(7.31)	(7.25)	(5.55)	(5.49)
Avg. salinity of district	-0.016***	-0.017***	-0.054**	-0.064**
	(-3.21)	(-3.15)	(-1.97)	(-2.01)
Duration of piped water flow in district (per day)	0.043***	0.038***	0.078**	0.080**
	(2.91)	(2.89)	(2.12)	(2.22)
Mean bacteria present in piped water (district)	-0.153*	-0.154*	-0.224*	-0.227*
	(-1.82)	(-1.78)	(-1.87)	(-1.71)

**p<0.1, **p<0.05, ***p<0.01, t-statistics in brackets,*

^ Omitted category: all other sources of water, ^^Omitted category: Hand pumps

Table 4.13: Marginal Willingness to Pay for In-home Piped Water under Different Levels of Bacteria Incidence and Daily Duration of Service – All Zones

All Zones						
	Rural			Urban		
How computed	Marginal Effect	Mean imputed monthly rent (Rs.)	MWTP (Rs.)	Marginal Effect	Mean imputed monthly rent (Rs.)	MWTP (Rs.)
At mean depth, salinity, duration, bacteria	**0.1145**	**154.32**	**18.72**	**0.2662**	**600.64**	**183.19**
Increased duration (by 1 Hour)	0.1393	154.32	23.07	0.3137	600.64	221.32
At reduced bacteria (by 10%)	0.2376	154.32	41.39	0.4702	600.64	360.57
At increased duration (to 24 hr/day)	0.5408	154.32	110.70	1.0600	600.64	1133.04
At reduced bacteria (to 0)	0.7448	154.32	170.68	1.3189	600.64	1645.34

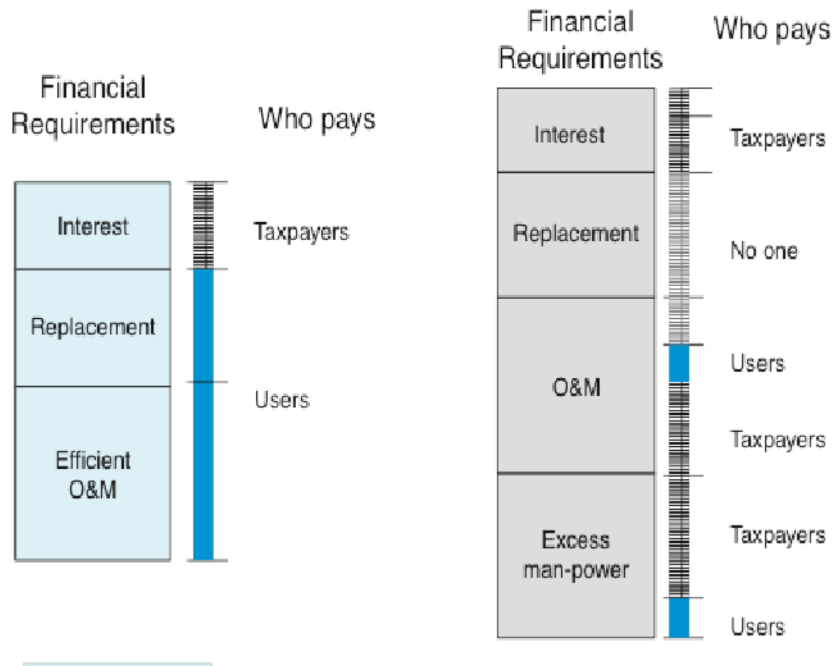
Figure 4.14: Marginal Willingness to Pay for In-home Piped Water under Different Levels of Bacteria Incidence and Daily Service Duration – Sweet Water Zone and Other Zone

Sweet Water Zone

	Rural			Urban		
How computed	Marginal Effect	Mean imputed monthly rent (Rs.)	MWTP (Rs.)	Marginal Effect	Mean imputed monthly rent (Rs.)	MWTP (Rs.)
At mean (depth, salinity, duration, bacteria)	**0.0712**	**184.34**	**13.60**	**0.1422**	**566.46**	**86.56**
Increased duration (by 1 Hour)	0.0732	184.34	14.00	0.1539	566.46	94.24
At reduced bacteria (by 10%)	0.1671	184.34	35.53	0.2693	566.46	175.06
At increased duration (to 24 hrs/day)	0.1030	184.34	20.00	0.3219	566.46	215.11
At reduced bacteria (to 0)	0.4539	184.34	105.89	0.6302	566.46	497.34

Other Zone

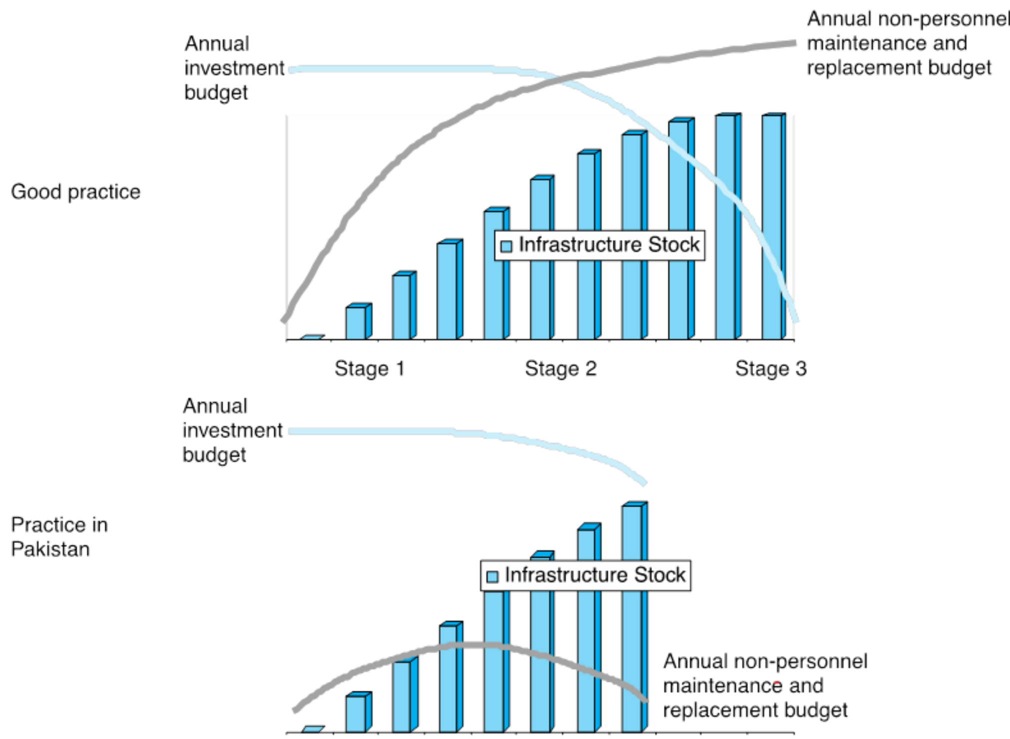
	Rural			Urban		
How computed	Marginal Effect	Mean imputed monthly rent (Rs.)	MWTP (Rs.)	Marginal Effect	Mean imputed monthly rent (Rs.)	MWTP (Rs.)
At mean (depth, salinity, duration, bacteria)	**0.2005**	**143.41**	**31.84**	**0.4018**	**613.39**	**303.33**
Increased duration (by 1 Hour)	0.2373	143.41	38.41	0.4591	613.39	357.39
At reduced bacteria (by 10%)	0.3528	143.41	60.67	0.6236	613.39	530.97
At increased duration (to 24 hrs/day)	0.8639	143.41	196.81	1.4060	613.39	1889.00
At reduced bacteria (to 0)	1.0214	143.41	254.85	1.5352	613.39	2234.12



a. Well-structured water system b. Pakistan

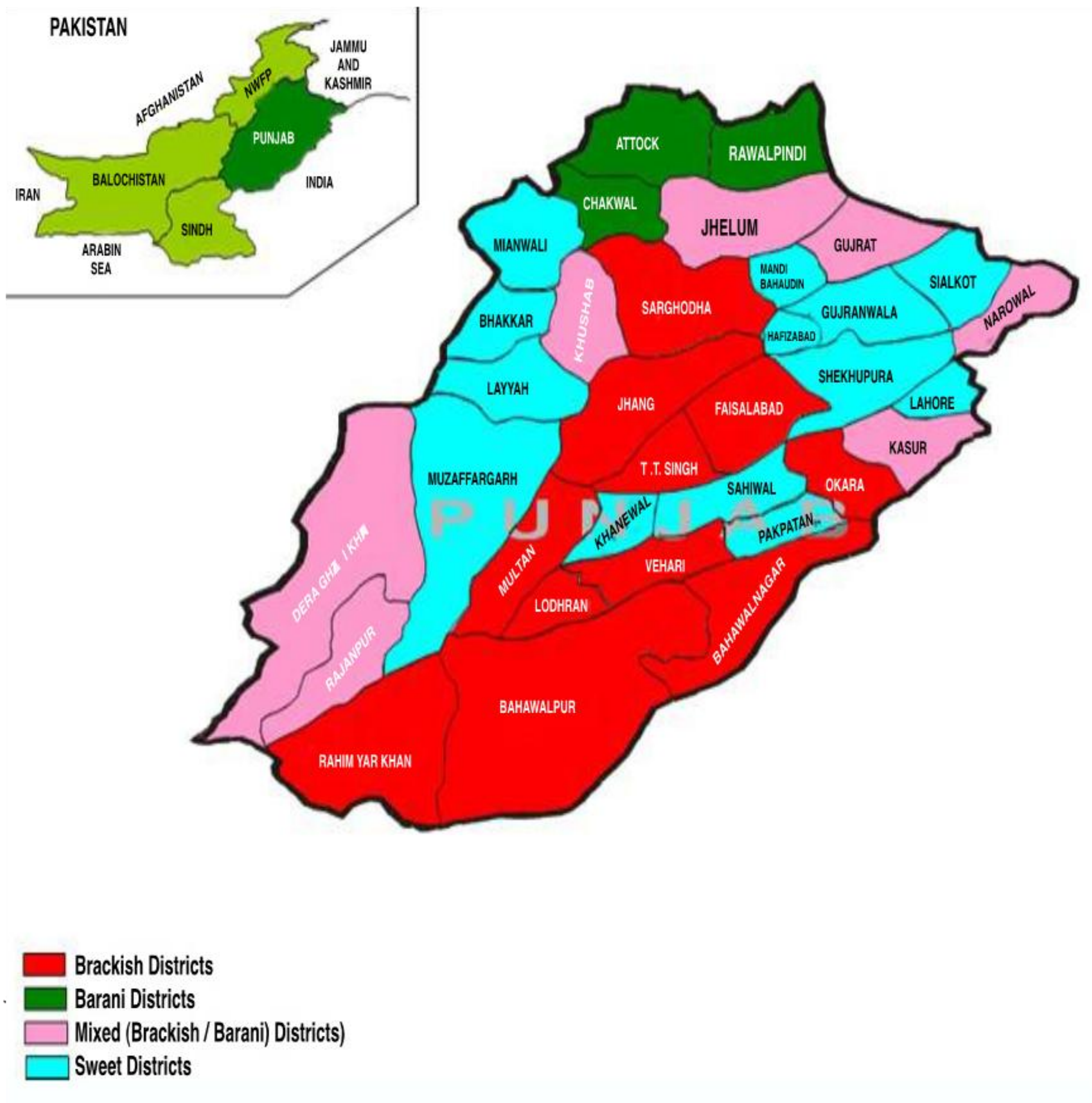
Source: World Bank, 2005

Figure 4.1: The Financing of Water Services in Pakistan



Source: World Bank, 2005

Figure 4.2: Depleting Pakistani Infrastructure Stock



Source: Government of Punjab, 2008

Figure 4.3: Map of Punjab Depicting Districts in Sweet, Brackish, and Barani Zones

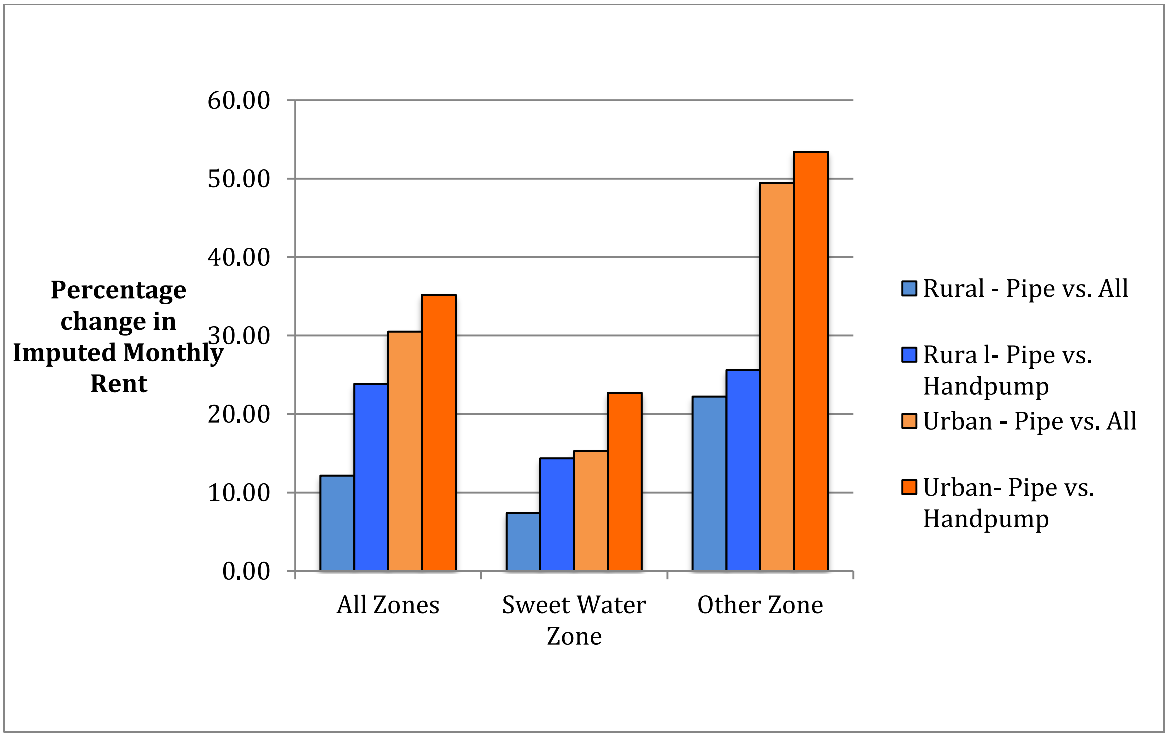


Figure 4.4: The Value Piped Water Adds to the Imputed Monthly Rent Across Different Zones and Areas

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CHAPTER 5
CONCLUSION

The objectives of this study were twofold. First, to assess the impact of piped water on the incidence of diarrhea in children in Punjab – home to the majority of Pakistanis. Second, to estimate households' willingness to pay for piped water – at mean levels of existing service, as well as at higher levels of water quality or service reliability.

The primary dataset used for household level information was the 2007-2008 Punjab Multiple Indicator Survey (MICS). Since information on salinity, water table depth, and duration of piped water flow were not available in the MICS, these household level data were supplemented with data obtained from the Directorate of Land Reclamation (DLR) of the Pakistan Irrigation and Power Department, and the Pakistan Council of Research in Water Resources (PCRWR).

As a first step, the study briefly looked at factors that may determine the public placement of piped water across tehsils. This was done by using a logit model to regress a measure of piped water availability against groundwater quality and other socioeconomic variables.

Next, the study measured the health effects of piped water in both rural and urban areas and across socioeconomic groups. Specifically, a logit model was used to estimate the effect of piped water on the incidence of diarrhea in children under the age of 5. Further, the possibility of cross-contamination of water and sewage pipelines was explored by analyzing the interaction effects of sewage and water pipelines on the presence or absence of bacteria in water.

Finally, a hedonic approach was used to measure households' marginal willingness to pay for piped water in both rural and urban areas of the Punjab. Also evaluated was the MWTP for public policy changes that improve the quality and service of piped water systems

– specifically, by reducing contamination and increasing the duration of flow of piped water.

5.1 SUMMARY OF FINDINGS

The results from the first part of the study analyzing the factors determining piped water placement are supportive of contentions that in both rural and urban areas policy makers base part of their decisions on piped water placement on the groundwater salinity of the region, and that they prioritize wealthier tehsils over others. In areas with highly brackish water, salinity levels make ground water inconsumable and therefore pumped water is frequently an unsuitable source of water. It is thus sensible that households in such areas, who are in need of alternative sources of water, be given priority in the placement of piped water *vis-à-vis* households in areas where groundwater is sweet and hence pumped water is a relatively more feasible alternative.

The results from the second part of the study, which analyzes the impact of piped water on diarrhea in children, show that piped water has no significant effect on diarrhea in children in rural areas; that piped water has an adverse health effect in urban areas, and is associated with increasing the probability of diarrhea in children by an average of 2.2 percentage points; and that in both areas proximity of piped drinking water and wastewater confers addition health risks, presumably due to cross-contamination. At the very least, these empirical findings offer no support to the view held by some that publicly provided water has beneficial health impacts. Indeed, for urban areas they implicate piped water as contributing to negative child health outcomes.

Finally, the results from the analysis of the willingness to pay for piped water show that piped water connections add a positive and significant value to the imputed house rental price in both rural and urban areas; that the value of piped water increases as water table depth, groundwater salinity, and duration of piped water flow per day increases; and that it falls as the percentage of households in a district with bacteria present in their piped water increases. These findings suggest that improving both the quantity (i.e., increasing the duration of flow daily) and water quality would have a significant effect in increasing the willingness to pay for piped water. The results also indicate that households are willing to pay more for an improvement in quality of piped water than for an increase in the duration of flow, and that the response is higher in areas where alternatives to piped water are harder or more costly to find.

Taken as a whole, the results indicate that piped water has a negative health effect in urban areas and that, regardless of whether or not they recognize these negative health effects, households are willing to pay more for better water quality. The key to breaking away from the vicious cycle of low quality, low payments, and declining revenues which further widen the gap between maintenance and replacement, is to first improve the quality and service of piped water. The results additionally suggest that water system managers are likely to be more successful in collecting higher tariffs (thereby covering the increased cost of service) in the Brackish and Arid Zone districts than in Sweet Water Zone districts, and in urban areas over rural areas.

5.2 IMPLICATIONS

The findings of this study have important policy implications. First, public policy and donor funding has, in the past, been too focused on increasing coverage of public water services in rural areas, with less attention on urban areas (ADB, 2009). The differing results for rural and urban areas that have been found here suggest that adding focus to urban areas merits attention.

This, in combination with the evidence drinking water seems to be contaminated with sewage water, suggests significant scope for improving the quality of piped water service through better construction and maintenance of pipelines. To date, the construction of water and sewage pipelines have followed an outdated and ill-advised 1998 Public Health and Engineering Department Design Criteria. For future placement of pipelines, modifying the Design Criteria to follow better standards of construction and maintenance is likely to reduce the possibility of cross contamination of sewage and water pipelines. Furthermore, current pipelines must be adequately maintained on a regular basis to fix and prevent future leakages.

In order to be able to finance these maintenance costs, tariff payments need to be increased. But collecting those higher tariffs requires improved accountability and quality of service. The results of the hedonic analysis imply substantial willingness to pay for better water service and better water quality, which may be translated into an ability to charge (and recover) higher water tariffs. Moreover, the results show that policy makers are likely to be more successful in enforcing these higher tariffs in urban areas and in Brackish and Arid Zone districts where alternative sources of water are harder or more costly to find.

5.3 CONTRIBUTIONS AND FUTURE RESEARCH

This research makes a number of contributions to existing literature. First, it analyzes the effect of piped water on the incidence of diarrhea in children in both rural and urban areas. Most of the previous empirical work on the health impacts of public water services in developing countries comes from rural projects, with only limited external validity to cities. In fact, urban and rural water supply and sanitation systems may differ considerably, and the findings in this study show that this is indeed that case for Punjab. This level of analysis is particularly important for Pakistan since a comprehensive health analysis of piped water in urban areas seems to be lacking.

Second, by using household-level variables on bacterial presence in water, this study analyzes possible explanations of the adverse health effects of piped water by relating it to the presence or absence of bacteria in piped water. Such an analysis has not yet been carried out in Pakistan.

Third, by measuring households' willingness to pay (WTP) for piped water in both rural and urban areas of the Punjab, this study measures the response in WTP to public policy changes that improve the quality and service of piped water. Presently there are very few studies on the willingness to pay for piped water in Pakistan, and most are localized to a certain area or small number of cities (Altaf et al. 1993, Akram and Sheila 2010).

There are several directions that future research can take to improve the current research or extend it. Firstly, this study has only briefly looked at the factors determining piped water placement. There are many theories in Punjab relating to the unfair distribution of piped water through political and agricultural clout (Kugelman and Hathaway, 2009). This study was only weakly able to capture these forces due to data limitations. It would be interesting to use a more comprehensive dataset with variables adequately capturing these effects to determine whether they do, in fact, have influence on public policy.

Furthermore, the current study only looked at the health impacts of piped water, also due to data limitations. A more holistic study would include the impact of piped water on time allocation, since an on-premise source of water such as piped water would free up time required to collect water from off-premise sources – a task predominantly carried out by women and children in developing countries. In fact, there are studies that capture both impacts in other developing countries and find that, although piped water may not have a significant positive health effect, it does free up time which would otherwise be used in water collection for other (mainly leisure) activities (Devoto et al., 2012). This may also hold true for Punjab also, since the Asian Development Bank found that its two main projects (PCRWSS and PRWSS) directed towards increasing piped water service in rural Punjab were, although not significant in improving health, successful in freeing up time for other activities. However, to do this properly, time diaries would be needed.[71]

Related to the impacts of piped water, it would also be interesting to explore other possible causes of the negative health effects observed. The results in this study centered on one possible cause: cross-contamination between drinking water and sewage water. However, even after controlling for interactions between water and sewage, the effect of piped water on bacterial contamination was still positive and significant. This implies that a

[71] Consideration was given to using the Government of Pakistan's Time Use Survey (2007) – the first dataset of this sort – for this study. However, it lacked certain key variables to quantify the time allocation effects of piped water service.

significant element of water contamination emanates from its source (from which it is then piped through the system). In fact, according to the United Nations Water Activity Information System (2009), it is estimated that only 1 percent of all wastewater in urban areas of Pakistan is treated in municipal treatment plants, and none in rural areas. Future research can try to quantify the health effects due to this lack of treatment of water, or due to other causes. In this effort, a recent paper by Lechtenfeld et al. (2012) used data on different levels of water handling (at the main source, at the tap, and at point of use) to analyze the source of contamination of piped water in Urban Yemen, and found contamination at all three levels. Studies like these should be extended for other developing countries, such as Pakistan.

Another possible improvement in the study would be to evaluate the willingness to pay for piped water using contingent valuation, or other stated preference methods. Although these methods come with their own host of problems – related to subjective responses – revealed preference methods such as hedonics are reliant on a number of factors that may over or underestimate the true MWTP (Lumbantobing, 2010; Akram and Olmstead, 2010).

Finally, this study has used a cross-sectional dataset to analyze the health effects and willingness to pay for piped water. At the time this study was initiated, only two rounds of the Multiple Indicator Cluster Survey had been carried out in Punjab. Inconsistencies in the data collected between rounds precluded using a panel dataset to assess the health impacts of piped water across time. It would be interesting to see how that effect may have changed through time, and if any improvements have been made through the years by using further rounds of the dataset.

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