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Diarrheal Diseases Due to Unsafe Drinking Water in Pakistan: A Defensive Behaviour Approach

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The urbanisation and the population boom in the last few centuries have resulted in extreme deterioration of the environment and production of excessive externalities. Over time, it has resulted in a dire impact on the health of human beings, ultimately impacting the economic and social prosperity of human beings all around the globe. Water pollution is one such externality which has led to many epidemics in the past. The present study provides an investigation into the health effects due to unsafe drinking water among households in Pakistan. The study utilises cross-sectional data from Pakistan Demographic and Health Survey (PDHS) 2012-13 which is representative at the national and provincial levels. Using household as the unit of analysis with a sample size of 13,409, the paper uses 2SLS model to estimate a dose-response function and a defensive behaviour function to determine the effectiveness of treatment of drinking water on the prevalence of diarrheal diseases among households in Pakistan. Moreover, since defensive behaviour is a choice variable, it has also been checked for endogeneity. The results conform to the reviewed literature and the economic theory that defensive behaviour leads to a lower prevalence of diarrheal diseases among households of Pakistan. This study finds that household exhibiting defensive behaviour, i.e. treating water prior to drinking, are is 31.5 percent less likely to report any cases of diarrheal diseases in the household as opposed to those not employing any such method. Possible recommendations and future research agenda have been provided at the conclusion of the study to assist researchers further the results in this regard. The results of the study could assist in devising policies which could be helpful in developing sustainable societies where clean water is readily available.

JEL Classification: Q53, I15, H51
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1. INTRODUCTION

Being the prime factor for the origination of life, access to safe and clean drinking water is a highly crucial determinant of a healthy human life. However, since the dawn of

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the Industrial Revolution, the global urbanisation coupled with the population boom has resulted in an unprecedented stress on the scarce resources available. One significant consequence of the aforementioned phenomenon is the consistent increase in the environmental externalities owing to anthropogenic activities. According to the World Health Organisation, in terms of deaths per year, 58 percent of the total DALY global burden of disease (842,000 deaths) can be attributed to unsafe drinking water, inadequate sanitation, and poor hygiene. A standard measure of unsafe water provision and inadequate sanitation is the incidence and prevalence of diarrheal diseases. These alone amounts to an estimated 3.6 percent of the total DALY global burden of disease and resulting in mortality estimates of 1.5 million people every year.[1]

Pakistan is a developing country with an average annual income of $1275 and 64 percent of its population lives in rural areas.[2] Taking into account the situation in Pakistan, although about 93.7 percent of the household in Pakistan has access to improved water sources, 30.4 percent of the households still have no access to any kind of improved sanitation [DHS (2012-13)]. According to WHO, the mortality rate owing to diarrheal diseases almost halved between 2000 and 2015, but still resulted in 1.4 million deaths in 2015.[3] Similar ranking was assigned to the distribution of causes of death in children under 5 with 11 percent of the infant mortality being attributed to the cause.[4] Diarrheal diseases remain the leading causes of childhood deaths in Pakistan that are preventable with primary health care measures [NIPS and Macro International (2008)]. Such alarming mortality rate among children warrant attention towards the probable link between the provisions of unsafe drinking water, poor sanitation and the incidence of diarrheal diseases among children, particularly in rural areas. Since the poor health of children is representative of current as well as the future economic burden, the present study investigates whether, and to what extent, the households which employ techniques to treat water prior to drinking are successful in thwarting diarrheal diseases as opposed to those who use unsafe water for drinking purposes.

The first step to formalise the relationship between the concerned variables will be an exhaustive review of the previously published literature on this topic. In light of the aforementioned discussion, the optimal methodology when drafting the literature review in this context is to form interconnected themes, each one elaborating particular aspect of the concerned topic. Here, the first theme will comprehensively develop the deteriorating effects of water pollution on the population of Pakistan through various qualitative and quantitative research previously carried out. The next theme will be a detailed insight into the methodologies that have been previously adopted to substantiate the link between water pollution and the health effects followed by the valuation of these consequences in monetary terms. A critical analysis of the most relevant literature from all the themes will form the crux of the last segment of the literature view along with identification of gaps in the literature and the contribution that this report will make to fill this gap potentially. Following the review of the literature, data will be selected from appropriate sources, a formal relationship will be estimated between the selected variables, and the results will be interpreted in the light of the literature review. Conclusively, policy recommendations will be provided along with potential directions into which further research can be taken.

[1]http://www.who.int/water_sanitation_health/diseases-risks/en/
[2]http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS
[3]http://www.who.int/mediacentre/factsheets/fs310/en/
[4]http://www.who.int/mediacentre/factsheets/fs330/en/

2. LITERATURE REVIEW

Since the wake of Industrial Revolution during the late 18th century, pollution has been present as the negative externality of the mechanical and economic transformation; but it is relatively recently that it has been considered a problem. Although higher economies of scale are the result of modern industrialisation along with the formation of urban centres, these same factors also result in various externalities, the most important of which is environmental degradation. This is due to the simple fact that public, legislative and scientific awareness of the seriousness of air pollution has come only, after many major episodes, in the last decade.

2.1. BOD due to Unsafe Drinking Water—Local Evidence

Water being the crucial factor for the existence of life, access to clean drinking water is the most imperative determinant for a healthy human life. Water pollution has become one of the crucial factors impacting the public health. Pakistan has poor drinking water quality since water sources are contaminated with harmful chemicals and bacteria. The benchmark set by WHO regarding water quality in Pakistan is continuously being violated. This has become a source of concern for both urban and rural areas. Toxic metals, pesticides and improper treatment of sewage waste before dumping in water has been responsible for the contamination of ground and surface water.

Haydar, Arshad, and Aziz (2009) attempted to assess the quality of water in Lahore, supplied by Water and Sanitation Agency (WASA). Water samples were collected before and after monsoon from four different sources in southern Lahore. Four most important physicochemical parameters and two bacteriological parameters were examined and were also analysed with respect to the benchmark provided by World Health Organisation (WHO) regarding clean drinking water. Results revealed that physicochemical parameter of clean drinking water was observed to be satisfactory; however, before the monsoon, 50 to 62.5 percent samples had presence of bacteriological contamination. It was also estimated that contaminated water supply sources are responsible for 40 percent of deaths and 30 percent of the diseases in Pakistan. Diarrhea was found to be majorly responsible for the death of infants. Hence, it can be concluded that water pollution is heavily responsible for poor public health as it contaminates the water sources. This study recommends that chlorination of water is imperative to eradicate the bacteriological contamination.

Ashraf, Maah, Yusoff, and Mehmood (2010) investigated the polluted water irrigation impact on the health of people living in Jamber, Kasur district, Pakistan and also its impact on the environment. Theoretically, it's evident that using polluted water for irrigation will alter groundwater quality and will exhibit negative impact on the health of people and environment. To analyse the water quality, various parameters were examined including physiochemical parameters, cations, anions, heavy metals and sodium absorption ratio. To evaluate the results, they were compared with National Environment Quality Standards (NEQS) and they revealed that increase in conductivity, sodium absorption ratio and total dissolved solids had been observed due to polluted water used for irrigation since they exceed the prescribed limit of NEQS. For further analysis, a survey was conducted by interviewing 3222 inhabitants for 12 months. Results revealed that 2351 inhabitants were impacted by various diseases. The problems affiliated due to polluted water irrigation were mainly skin issues, nail problem, fever and diarrhea. It further indicated that these diseases results due to the usage of polluted water for drinking or irrigation purposes and mainly impacted children with age 1-10. The results obtained in Jamber was quite similar to the analysis done in southern Lahore by Haydar, Arshad, and Aziz (2009) as it also stated that exposure to water pollution leads to disease like diarrhoea which was common among children and infant. Improvement in sanitation facilities and proper drainage system are some possible solutions suggested by the authors to rectify the issue of water contamination.

Similarly, the analysis of water quality provided by Ashraf, Maah, Yusoff, and Mehmood (2010) at a local level was further extended to the whole of Pakistan by Azizullah, Khattak, Richter, and Häder (2011) as they discussed the prevailing condition of poor drinking water quality in Pakistan. They have attempted to analyse the major pollutants, health issues related to these pollutants and their sources. Conclusions drawn were similar to Ashraf (2010) and Haydar (2009), as it also strengthens the claim regarding children being highly impacted by diarrheal diseases due to exposure to water contamination and poor drinking water quality. The data evaluated was extracted from a variety of papers in various journals. The critical evaluation of data validates the mentioned concern and also revealed that immediate measures need to be undertaken. It also discusses the environmental legislation introduced in Pakistan and raises the concern on the commitment of government since these legislations have been ineffective to tackle the issue mainly due to the absence of sincerity at the higher level.

The presence of heavy metal in water channels used for drinking purposes can be extremely hazardous to health, as discussed in the literature. To further strengthen the validation of this claim Muhammad, Shah, and Khan (2011) evaluated the health risk associated with the presence of high heavy metal concentration in the surface and ground water samples from Kohistan region, Pakistan, used for drinking purposes. Graphite fumace atomic absorption spectrometer was used to investigate the heavy metal concentration and compared with standard limits provided by World Health Organisation and Pakistan Environmental Protection Agency (PEPA). Furthermore, health risk was evaluated such as Hazard Quotient (HQ) and Chronic Daily Intake (CDI) using the heavy metal concentration. Results of CDI revealed that the concentration of zinc (Zn) was highest while Cobalt (Co) had the lowest concentration. Moreover, no risk on health was indicated by HQ on the water samples that were evaluated. The concentration of the majority of heavy metals was within given bench mark set by PEPA and WHO. Anthropogenic and geogenic activities were held majorly responsible for the contamination of water in Kohistan, by multivariate statistical analysis for example cluster analysis (CA), principal component analysis (PCA) and one-way ANOVA. The author concluded that water in the examined area does not influence health negatively, but also suggest that since some heavy metal exceed the permissible limits like lead (Pb) in water samples, it is advisable to consume the water after the treatment.

Further Investigation of deterioration of drinking water quality in different urban areas of Pakistan was also done. Farid, Baloch and Ahmed (2012) evaluated the contamination of drinking water in Faisalabad due to rapid boom in urbanisation and industrialisation in past decade. Since the discharge of untreated and excess toxic solid waste from industries into water channels has led to disastrous consequences on health due to deterioration of drinking water quality as hazardous toxic and metal concentration has increased in ground water. Like Ashraf, Maah, Yusoff, and Mehmood (2010), the author used the same technique to evaluate water samples that were collected from hand pumps located within a circle of 10 meters of the sewage source. Parameters evaluated included pH, Total Dissolved Solids, hardness, few anions and cations by using the technique prescribed by American society for testing and materials. Moreover, the presence of some heavy metal ions was analysed using series atomic absorption spectrophotometer. Result validates the hypothesis claim that high contamination of these samples made the water from hand pumps unfit for human consumption. The author also proposed that to curtail the high level of contamination, it is essential to treat industrial waste before dumping it into water bodies and also to install water pumps at least 20 meters away from sewage channels.

Further evaluation was done in the province of Khyber Pakhtunkhwa by Khan, Shahnaz, Jehan, Rehman, Shah, and Din (2013) analysing the drinking water quality and its associated risk on human health in Charasadda district. For this purpose samples of water from tube-wells, hand pumps and dug-wells were collected and investigated for physical characteristics, coliform bacteria, heavy metals and anions similar to the analysis done by Haydar, Arshad, and Aziz (2009) and Ashraf, Maah, Yusoff, and Mehmood (2010). Analysis revealed that concentration of Nitrates and sulfates were exceeding the prescribed limit as set by PEPA and WHO. High concentration of some heavy metals like lead (Pb) and Iron (Fe) were also exceeding the prescribed limit. Moreover, the presence of coliform bacterial contamination was also confirmed. Author extended its investigation by exploring the causes behind water contamination in this district and it was found that improper sewage disposal, over usage of pesticide and fertilisers and poor piping network is responsible for this prevailing situation in this district. To examine the impact on health due to bacterial contamination, the author used questionnaire survey which revealed similar results as of Haydar, Arshad, and Aziz (2009). Bacterial contamination was found to be majorly responsible for diarrhea and other related water-borne diseases. To make the evaluation more constructive, the author also recommended some measures like awareness among women and children and proper treatment of sewage disposal in order to rectify this prevailing issue in that district.

Qadir and Malik (2011) provided evidence that impact on aquatic life due to water pollution can harm public health. Similarly, Waseem, Arshad, Iqbal, Sajjad, Mehmood, and Murtaza (2014) investigated the impact of contamination of water, vegetables and soil impact on public health in Pakistan. Samples of water and vegetables were collected and then they were analysed. Results revealed that metal contamination in vegetables, soil and water have severely impacted drinking water quality, food chain and ecological environment which in turn exposes a great threat to human health. To evaluate the health impact author has used different studies in various parts of Pakistan in order to validate the aforementioned claim.

Similarly, Qureshi (2014) did an overall assessment of water quality in Pakistan like Azizullah, Khattak, Richter, and Häder (2011). He analysed physiochemical parameters, bacteriological parameters, concentration of heavy metals, sodium absorption ratio, total dissolved solids and few other parameters from various water samples and samples of toxic waste from various industries that are eventually dumped into water channels. The evaluation revealed the presence of microbial contamination is present in water in many areas. It further revealed that water quality is deteriorating due to lack of proper attention. High concentration of heavy metals was observed due to the disposal of untreated sewage waste into water bodies. The author also suggests that all major cities should have sewage treatment plants and also laid emphasis on the formulation of national standards for drinking water quality that can help to tackle the prevailing poor water quality condition in Pakistan.

After a thorough review of the existing literature, we were not able to find any study assessing the link between the unsafe drinking water and the prevalence of diarrheal diseases in the country along with the effectiveness of any defensive activity against the diseases. We hope that the present study will prove to be an initiation into a new arena of research that the future researchers will carry forward.

2.2. Valuation of Health Effects due to Unsafe Drinking Water

A seminal study in this context was performed by Alberini, Eskeland, Krupnick, and McGranahan (1996) who estimated the effects of infrastructural and behavioural variables on the prevalence of diarrheal diseases in Jakarta using household defensive expenditure function. Employing a major household survey conducted by the Stockholm Environment Institute in 1991, the authors have attempted to model two simultaneous equations representing the diarrheal illness and the defensive behaviour by the household using bivariate probit regression; however, owing to the fact that almost all the households included in the sample boil their water prior to drinking, the study utilises hand-washing as the proxy for defensive behaviour. The results indicate that interruptions in the water supply act as hindrance to defensive behaviour (handwashing) which results in a higher incidence of diarrheal diseases. Consequently, the presence of a washbasin near the latrine area is strongly associated with defensive behaviour and leads to lower illness. The authors, however, also point out the fact that the incidence of illness in the sample used was really low and hence hypothesis-testing was rather difficult.

Influencing the work of Dasgupta (2004) (from which this study partially draws inspiration from), the author attempted to value health consequences of water pollution in Delhi. Using a health production function framework, the author jointly estimated the dose-response and the defensive behaviour functions to model real-life situations. The WTA measure for the reduction in water quality for the entire population of Delhi has been estimated using cost-of-illness (COI) framework eventually. Dwight, Fernandez, Baker, Semenza and Olsen (2005) also utilised an extensive COI approach to value the GI, ARI, ear and eye ailments resulting from polluted recreational waters in Orange County, California. The resulting costs are considerable which can be utilised along with the public health cost variable introduced in the paper for CBA purposes when devising abatement strategies.

Realising the increasing prominence of non-point source pollution, Baerenklau, Bishop and Stumborg (2001) employed a contingent valuation study to estimate the WTP of Wisconsin residents for improvement in the water quality of Lake Mendota. Using a Tobit estimation technique, the study realised that there will be considerable possible aggregate net benefits in the future if the plan of Improvement in the recreational site in undertaken. However, it also points out the recurring theme in literature that utilising market interest rates for discounting costs and benefits fails to capture all aspects of the intertemporal decision-making process. Estimation of WTP for water pollution abatement in several European remote lakes was also carried out by Mahieu and Giergiczny (2012); however, they employed an interval data model using data collected through payment card method. Ramajo-Hernandez and Saz-Salazar (2012) also conducted a similar CV study for the Guadiana River Basin of Spain and estimated WTP using logit and spike models to account for null WTP.

Barton (2002) and Barton and Mourato (2003) undertook nearly identical studies to assess the reliability of benefit transfer methods to value water quality improvement. Barton (2002) conducted the study at two different sites in Costa Rica, carrying out contingent valuation studies at the two places; while Barton and Mourato (2003) targeted seafronts in Costa Rica and Portugal. The studies do not find any evidence of the benefit function transfer performing better than other benefit transfer methods, as propagated in the literature. Barton (2002) also rejects the claim that transferability of benefit is directly related to the proximity of the two sites, while also encouraging the idea of finding different sites and attempting to control for these differences. Barton and Mourato (2003) have advised against the usage of benefit transfer for policy analysis since it could lead to very unhealthy results.

Loomis, Bell, Cooney and Asmus (2009) adopted a choice experiment method to estimate WTP of parents located in San Luis Valley (Colorado) for safer quality water when faced with the risk of shock, brain damage or death of their children. Using non-parents in the survey, they also incorporated the behaviour of altruism in the model. Their results indicate that the theoretical estimates are highly overvalued in comparison to the real values, indicating hypothetical bias.

Using the distance functions initially developed by Fare, *et al.* (1993), Hernandez-Sancho, Molinos-Senante, and Sala-Garrido (2009) have estimated the shadow prices for undesirable water pollutants which can be utilised to construct a CBA framework in order to prioritise the elimination of some specific undesirable pollutants.

Cheng, Schuster-Wallace, Watt, Newbold, and Mente (2012) conducted an extensive study on 193 nations to quantify the effect of water quality on infant, child and maternal mortality. With particular emphasis on the attainment of the Millennium Development Goals (MDGs) related to infant health, maternal health and environmental sustainability, the authors employed simple linear regression and logit model to find statistically significant decrease in mortality with improvement In water and sanitation in every case.

Mishra (2014) attempted to value the recreational benefits from the Hussain Sagar Lake in Hyderabad (India) by using a blend of CVM (Stated Preference Approach) and Travel Cost Model (Revealed Preference Approach). The author estimated the demand curve for the improvement in the lake quality, followed by the shift in demand curve due to proposed increase in the admission fee. The estimates seem to be very beneficial from implementation viewpoint for increase in government revenue from the lake.

For a meta-analysis and critical survey of the available techniques to determine the total use value of water resources, Birol, Karousakis, and Koundouri (2006) can be referred.

2.3. Critical Analysis and Contribution to Literature

Undoubtedly, there is no dearth of evidence regarding contamination of water bodies all over Pakistan, as evident from Table 1 (for evidence from before 2010, Azizullah, *et al.* (2010) provides an extensive meta-analysis). However, there has not been much work in the context of health effects due to contamination of these water resources. While most of the studies do report correlation between the degradation of water quality samples and the prevalence of water-borne diseases in the target area, correlation does not always imply causation. To contribute towards this gap in the literature, this study uses a revealed preference approach grounded in economic theory to substantiate the relationship between the rampant water pollution in the country and its effect on the health of the most sensitive fraction of the population: children. The study also takes into account the defensive behaviour of the household to assess if it leads to a reduction in the incidence of the illness. As discussed in later sections, the results of this study find significant application in many areas.

Table 1

Post-2009 Literature Regarding Drinking Water-Quality in Pakistan

Authors	Year	Target Area	Results
Hayder, Arshad and Aziz	2009	Southern Lahore	62.5 percent connections had T.C; 50 percent had F.C; possibly due to mixing of sewage.
Memon, Soomro, Akhtar and Memon	2010	Thatta, Badin and Thar; Sindh	Coliform and soluble salts in all water bodies; diarrhea in 60 percent sample population.
Ashraf, Maah, Yusoff and Mehmood	2010	Jamber, Punjab	Parameters exceed NEQS guidelines for both irrigation and drinking purposes.
Muhammad, Shah and Khan	2011	Kohistan; KPK	Cd, Ni, Pb, Zn concentrations higher than prescribed limits.
Qadir and Malik	2011	River Chenab	Higher concentrations of heavy metals in fish rendering it unfit for human diet.
Farid, Baloch and Ahmed	2012	Faisalabad	Ground water unfit for human consumption particularly near sewage channels.
Khan, Shehnaz, Jehan, Rehman, Shah and Din	2012	Charsadda, KPK	Drinking water contaminated with heavy metals and coliform; 47-59 percent people reported diarrhea (most common illness).
Kazi	2014	Karachi and Hyderabad	Heavy metals, arsenic and ecoliforms found in all samples.

3. DATA

The data source primarily used for this study is the 2012-13 Pakistan Demographic and Health Survey (PDHS). The National Institute of Population Studies (NIPS) undertook the responsibility of implementing the 2012-13 PDHS project, and the project was executed by the Pakistan Planning and Development Division (Islamabad). The Pakistan Bureau of Statistics (PBS) provided the sample design and household listings for the sampled areas across the country. The funding for the survey was provided by the United States Introduction Agency for International Development (USAID), while technical and logistical support was provided by ICF International through its measure DHS project.

For the Pakistan Demographic and Health Survey (PDHS) 2012-13, the target sample was the entire population of the nation except for the population residing in Azad Jammu and Kashmir, FATA, and restricted military and protected areas. Taking into consideration the 1998 Population Census, the population of the country has been ramified into urban and rural areas of the four provinces and the GB area. Furthermore, all urban cities and towns have been categorised into mutually exclusive, small areas, known as enumeration blocks which have clear boundaries on the map and comprise of about 200 to 250 households on average. These were further categorised into low-, middle-, and high-income categories. However, owing to the absence of any such ramification in rural areas, lists of villages/mouzas/dehs developed through the 1998 population census were used as the sample frame. Ultimately, the sample was comprised of 14,000 households which were deemed adequate for high precision results by the survey. To select individual households in the second round of the sampling, 28 households were selected by applying a systematic sampling technique with a random start. This resulted in 14,000 households being selected (6,944 in urban areas and 7,056 in rural areas) with a response rate of 96 percent [PDHS (2012-13)].

3. MODEL AND ESTIMATION METHOD

3.1. Theoretical Framework

Most of the formal models used for deriving the value of reduced morbidity use some variant of the health production function first developed by Grossman (1972). Since then, numerous models have been formulated to explore different aspects of the health production function. While Cropper (1981) explored the consequences of introducing pollution variables in the health production function, Harrington and Portney (1987) extended the framework to a model deriving individual choice in terms of willingness-to-pay. The following model of defensive behaviour and illness is based on the treatment by Alberini, *et al.* (1996) which itself was inspired from the work of Harrington, Krupnick, and Spofford (1989).

The individual derives utility from the consumption of a numeraire good Z, normalised with a price of one, leisure L while illness S causes disutility; thus,

$$U = U(Z, L, S)$$
$$\text{with} \quad U_X, U_L > 0;\ U_S < 0$$

Times pent ill S is modeled as a function of the exposure to contaminants C and averting or defensive behaviour to reduce the likelihood of illness which we express as the time T_d the household spends on defensive activities [Alberini, *et al.* (1996)]. Defensive activity reduces the impact of the exposure to the contaminant, thereby affecting the household's well-being. Thus, the health production function can be specified as

$$S = S(C, T_d)$$

with $S_C > 0;\ S_{T_d} < 0$

The household's budget constraint can then be specified as

$$I + w(T - L - T_d - S) = Z + p_d T_d$$

where I is total non-labour income, w is the wage rate, T is total time, p_d is the price of defensive activity.

The first-order conditions for optimising the Lagrangian:

$$\mathfrak{L} = U\big(Z, L, S(C, T_d)\big) + \lambda[I + w(T - L - T_d - S) - Z - p_d T_d]$$

with respect to Z, L, and T_d are easily shown to be:

$$U_Z - \lambda = 0$$
$$U_L - \lambda w = 0$$
$$U_S \frac{\partial S}{\partial T_d} - \lambda(w \frac{\partial S}{\partial T_d} + p_d) = 0$$

The optimal defensive behaviour derived from the first-order conditions:

$$T_d^* = T_d^*(w, I, C, p_d)$$

is therefore a function of the wage rate, w, of non-labor income, I, of the cost of the defensive activity, p_d, and of the threat of contamination, C. On inserting the optimal T_d^* into the dose-response function S, we obtain:

$$S = S(C, T_d^*)$$

The study will attempt to estimate the last two equations, dose-response function and the defensive behaviour function from the available data.

3.2. Econometric Specification of the Model

The model specified in the last section therefore would estimate the health production function and the defensive behaviour function using household-level data to determine how individuals respond to a threat of contamination and illness.

While controlling for other variables that affect health status, the estimation procedure involves the estimation of a relationship between illness and the contamination levels. However, while performing actual estimations of the health production function, we would need to be controlling for various other determinants of health stock, such as physical and socio-economic characteristics of age, gender, wage, and education level. Such a model captures the effect of behaviour on health while allowing for the joint determination of health and behaviour, and is therefore useful for analysing real-world situations. This is due to the fact that it treats health and behaviour as interlinked variables. For both equations the dependent variable will be modelled as a dichotomous observed variable, because of the nature of behaviour (e.g., households either treat or do not treat water) or lack of more accurate information (we have information regarding presence of diarrheal illness but not its duration).

Suppose that individuals exhibit defensive behaviour if the value assumed by a random variable y_1, is greater than zero. Let y_1 be determined by individual/household characteristics (including the wage rate, non-labor income and the cost of defensive behaviour) and the risk factors, both represented by the vector of regressors x_1:

$$y_1 = \beta_1 x_1 + \epsilon$$

Furthermore, suppose that diarrheal disease is present in a household when a second random variable y_2 defined as:

$$y_2 = \beta_2 x_2 + \eta y_1 + \xi$$

takes on a value greater than zero. Here x_2 is also a set of individual and household characteristics and sources of risk for diarrheal disease. The above two simultaneous equations contain two endogenous variables, y_1 and y_2, and hence can be estimated using instrumental variable regression techniques. Instead of converting the equations into the reduced-form and then estimating them, the procedure will use the household characteristics are instruments in the defensive behaviour function and then estimate the health production function. However, the endogeneity of the variables must also be assessed to assure the reliability of the results.

The dependent variable for the health production function is diarrheal illness – it assumes a value of 1 if the household reports at least one case of diarrheal illness, otherwise 0. For the defensive behaviour equation, as the literature suggests [see Alberini (1996)] purification of water has been taken as the variable of interest– it takes a value of 1 when the household reports that it employs measures to purify water prior to drinking the same, otherwise it takes a value of 0. In the survey, sources that are likely to provide water approprite for drinking are identified as improved sources. These include a piped source within the dwelling, yard, or plot; borehole; a protected well; a public tap/standpipe; rainwater; and spring water [WHO and UNICEF Joint Monitoring Program for Water Supply and Sanitation (2010)].

The source of water is taken to be the primary source of water contamination in the household. It takes a value of 1 if it is an improved water source (piped into household, protected well, protected spring, bottled water and filtration plant); otherwise it takes a value of zero (unprotected well, unprotected spring, surface water, tanker truck). Other exogenous variables include household income (categorical variable with five states), education of the head (in years) and the time it takes to get to the water source (in hours).

As evident from the economic framework, the defensive behaviour is an endogenous variable in the construction of the health-production function. As such, a Two-Stage Least Square (2SLS) procedure has been employed to estimate the effect of improved water sources and defensive behaviour on the presence of diarrheal diseases among households in Pakistan. The linear specification implies the fact that the estimates of the model can be interpreted directly as the marginal effects of a unit change in one variable while keeping everything else constant. Although both equations have binary dependent variables, Angrist and Pischke (2008) suggest utilising a linear model while taking into account the fact that LPM only gives an approximation of the marginal effects. Nevertheless, to confirm endogeneity of the defensive behaviour variable, endogeneity test statistics will also be reported. The variables for this study are listed in Table 2.

Table 2

Description of Variables

Diarrheal Disease (Response variable)	
1 if household reports at least one case of diarrhoea; 0 otherwise	
Source of Drinking Water (Contamination Source)	
1 if household uses improved water source; 0 otherwise	
Treatment of Drinking Water (Defensive Behaviour)	
1 if household uses any method to treat water prior to drinking; 0 otherwise	
Control variables	
Household Characteristics	Income category of the household
	Time to get to water source
	Education of household head

3.3. Hypothesis

(i) Treatment of water prior to drinking has no effect on the prevalence of diarrheal diseases among households in Pakistan.

(ii) Household characteristics do not affect prevalence of diarrheal diseases among households in Pakistan.

(iii) Treatment of water prior to drinking (defensive behaviour) is not an endogenous variable in the health-production function.

4. RESULTS AND DISCUSSION

In this section we report the descriptive statistics and regression results of this study, discuss the strengths and weaknesses of those results and recommend future research prospects in this area.

4.1. Descriptive Statistics

Access to safe water and sanitation are basic determinants of better health. Lack of access to safe drinking water and sanitation facilities and poor hygiene are associated with skin diseases, acute respiratory infections (ARIs), and diarrheal diseases. Diarrheal diseases remain the leading causes of childhood deaths in Pakistan that are preventable with primary health care measures [NIPS and Macro International (2008)].

In the 2012-13 PDHS, information on diarrhoea was gathered by asking mothers whether their child had experienced any episode of diarrhoea in the two weeks before the survey. If the child had had diarrhoea, the mother was asked about feeding practices during diarrhoea, types of treatment, and her knowledge and use of ORS.

Table 3

Descriptive Statistics

Background Characteristics	Diarrheal Incidence (%)
Age in Months	
<6	25.8
6-11	35.3
12-23	32.9
24-35	22.0
36-47	16.3
48-59	12.0
Sex	
Male	22.7
Female	22.3
Source of Drinking Water[5] Improved	22.2
Not improved	25.5
Other/missing	35.5
Toilet Facility[6]	
Improved, not shared	21.9
Shared	23.2
Non-improved	23.2
Mother's Education	
No education	22.9
Primary	25.0
Middle	22.6
Secondary	21.1
Higher	16.4
Wealth quintile	
Lowest	22.8
Second	24.3
Middle	23.7
Fourth	23.6
Highest	17.1
Total	22.5

According to the descriptive statistics in Table 2, 23 percent of children under age 5 suffered from diarrhoea in the two weeks preceding the survey. The prevalence of diarrhoea was reported to be 15 percent in 1990-91 and 22 percent in 2006-07. Although diarrhoea prevalence varies seasonally, the three PDHS surveys were conducted in more or less the same period, and thus the diarrhoea episodes reported in the three surveys depict a realistic trend. For children age 6-11 months (35 percent), the prevalence of diarrhea is highest owing to the fact that this is the time during which solid foods are first introduced into the child's daily diet. During this period, children are most exposed to diseases since their immune system is still developing. Prevalence of diarrhoea does not show variations by sex of the child, type of toilet facility, or residence. Diarrheal

[5]Improved drinking water sources include a piped source within the dwelling, yard, or plot; a public tap/standpipe; borehole; a protected well; spring water; and rainwater.

[6]A household is classified as having an improved toilet if it is used only by household members (is not shared with another household) and if it separates waste from human contact.

prevalence is higher among households using a non-improved source of drinking water than among households using an improved source. There are no substantial variations by mother's education and wealth quintile, except that children of mothers who have a higher education (16 percent) and children of mothers in the highest wealth quintile (17 percent) are less likely to suffer from diarrhoea.

4.2. Regression Results

Using instrumental variable techniques, the defensive behaviour function has been estimated in the first step, while the second step estimates the health production function (hence the name Two-Stage Least Squares). The Table 4 gives the estimates of the 2SLS model, separately reporting both the defensive behaviour function and the dose-response function.

Table 4

Instrumental Variable Regression Results

Variables	Coefficients
A. Stage 1: Treatment of water	
Constant	0.013*
	(0.007)
Improved water source[7]	0.045***
	(0.006)
Income category I: Richest[8]	0.176***
	(0.009)
Income category II: Richer	0.029***
	(0.009)
Income category III: Middle	-0.008
	(0.008)
Income category IV: Poorer	-0.022*
	(0.008)
Household head education	0.003***
	(0.0005)
Time required to get to water source	0.029***
	(0.007)
Observations	13,409
F (7, 13401)	189.79
B. Stage 2: Presence of Diarrheal disease	
Constant	0.192***
	(0.006)
Improved water source[9]	-0.016**
	(0.007)
Treated water[10]	-0.315***
	(0.047)
Household head education	0.00018
	(0.0007)
Time required to get to water source	0.0007
	(0.009)
Observations	13,409
Wald Chi2	108.35

Notes: *, ** and *** denote significance at 10 percent, 5 percent and 1 percent. Standard errors in parenthesis.

[7] Reference category: Unimproved water source
[8] Reference category: Poorest.
[9] Reference category: Unimproved water source.
[10] Reference category: Untreated water.

In the first stage, the defensive behaviour (treatment of water by the household) has been regressed on different structural and behavioural characteristics. The first thing that needs our notice is that the signs of the income categories change when we move up the income ladder. The households in the lowest income category are negatively related to the defensive behaviour; however, for higher categories, such households are more likely to respond to risk of contamination. Furthermore, as we move up from the middle category to the richest, the coefficient also increases in size, representing the fact that the more endowed the household is, the more it will reflect defensive behaviour. Except for the middle income category, the rest of the categories ae significant as well. Therefore, while a household which is relatively poorer is about 2.2 percent less likely to treat water prior to drinking, the richest household are about 17.6 percent more likely to express defensive behaviour.

An improved source of water is also positively and significantly related to the defensive behaviour which is also a proxy for the wealth of the household; a wealthier household is more likely to indulge in defensive behaviour, conforming to the economic theory. Hence, households using an improved water source are 4.5 percent more likely to also treat it prior to drinking, and is a significant determinant of the decision to undertake defensive activity. The education of the household head is also significantly related to defensive behaviour implying that the more educated the head is, the more that household will be aware regarding the benefits of treating its water before drinking. Using education of the mother instead of household head's education (not reported) results in a similar coefficient and significance.

Finally, the time taken to get to the water source is also positively and significantly related to the defensive behaviour which could be representative of the fact that households perceive such sources to be contaminated with pollutants and hence are 3 percent more likely to treat it prior to drinking.

In the next step, the household health production function has been estimated where the treatment of water is being treated as an endogenous variable. As indicated by economic theory and the comprehensive literature review, the utilisation of an improved water source of drinking water and the treatment of water before drinking (expression of defensive behaviour) lead to a decrease in the presence of diarrheal diseases in the house. In fact, a household which treats water prior to drinking is 31.5 percent less likely to report any case of diarrheal disease as opposed to those who do not undertake any such activity. Similarly, if the household utilises an improved water source, it is 1.6 percent less likely to report presence of diarrheal diseases.

Finally, to check whether the use of an endogenous variable in the household production function was justified, endogeneity tests results have also been reported. Both, the Durbin test as well as the Wu-Hausman test, result in the rejection of the null hypothesis of the variable being exogenous and hence our choice of endogenous variable is correct, reinforcing the reliability of the 2SLS model.

The household exhibiting defensive behaviour, i.e. treating water prior to drinking, are 31.5 percent less likely to report any cases of diarrheal diseases in the household as opposed to those not employing any such method. The results are comparable to the studies previously done in Jakarta [Alberini (1996)] and India [Dasgupta (2004)]. However, unlike the mentioned studies, the estimation takes into account the endogenous nature of the defensive behaviour as dictated by the economic theory. The confirmation of the endogenous nature of the variable reinforces the reliability of the results while also conforming to the theoretical framework.

4.3. Limitations of the Study

Although this study is the first to be employed in Pakistan to the best of our knowledge, it also exhibits many limitations that the future researchers can improve upon. The first such shortcoming is that the study utilises indirect exposure to contaminants (unimproved water source) instead of the direct contamination source, which drastically reduces the link between the diarrheal disease and the contaminant. However, this can be remedied by epidemiological studies at the site of the data collection. This will result in a better classification of the water sources as opposed to the one already in use. Similarly, the lack of information on the exact wage of the household, price of diarrheal treatment, price of water treatment and the days spent sick result in deviation from the pure form of the household health-production function. One step in this direction is the extension of DHS to inquire regarding the wages of the households and the exact cost of treatment to recover from diarrheal diseases. These values can be combined with the results of the study to provide an estimate of the wages lost and the cost of defensive behaviour by the household, which will give us a lower bound of the cost of diarrheal illness in the household. This cost can be used by policy-makers to value programs being implemented to tackle diarrheal illnesses across Pakistan. Moreover, the availability of time-series data along with cross-sectional will allow us to model the dynamics of the disease and the household behaviour in real time.

Table 5

Diagnostic Tests

Endogeneity Tests	Coefficient	p-value
Durbin score	50.2549	0.000
Wu-Hausman	50.4214	0.000

5. CONCLUSION

This study finds that household exhibiting defensive behaviour, i.e. treating water prior to drinking, are 31.5 percent less likely to report any cases of diarrheal diseases in the household as opposed to those not employing any such method. As discussed before, diarrheal illness has proven to be a significant contributor to the burden of disease among Pakistani population and is a primary reason for infant mortality in the country. Not only does it pose a threat to the health of the children, it also imposes considerable monetary and cognitive burden. The result of the study calls for an immediate state level policy intervention to spread awareness among the public regarding the benefits of water treatment prior to drinking. Moreover, it also serves as a reminder of the responsibility of the state to ensure better health of its citizens by making sure that the basic resources, especially as necessary as drinking water, is safe to consume and implement measures to mitigate the health hazards if it is not the case. Conclusively, further exploration regarding the cost of illness due to unsafe drinking water in the country should allow the government to construct and implement inherently efficient policies and schemes in the future.

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