Coping with unreliable public water supplies: Averting expenditures by households in Kathmandu, Nepal

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[1]   This paper investigates two complementary pieces of data on households' demand for improved water services, coping costs and willingness to pay (WTP), from a survey of 1500 randomly sampled households in Kathmandu, Nepal. We evaluate how coping costs and WTP vary across types of water users and income. We find that households in Kathmandu Valley engage in five main types of coping behaviors: collecting, pumping, treating, storing, and purchasing. These activities impose coping costs on an average household of as much as 3 U.S. dollars per month or about 1% of current incomes, representing hidden but real costs of poor infrastructure service. We find that these coping costs are almost twice as much as the current monthly bills paid to the water utility but are significantly lower than estimates of WTP for improved services. We find that coping costs are statistically correlated with WTP and several household characteristics.

1.   Introduction

[2]   The design of policies for improving municipal water services rests on a clear and conclusive evaluation of social benefits, which in turn depends on information about people's demand for improved piped water services. We draw on data from a survey of 1500 randomly sampled households in Kathmandu, Nepal, to study two complementary pieces of information on households' demand for improved water services: coping costs and willingness to pay (WTP). We provide an estimate of coping expenditures and examine how it is correlated with WTP, income, and type of water user in one of South Asia's poorest countries.

[3]   Chronic shortage of clean water is one of the main complaints of the approximately 1 million people living in Kathmandu Valley (see *Halwai* [2000], *SILT Consultants and Development Research and Training Center* (*SILT-DRTC*) [1999], *Tiwari* [2000], *Nepal Water for Health and Water Aid and Water and Sanitation Program* [2000], and *Whittington et al.* [2002] for additional details). Although about 70% of this population has a private connection to the piped water system, most households only receive water for a few hours a day from the system that suffers from negative pressures and chronic contamination. To combat this water shortage situation, households engage in a variety of coping behaviors, including collecting water from public taps; purchasing it from vendors and neighbors; investing in tube wells, storage tanks, and filtration systems; and boiling water before drinking or cooking. Although hidden, these are real costs of a water supply system that delivers low volumes of poor-quality water on an irregular basis. We use household level data on coping behaviors and the associated expenditures to uncover elements of demand for improved water services.

[4]   Our specific goal is to utilize existing theory to test hypotheses regarding coping costs using a unique survey data set that contains information on both households' coping costs and stated preferences (WTP) for improved piped water services. We begin by presenting a conceptual framework that relies on household production theory and a review of the empirical literature on household coping costs in developing countries. We then describe general features of municipal water supply in our study area, the Kathmandu Valley, and our data collection and sampling procedures. We report our findings that coping costs (1) arise from five behaviors: collecting, pumping, treating, storing, and purchasing; (2) are equivalent to 1% of current incomes; (3) are correlated with but are significantly lower than WTP; and (4) vary across house-

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holds with different socioeconomic profiles. We conclude with a discussion of the policy value of estimating coping costs.

2. Simple Analytics of Coping Costs

[5] Understanding household demand and preferences for improved water supply is complicated by the fact that sufficient, reliable, and potable water is a nonmarket commodity. Nevertheless, we can turn to microeconomic theory, particularly concepts from environmental and development economics, to better understand demand for improved water services by studying household uses of market commodities related to water supply. In the context of Kathmandu, for example, we know that households spend time on collecting water from public sources, storing water, and treating water before consumption. Some households also spend money on bottled water and water from public tanker trucks and private distributing vendors. In addition, they invest in storage tanks, water filters, tube wells, and chemicals, and on replacement items for upkeep and maintenance of these "capital" inputs. Households could avoid all of these coping costs if piped water services are improved (i.e., water is sufficient, reliable, and potable); therefore, coping costs provide a starting point for understanding household demand for improved piped water provided by the municipality. As described by *Pattanayak and Van Houtven* [2004] and *Whittington et al.* [2002], we can also learn about water demand by asking households to consider a scenario under which they could pay for the implementation of a particular management plan or program that would improve their water service. *Whittington et al.* [2002] illustrate how survey responses can be used to estimate this demand (i.e., "WTP") for improved water services in the case of Kathmandu.

[6] The household production function provides the conceptual underpinnings for understanding coping costs (also described in this literature as averting, mitigating and/or defensive expenditures). The household production model is a special case of consumption or utility maximization theory [*Freeman*, 1993; *McConnell and Rosado*, 2000]. Households "produce" utility-yielding services such as health by combining their labor, money, capital, and environmental inputs. Consider the following stylized model that briefly summarizes the household production approach for understanding coping costs. A typical household maximizes utility by allocating its time and income budgets to leisure (T_1), health (S), and a composite consumption good (Z). This utility is conditional on preference parameters (θ) that characterize the shape of the utility curve, usually proxied by socioeconomic data. Health is measured by the number of days household members are sick (in effect, ignoring the reduction in mortality risk that improved water supplies provide). Utility is maximized subject to two constraints. First, the household faces a health production function such that health (H) depends on water supply (W) and the extent of coping activities (C). W is a vector of water quality (i.e., free of biological and chemical contaminants that cause sickness) and quantity (i.e., daily access to a minimum volume of water) elements. W depends on public policies (G) such as the expansion of infrastructure network and hygiene education campaign. If the water supplied by the municipal government is not potable,

reliable, or sufficient, then households engage in wide variety of coping activities (C), spending time (T_2) and money on market commodities (M) related to water to obtain the desired level of health. This utility maximization framework leads us to suggest that water supply service is best viewed as a publicly provided private good that requires households to complement public infrastructure with private coping inputs [*McConnell and Rosado*, 2000; *Rosen and Vincent*, 1999]. These coping goods and services are not, however, perfect substitutes or complements for W in part because households do not typically hold clear property rights to raw water sources. The model can be easily extended to include the nonhealth utility of such water-using activities as some types of washing and gardening (see *Abrahams et al.* [2000] for an example).

[7] Second, the household faces a budget constraint where expenditures on consumption items (Z and T_1) and household production inputs (T_2 and M) are no greater than total income, the sum of exogenous income (N) such as returns on capital, remittances, etc. and earned income (E). Earned income is limited by the total amount of time available to the household (T), which is spent on leisure (T_1), coping (T_2), or being sick (S). All prices are normalized by the price of Z. Without loss of generality, we assume that the time constraint and the health production constraint are binding and therefore use a full income constraint below. The Lagrangian for this problem (ℓ) is presented in equation (1), where μ is a Lagrangian multiplier that represents the marginal utility of income:

$$\ell_{T_1,T_2,Z,M} = \text{Max} U[T_1, Z, S(C\{T_2, M\}, W\{G\}), \theta]$$
$$+ \mu[N + w(T - S - T_1 - T_2) - pM - Z]. \qquad (1)$$

The first-order conditions yield the optimal consumption of S, Z, and T_1 based on the optimal amount of C. In essence, time and money are allocated so that marginal opportunity costs of both are equal to marginal utility of consumption generated by these efforts. Note, the optimal amounts of T_1^*, T_2^*, M^* and Z^* will all depend on the level of W available to each household.

[8] We are interested in how changes in W (from W^* to W'), for example due to a change in government policy (G to G') affect household utility. We can then derive an economic measure of the utility gains (i.e., WTP) and relate it to coping expenditures. We can conduct comparative static analysis for the above model, for example, by taking total derivatives of the first-order conditions of the Lagrangian in equation (1) (*Pattanayak and Kramer* [2001] and *Van Houtven and Pattanayak* [1999] provide examples for rural and urban water supply). This can be expressed more directly in cost terms by appealing to duality theory [*Freeman*, 1993]. In the dual characterization, let e^* be the minimum cost required to attain U^*, the optimum utility that is consistent with household production and consumption choices. Now consider a different kind of cost function (Ω) that represents the minimum exogenous income, N, necessary to achieve utility level U^*, given the health production function, time endowment, preferences, and prices. Ω meets all the conditions of a regular expenditure function [*Strauss*, 1986]. It has been referred to in the environmental economics literature as the variation function

[*McConnell*, 1990] and is typically applied to value changes in environmental resources [*Whitehead*, 1995]:

$$\Omega_{T_1,T_2,M,Z} = \text{Min } w(S + T_1 + T_2) + pM + Z - wT$$
$$+ \lambda\{U^* - U(T_1, Z, S(C[T_2, M], W[G]); \theta)\}. \qquad (2)$$

By applying the envelope theorem, we can take the first derivative of this quasi-expenditure function with respect to W to derive a utility-constant WTP measure as the change in exogenous income that will compensate for a change in W. Recognizing that the optimal amounts of T_1^*, T_2^*, S^*, and M^* all depend on the level of W, WTP can be described as follows:

$$\frac{\partial\Omega}{\partial W} = \left[p\frac{\partial M}{\partial W} + w\frac{\partial T_2}{\partial W}\right] + w\frac{\partial S}{\partial W} - \lambda\frac{\partial U}{\partial S}\frac{\partial S}{\partial W}. \qquad (3)$$

This $\partial\Omega/\partial W$ is the amount of exogenous income, dN, that could be taken away from the household to compensate for the ∂U arising out of ∂W, holding the household at the initial welfare level, U^*. Thus the four terms in equation (3) suggest that WTP for water supply improvements comprises coping costs, cost of illness, opportunity costs of lost work days, and monetary value of pain and suffering. If W enters utility directly or through other nonhealth services, it will introduce other impacts on utility (see *Dickie and Gerking* [1991] for multiple symptoms and *Abrahams et al.* [2000] for nonhealth effects).

[9] In theory, coping costs and WTP are conceptually related to the same underlying preferences for improved water services. Nevertheless, there are important differences between the two concepts, and coping costs can generally be expected to represent a lower bound for WTP for a management plan that would deliver comprehensive improvements in water services (e.g., increased quantities of water, improved water quality, and reliable service). As shown in equation (3), we see that empirical approximations of coping expenditures can be less than theoretically correct measures of WTP for comprehensive improvements in W. The theoretical distinction relates to "income effects" from improved water services, the specific relationship between coping behaviors and water (complements, substitutes), and the pathways through which water affects household utility. Collectively, these create what *McConnell and Rosado* [2000] have described as a "wedge" such that coping costs will underestimate WTP [*Courant and Porter*, 1981; *Bartik*, 1988]. Coping costs will diverge from "true" WTP for improved services if coping behaviors are suboptimal, inefficient, or incomplete for reasons such as information costs, uncertainty, or limited property rights to raw water sources. Practically, even the best available empirical data on coping costs will not fully account for savings in the full range of mitigating and averting costs, monetary costs of illnesses, work days and productivity losses, pain and suffering, and reduced leisure. In addition, our estimates of coping costs will not include intrahousehold effects such as time reallocation among family members or costs to caregivers, or altruistic factors such as benefits to the community or future generations from improving water services. Analysts thus have little theoretical guidance as to the magnitude of the difference between coping costs and WTP for comprehensive water supply improvements, and

have been forced to rely on empirical work to better understand both coping costs and WTP.

[10] Unfortunately, there has been very little empirical research on coping costs in the municipal water supply sector, particularly in developing countries. There are only two previous studies from India [*Choe et al.*, 1996; *Zerah*, 2000]. *Zerah* [2000] found that household water storage in Delhi is correlated with the hours of water supply, household income, residence in a private colony, and house ownership. In a study from Russia, *Larson and Gnedenko* [1999] examined four types of coping behaviors (not coping costs), boiling, settling, filtering, and purchasing bottled water, to reduce or avoid the health risks from tap water. Their logit regressions showed income, perception of water quality, and location of residence to be the primary determinants of these behaviors. *McConnell and Rosado* [2000] found that demand for water boiling in Brazil depends on income, the number of small children, and the respondent's education, gender, and job type. *Wu and Huang* [2001] compared coping costs and WTP in a study from southern Taiwan and found coping costs to be a lower bound of WTP estimates. *Um et al.* [2002] investigated the factors underlying coping costs in Korea and determined that models including perceived water quality (as opposed to objective water quality) provided more reliable and higher estimates of coping costs. In summary, this thin empirical literature on coping costs is both incomplete in its coverage of coping behaviors and insufficient for making conclusive statements regarding the theoretical properties of coping costs. We respond to each of these challenges by using data from a household survey in Kathmandu to describe coping behaviors, to estimate coping costs, and to compare coping costs to WTP estimates presented by *Whittington et al.* [2002].

[11] We have neither attempted to develop new theory of household water demand behavior nor to fill in theoretical gaps in this literature on averting behaviors and coping costs of inadequate water supply. Instead, we have focused on using the existing theory to empirically evaluate three testable hypotheses. First, coping costs should be increasing in unit prices of coping inputs (e.g., wages and price of filters) and in factors that economic theory suggests should increase the demand for water (e.g., income). These are properties of all expenditure functions. Second, coping costs should be a lower bound for WTP for comprehensive service improvements to a water supply system. Third, coping costs should be positively correlated with WTP because both concepts reflect the same underlying preference for improved service.

[12] The theoretical and empirical literatures identify several determinants of coping costs. It is useful to draw parallels between production theory of the firm and of the household, and to view coping cost functions similar to cost functions of the firm that depend on the unit prices of inputs and outputs, conditional on the production technology and household preferences. Recognizing that the commodity in question is a utility-yielding service, we can imagine it will have quantity, reliability, and quality dimensions. Moreover, acknowledging differences among people in terms of different preferences, coping costs will be conditional on taste parameters that capture population heterogeneity. Empirical estimation of coping cost models must, however, contend with finding variables for the notoriously imprecise concepts of technology, tastes, and prices of inputs and outputs.

We find that empirical applications often end up using proxy variables, such as income and wealth, that invariably capture several elements, including technology, tastes, and quantity of consumption. Other examples of proxy variables in the empirical literature include household water sources such as private piped connections, tube wells, public taps, and wells; water-related risks such as perceptions and knowledge; prices of coping goods such as filters, tanks, pumps, chemicals, and time; and household demographics such as number of young children and education as determinants of coping costs [*Smith and Desvousges*, 1986; *Larson and Gnedenko*, 1999; *Wu and Huang*, 2001; *Um et al.*, 2002; *Jalan et al.*, 2003; *Dasgupta*, 2004]. Our own empirical model of coping costs presented below includes several proxy variables for unit prices, household production, technology, and tastes.

3. Description of the Study Site, Fieldwork, and Sample Households

3.1. Water Supply in the Kathmandu Valley

[13] Kathmandu Valley is supplied through seven piped systems fed by 17 springs from surrounding hills and 15 deep tube wells. The National Water Supply Corporation (NWSC) produces about 120 million L per day during wet season and 80 million L per day during dry season. It serves about 70% of the valley population through approximately 100,000 private connections and 1300 public taps. The consumers are primarily households (95%); institutions (2%), commercial enterprises (2%), and industrial firms (1%) compose the remainder. Although about 70% of the connections have meters, only a small percentage is working well.

[14] Unfortunately, the public water supply in Kathmandu is neither sufficient, reliable, nor safe. Most of the city receives water for less than 4 hours per day even in the wet season. A consumer satisfaction survey [*SILT-DRC*, 1999] reveals that about 50% of the NWSC customers felt that the quality of service was "poor," whereas another 15% reported that their connection produced practically "no water." Water shortage is blamed on leaking pipes, stealing from the system, and declining well yields. Of the 35 deep tube wells supplying water to the NWSC system, only 15 are functional and another four need significant maintenance before they can be operated. These shortages are exacerbated by rapid population growth (4% per annum), delays in development and implementation of alternative raw water supplies, below cost tariffs, and poor collection of monthly water bills.

[15] The quantity concerns are compounded by quality issues. Poor-quality and insufficient water impose environmental health risks on the population in the valley. Water is contaminated with high concentrations of nitrogen-ammonia and fecal coliform: approximately 70 to 80% of the tap water samples tested between 1988 and 1992 showed high concentration of fecal coliform during the wet season. *Halwai* [2000], *Tiwari* [2000], *SILT-DRC* [1999], and *Whittington et al.* [2004] present additional details on the poor state of the water supply situation in the Valley.

3.2. Data Collection

[16] The data used in this paper are drawn from a survey of 1500 randomly sampled households in five municipali-

Table 1. Demographic and Socioeconomic Profile of Sample Households

Variable	Mean
Age of household head, years	36.7
Percentage of respondents who are male	62.7
Education of household head, years	8
Percentage of respondents who are married	85.5
Household size (number of people)	8
Monthly household income, US$	229
Monthly imputed property value, US$	261
Percentage of respondents who are homeowners	87.5
Percentage of households that have electricity	98.3
Percentage of households that have phone service	53.9
Percentage of households that have domestic servant(s)	11.5
Percentage of respondents who state that it is possible for their household to borrow US$ 40–70 from a money lender	63.3

ties of Kathmandu Valley, Kathmandu, Lalitpur, Bhaktapur, Kirtipur, and Madhyapur, in 2001. Households were selected using clustered sampling from a previous complete enumeration of all households (*SILT-DRTC* [1999] and population census), with clusters chosen according to probability-proportional-to-size [*Babbie*, 1990]. The survey instrument drew on the World Bank's Living Standard Measurement Survey (LSMS) guidance manual in developing questions related to household water uses [*Whittington*, 2000]. We conducted 17 purposive, open-ended discussions, 2 focus groups, and 150 pretests in designing the survey instrument. Survey respondents were asked about their existing water uses; perceptions of water quality in terms of color, taste, health risk, and reliability; expenditures on piped water; types of coping behaviors; and monetary and labor costs related to the coping activities. Details of the sampling and data collection are presented by *Pattanayak et al.* [2001].

3.3. Profile of Sample Households

[17] Table 1 presents a socioeconomic profile of an average household that responded to our survey. The average household had eight family members, including four children under 18 years of age. Almost 90% of the sample households owned their house, which was a single-family, multistory building that had at least four rooms, one of which was rented out. Ninety-eight percent of the households had electricity and about 54% had telephone service. The average reported household monthly income was about US$ 230 and average monthly expenditure was US$ 151. (The exchange rate used in this study is 72 Nepalese Rupees (Rs) to 1 U.S. dollar (US$).) Most households (63%) believed that it would have been possible to borrow US$ 40 to 70 for a month from a money lender.

[18] We considered five criteria to identify "poor" households in our sample: monthly income, monthly expenditures, housing construction materials, type of cooking fuel, and self-reported socioeconomic status. For the purposes of the analysis, we decided to use household income because it is highly correlated with the other four attributes. A household was classified as poor if it was in the bottom 40% of the income distribution (lowest four deciles), which translates into households with a monthly income of less than or equal to US$ 118. This criterion is consistent with the Nepal Living Standards Survey measure. By this definition, we identified 605 households as poor.

Table 2. Respondents' Perceptions of Water Quality from Available Sources[a]

Source/Quality	Poor Taste	Dirty/Very Dirty	Some/Serious Health Risks	Irregular/Unreliable
Private water connection (PWC)	53	77	82	60
Public taps	42	67	66	35
Public well	28	44	57	11
Neighbors that give water away	36	67	70	50
Private well[b]	40	50	75	7
Vendors/tank	16	33	70	52
Stone spouts	6	16	38	8
Other surface water sources (river/stream/lakes)	26	26	50	28
Rainwater	32	49	68	95
Bottle mineral water	. . .	. . .	9	. . .

[a]In percent.
[b]Private well is a broader category including tube wells and other wells that could be operated by hand/rower/electric pump.

[19] About 33% of the respondents from these poor households had never attended school. Over one-third said that it would not be possible for them to borrow US$ 40 to 70 from a money lender. Kerosene was the most commonly used cooking fuel among poor households (24% cooked with wood and dung). Over 50% of poor households owned a radio and a television (11% had neither).

3.4. Existing Water Uses and Perceptions

[20] The major sources of water for Kathmandu households include private water connections, water from neighbors, private wells, public taps, and public wells. About 70% of our sample is connected to the private water network, 43% of which has a metered connection. Only about 1% of the connected households share a connection with other households. Almost 80% of the nonpoor households were connected to the network, whereas only about 50% of the poor had connections. About 90% of the connected households pay NWSC for water on a monthly basis. The average water bill of a household with a metered connection that was working was about US$ 2.19 per month. The average monthly water bill of a household with an unmetered main connection was US$ 2.45 and branch connection (i.e., a connection to a tertiary to the main water line) was US$ 0.90.

[21] Given the poor reliability of the piped water supply, many households with private connections supplement the water they receive from the piped distribution network with water from other sources. An average household can access at least three sources and uses two of these. We asked connected households what they liked least about their water service. Considering that water was available from their connection on average about 2 hours per day in the wet season and 1 hour per day in the dry season, it is not surprising that 67% said unreliability.

[22] The approximately 30% of households without private connections to the piped distribution system obtained their water from a variety of sources, including private wells, public taps, stone spouts, and water vendors. About 25% of all the households relied exclusively on some combination of free community sources: neighbors, public taps, stone spouts, public wells, ponds, and streams.

[23] We asked households about their perceptions of taste, color, health risk, and reliability of water from the various sources. In general, water from the piped distribution system was rated negatively across the board; households reported that (1) the taste was poor; (2) the water was dirty or very dirty; (3) the water posed some or serious health risk, and (4) the supply was irregular or unreliable. In contrast, water from private wells was rated positively in terms of taste, color, and reliability. Households also seemed to think favorably of water from stone spouts (these dunge dhara constitute an ancient system of stone conduits), although a much smaller group of households (approximately 220) uses this source. Table 2 details the households' assessment of each water source to which they had access. Regarding taste and color, households viewed water from public taps and neighbors to be of poor quality and from public wells to be of reasonable quality. In terms of reliability, households considered water from public taps and public wells to be regular and dependable. All sources were viewed to pose some or serious health risks.

4. Results

[24] We present the results of our analyses in four ways. First, we describe coping behaviors and their associated costs. Second, we analyze the distribution of total coping costs across the income distribution. Third, we compare monthly coping costs to estimates of current monthly water bills and to estimates of WTP based on contingent valuation questions. Fourth, we estimate a multivariate regression model to identify factors that are correlated with coping costs.

4.1. Coping Behaviors and Costs

[25] Our survey reveals five common household coping behaviors: collecting, pumping, treating, storing, and purchasing. These coping behaviors were identified during the development of the survey instrument, and the data were collected using close-ended questions. Collection comprises walking to and from and waiting at a public water source. On average, a water collection trip took 5 to 10 min, with an additional 5 to 15 min of waiting at the source. In total, approximately 1000 households engaged in some water collection outside their home during the month prior to the survey. Given the unreliability and low volumes of tap water service, it is not surprising that 57% of households connected to the piped network engaged in some collection from public sources.

[26] Three hundred and fifty households in our sample have private tube wells and 100 households have hand-dug wells. Rope and buckets were the primary equipment for drawing water from hand-dug wells, whereas electric or

Table 3. Average Monthly Coping Costs by Connection Type and Poverty Classification

Users Category	Overall		Poor		Nonpoor	
	Number of Respondents	US$	Number of Respondents	US$	Number of Respondents	US$
Collection costs	1013	1.58	494	0.96	519	2.35
Connected to PWN[a]	562	1.57	194	0.85	368	1.94
Unconnected to PWN	451	1.60	300	0.99	151	2.81
Pumping and other costs	568	0.49	165	0.36	403	0.54
Connected to PWN	346	0.50	70	0.40	276	0.53
Unconnected to PWN	222	0.46	95	0.33	127	0.57
Treatment costs	949	0.79	243	0.69	706	0.83
Connected to PWN	731	0.78	157	0.71	574	0.79
Unconnected to PWN	218	0.83	86	0.65	132	0.94
Storage costs	770	1.24	149	0.77	621	1.33
Connected to PWN	636	1.22	117	0.69	519	1.33
Unconnected to PWN	134	1.29	32	1.06	102	1.36
Purchase costs	49	17.18	9	3.85	40	20.18
Connected to PWN	27	21.35	3	4.86	24	23.40
Unconnected to PWN	22	12.08	6	3.33	16	15.36
Total coping costs	1500	2.94	605	1.39	895	4.00
Connected to PWN	982	3.03	292	1.38	690	3.72
Unconnected to PWN	518	2.79	313	1.40	205	4.90

[a]PWN, piped water network.

hand pumps were used to raise water from tube wells. A few households had also invested in devices to collect rainwater.

[27] Treatment of water by households typically comprised two activities: boiling and/or filtering. Approximately two-thirds of the households engaged in some form of treatment, with boiling being the most common activity. Households that used filters typically replace the candles (i.e., the ceramic filter elements) after 5 years. Only 11 households in our sample treated their drinking water using chemicals, such as chlorine, alum (i.e., aluminum sulfate), and potash (i.e., aluminum potassium sulfate).

[28] We also asked households about home storage in terms of the types and numbers of storage devices, their capacity and costs, and alternative storage sources. Overhead tanks were the main form of home storage. Seven hundred and seventy households owned at least one storage tank, with an average capacity of 1100 L.

[29] Finally, households have some options for purchasing water from vendors and neighbors. About 30 households also purchased bottled water, typically 1 L bottles. Public and private vendors deliver water by tanker truck, and about 7 households bought water from such vendors, typically in the outlying areas of Kathmandu Valley.

[30] Some of these coping costs are capital expenditures (e.g., overhead storage tanks, tube wells, rainwater collection devices, and filters for treating water). Households estimated the typical lifespan of each type of equipment that they own; these estimates were corroborated by expert opinions and background documents. The median lifespan of each type of equipment and an estimated annual (real) interest rate of 15% were used to amortize the associated coping expenditure into monthly costs. In general, most parameters used in the calculations below (e.g., lifespan estimates) are based on average statistics from our sample or from other studies in Nepal (when none was available from our survey) or our field notes (based on our discussions with key informants or experts).

4.1.1. Collection Costs

[31] Household members spend time walking to and waiting at the water source. We converted the time costs

of water collection into monetary terms by multiplying the time spent by a proportion of the hourly wage of an individual in the household. For this study, we considered 50% of the average hourly wage rate (mean hourly wage rate was US$ 0.28). The 50% estimate is similar to fractions used in estimating time costs in travel mode choice and recreation demand models (see *Whittington et al.* [1990] for a related example regarding household water source choice). For households with domestic servants (less than 10% of our sample), we used the bottom 5% wage rate in the neighborhood to estimate the time cost of water collection instead of the average household wage rate. Of 1500 sample households, 1013 incurred water collection costs. Most of them (68%) collected water from public wells and their neighbors. As presented in Table 3, mean monthly costs of time spent collecting water for different groups of households range from US$ 0.85 to US$ 2.81 per month. Not surprisingly, the time collection costs are much higher for unconnected households than for connected households.

4.1.2. Pumping and Drawing Costs

[32] A summary of costs associated with drawing, pumping, and other forms of water collection is presented in Table 3. Households that used different types of wells were asked about the current costs of putting in a new well and pumping water from it. The costs differed across types of wells and the pumping and drawing equipment used. These capital costs were amortized into monthly costs based on a 15 year lifespan of wells. Given the declining groundwater table, this assumption is optimistic. For households that invested in rainwater collection, the cost of equipment was amortized over a 30 year period.

4.1.3. Treatment Costs

[33] Home water treatment mainly involves boiling and filtering, possibly with sophisticated devices such as Euroguard, a type of water softener and purifier used in South Asia [*Tiwari*, 2000]. For households that used filters, we converted the cost of filters over the lifetime of the filters into monthly costs. The average monthly cost of filtration is US$ 0.60. The survey only gave us information on whether the household boiled their water, not their expenditures on
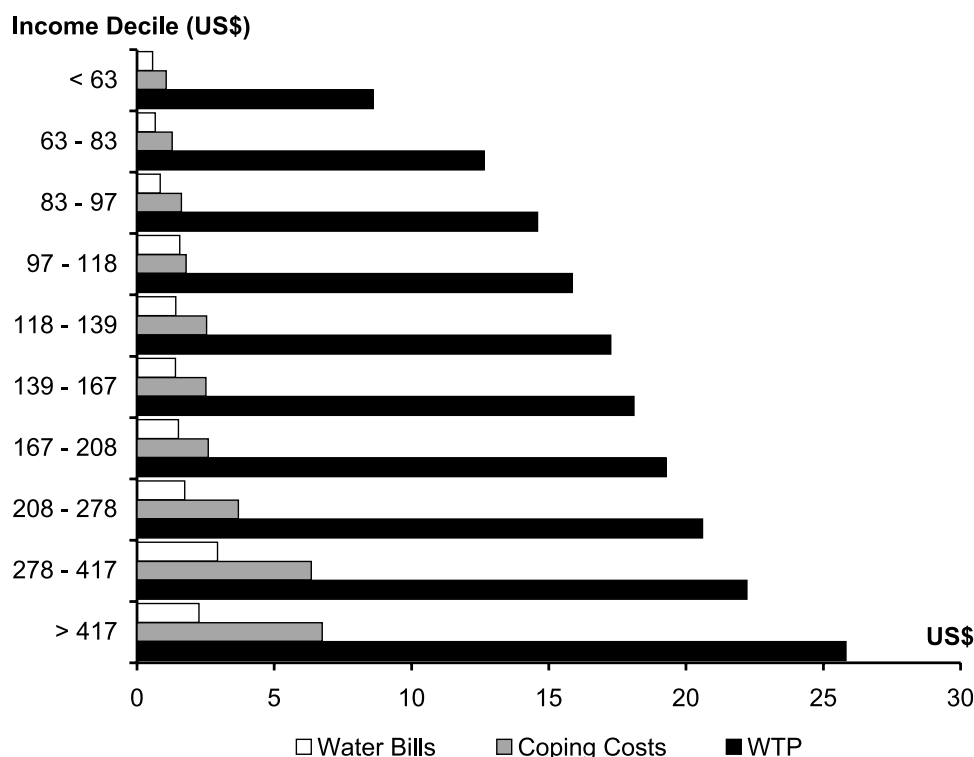
Figure 1. Household level mean monthly coping costs, water bill, and WTP by income decile.

boiling water. *Tiwari* [2000], however, provides an estimate of the average costs of boiling. We inflate his estimate of Rs 95 (which is about US$ 1.32) in 1998 dollars per household per month to Rs 112 (US$ 1.56) in 2001 dollars (Asian Development Bank, unpublished data, 2003) (see http://www.adb.org/Documents/CERs/NEP/2001/nep_cer103.asp), to impute the boiling costs for those who boil their water before drinking. On average, households that boiled and/or filtered their water before drinking spent about US$ 0.80 per month on these activities. Additional details on in-home treatment costs are reported in Table 3.

4.1.4. Storage Costs

[34] Of 1500 households, 770 incurred storage costs that can be expressed as the implicit rental value of their storage tanks. Again we amortize the reported values over 30 years. These costs are presented in Table 3. On average, nonpoor households spent US$ 1.33 on water storage per month, while the poor spent about US$ 0.80.

4.1.5. Purchase Costs

[35] Out of 1500 sample households, only 49 purchased water from their neighbors or vendors, or bought bottled water on a weekly basis. Most of them (82%) were nonpoor households. On average, these 40 nonpoor households spent about US$ 20 per month on water purchases, and the nine poor households spent about US$ 4.

4.2. Distribution of Total Coping Costs Across the Income Distribution

[36] Table 3 also summarizes the monthly coping costs for connected and unconnected households and by poverty status, including all five coping behaviors: collecting, pumping, treating, storing, and purchasing. Figure 1 presents a distribution of these coping costs across income deciles and offers two insights. First, households in

Kathmandu Valley incurred significant coping costs across all income groups because of serious water shortage and quality problems. Second, these costs are higher in absolute terms for the top quintile of the income distribution than for poorer households. In terms of average coping costs, we find a typical poor household incurred coping costs of approximately US$ 1.40 per month, while households in the top 20% of the income distribution incurred coping costs approximately four times higher. Nonpoor households tend to incur higher coping costs because they have and do use more resources in home water treatment and storage and their opportunity cost of time is higher than that of poor households. Among households that use public taps, however, poor households have higher coping costs than nonpoor households. Overall, the mean monthly coping cost of poor and nonpoor households is about US$ 3.

[37] About 45% of the coping costs can be attributed to the value of time spent collecting water, whereas only 10% results from pumping and 2% from purchasing water. Figure 2 shows how the composition of these costs changes across the income groups. Time collection costs are the biggest element of coping for the poorest households. However, storage and purchase of water make up larger percentages in the upper income groups. Table 3 reveals that income is not the sole determinant of coping costs; connection status matters for the relative importance of the components of coping costs. The connected households spent approximately equal amounts on collecting, treating, and storing water, with a similar pattern holding for poor as well as nonpoor households.

[38] In contrast, 65% of the coping costs for unconnected households can be attributed to the time spent collecting water from various sources. It is possible that the nonpoor
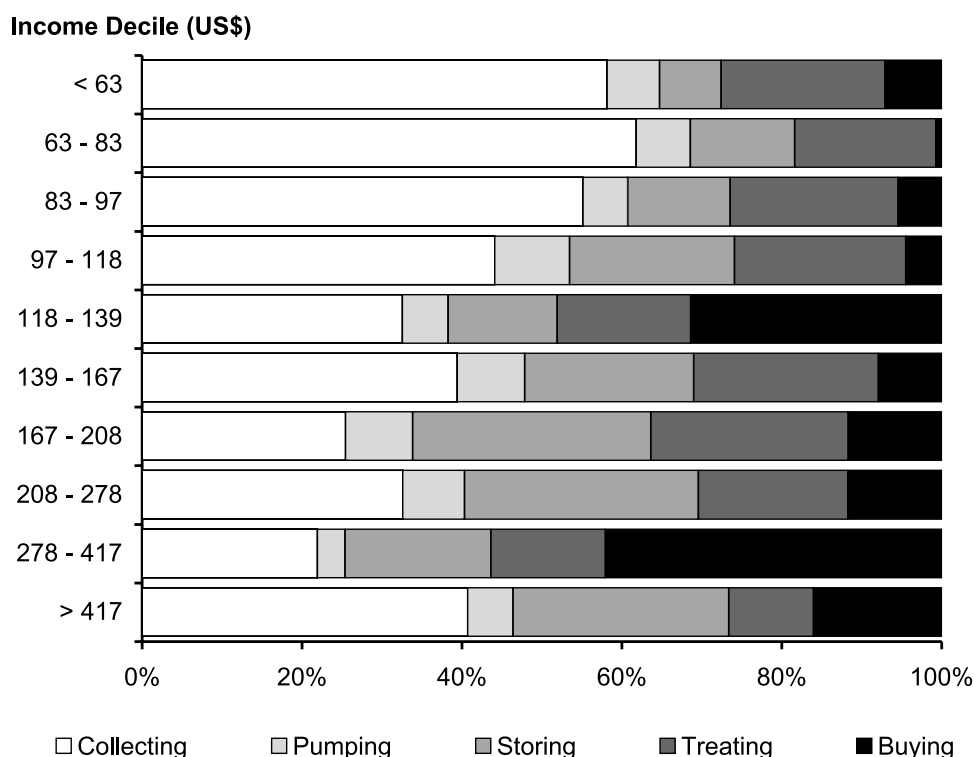
Figure 2. Composition of aggregate coping costs by income decile.

cope more both because they consume more water. It is certainly the case that among households that are currently connected to the network, the nonpoor consume more water than the poor [*Pattanayak and Yang*, 2002]. However, the difference in consumption is not statistically different between nonpoor and poor households who are not connected to the piped water network.

4.3. Comparisons With Water Utility Bills and WTP

[39] We compared our estimates of coping costs to current bills paid to the water utility and WTP estimates. Households paid more per month on coping behaviors than in bills to the water utility. Figure 1 illustrates that this result holds for each decile in the income distribution. Additionally, coping costs and monthly water bills are positively correlated across the distribution (see Table 4).

[40] As part of this study, contingent valuation (CV) questions were administered to both households connected to the piped network and to unconnected households. Both

types of households were asked to consider a plan under which a private sector operator would provide about 500 L of clean and safe water, 24 hours a day, with regular and fair billing based on metered use. As described in the CV survey, the service improvement proposed to respondents would effectively reduce or eliminate the need for all the existing coping behaviors: collection, storage, pumping, treatment, and purchase. Information on household WTP for the service improvements was obtained, using a referendum format CV questionnaire in which eight different monthly bills were randomly assigned to different groups of respondents. We estimated the mean WTP to be US$ 19.50 and US$ 12.82 for the connected and unconnected households, respectively. We found that WTP has the expected correlation with income, perceived seriousness of water contamination, extent of coping activities, and household demographics. Additional details on the study, the CV questions and the findings are presented by *Whittington et al.* [2002].

Table 4. Correlating Monthly Coping Costs to Willingness to Pay (WTP) and Water Bills by Private Connection to Water Network and Poverty Status

Users Category	Coping Costs and WTP		Coping Costs and Water Bills	
	Mean WTP, US$	Correlation Coefficient	Mean Bills, US$	Correlation Coefficient
Private connection to water network (n = 973)	19.50	0.26[a]	2.21	0.05[a]
Poor (n = 287)	15.78	0.10[b]	1.75	0.05
Nonpoor (n = 686)	21.06	0.21[a]	2.40	0.04
Unconnected to water network (n = 457)	12.82	0.41[a]	. . .	. . .
Poor (n = 271)	9.15	0.19[a]	. . .	. . .
Nonpoor (n = 186)	18.15	0.38[a]	. . .	. . .
Total (n = 1430)	17.36	0.26[a]	2.21	0.05[a]

[a]Significant at <1% level.
[b]Significant at 10% level.

Table 5. Robust and Clustered Regression Model of Coping Costs: Household Determinants[a]

Dependent Variables	Overall		Poor		Nonpoor	
	Coeff.	p-Value	Coeff.	p-Value	Coeff.	p-Value
Property value	0.003	0.000	0.001	0.111	0.003	0.002
Hourly wage rate	1.6	0.146	6.2	0.000	1.4	0.167
Household has private water connection (1, yes; 0, no)	−1.3	0.002	−0.5	0.017	−2.5	0.000
Number of water sources used	2.0	0.000	0.9	0.001	2.5	0.000
Household uses community sources only (1, yes; 0, no)	0.4	0.302	0.4	0.317	−0.9	0.252
Household believes that water contamination is the most serious environmental problem (1, yes; 0, no)	0.4	0.165	0.04	0.741	0.8	0.098
Respondent's education	0.1	0.000	0.05	0.005	0.1	0.034
Respondent's age	0.02	0.224	−0.002	0.728	0.02	0.232
Regression constant	−3.4	0.002	−1.3	0.074	−2.8	0.049
Number of observations		1500		605		895
F-statistics	11.8	0.000	4.02	0.001	9.49	0.000
R^2		0.146		0.226		0.134

[a]We apply robust regression methods (i.e., down-weighting outliers) and account for heteroskedasticity (i.e., cluster-specific variance) and error correlation within clusters (though independent across clusters). This process affects the standard errors of the estimated coefficients but not the coefficients per se.

[41] As shown in Table 4, the mean WTP for the entire sample at US$ 17.36 is clearly much greater than the mean coping costs of US$ 2.94. In section 2, we identify three factors that could be the source of divergence between true WTP and our estimates of coping expenditures: lost wage income, cost of illness, and pain and suffering. Although we did not collect survey data on lost wage income, cost of illness, and pain and suffering, we can consider secondary sources such as another survey in Kathmandu [*Tiwari*, 2000] to further investigate this issue. *Tiwari* [2000] claims that water shortage and contamination impose as much as Rs 500 (US$ 6.95) per month in terms of cost-of-illness and wage losses.

[42] Of course, the mean WTP estimates from the CV survey data are not necessary the "true" WTP; they may be overestimates due to the hypothetical nature of the CV questions. Compared to conventional nonmarket valuation, however, households are familiar with the context and elements of water supply services, and the survey was implemented with care (both instrument development and enumerator training and administration). Thus we expect this hypothetical bias to be small, a claim that is supported by the analysis of the WTP data reported by *Whittington et al.* [2002].

[43] Figure 1 shows that WTP estimates are greater than coping costs across the entire income distribution. However, although WTP is substantially larger than coping costs for nonpoor households, it is only slightly larger than coping costs for unconnected households in general, and the poor subgroup of connected households in particular. Given the lower income levels of unconnected households, this result is consistent with the discussion above that suggests differences between WTP and best available estimates of coping costs would increase with income. That is, several of the omitted benefits of improved water supply (see equation (3)) increase with income and therefore we would expect the divergence to increase with income.

[44] In addition to supporting one of our theoretical hypotheses (i.e., coping costs are a lower bound to WTP), Table 4 also shows that coping costs are positively correlated with WTP for the overall population. This positive correlation holds for different users and socioeconomic groups as well. The empirical literature to date has been inconclusive regarding this relationship (see *Laughland et al.* [1996] for example), a surprising finding given that both coping costs and WTP reflect a common underlying preference for improved water supply services. Thus our finding of a positive and statistically significant correlation between WTP and coping costs further validates each measure of demand for improved water services.

4.4. Multivariate Regression Model of Covariates With Coping Costs

[45] In this section we use multivariate regression analysis to test joint hypotheses regarding factors that are correlated with coping costs. We expect coping costs to be a function of the prices of inputs used in this production, production technology, and taste measures. Given the challenges in identifying variables that measure these imprecise concepts, we employed several proxy variables to model coping costs. First, except for hourly wage rates, unit prices for coping inputs do not vary substantially across the sample area and cannot be included in the regression model. Second, we expect proxy variables (e.g., income) to capture more than one effect; therefore, we restrict ourselves to reasonably simple specifications. Specifically, wage rates can reflect opportunity costs of coping (a supply side factor) and preference for improved water supply (a demand side factor). To distinguish this effect, we include a separate proxy for wealth: the monthly total value of housing stock (land plus structure).

[46] Given that our data were collected through clustered sampling, we apply robust regression methods and account for heteroskedasticity (i.e., cluster-specific variance) and error correlation within clusters (though independent across clusters). This process affects the standard errors of the estimated coefficients but not the coefficients per se. For all models, we estimate an aggregate model and separate models for the poor and nonpoor groups to explore heterogeneity in our sample. Overall model statistics such as sample size, predictive power, and statistical significance are presented at the bottom of each table. As shown in Table 5, the models generate parameters that are jointly statistically significant and credible. The overall explanatory power is reasonable (R^2 of 0.14–0.23) for such cross-sectional data sets.

[47] We find that wealthier households have higher coping costs in both the poor and nonpoor subsamples of households. That is, even in the subsample of poor households, wealth seems to change the household's ability to cope. This confirms the intuition that relatively rich households have more resources and therefore invest more in water treatment, storage, and purchases. We also find that hourly wage rates are positively correlated with coping costs. This reflects both the fact that time is the primary input into coping and that higher wages reflect higher opportunity costs of time. Households that are connected to the network have lower coping costs, presumably because they have a lower need to cope, controlling for wealth effects and opportunity costs. This result reflects a quantity effect (i.e., costs are increasing in quantity of water "produced" through coping activities, as discussed in the conceptual model). We also find that households who perceive drinking water contamination to be the most serious environmental problem in the city were more likely to engage in coping activities, reflecting the quality effect discussed in our conceptual section and suggested in the empirical literature. This perception variable is not, however, statistically significant for poor households.

[48] When we introduce additional household characteristics into the regression model, we find that more educated households have higher coping costs, possibly because more educated respondents are better informed about the health benefits of clean and plentiful water and therefore are more likely to engage in coping behaviors. It might also reflect the implicit correlation between education and wages, and therefore higher opportunity costs, or some form of preference heterogeneity. This could explain why the wage variable is significantly only at the 15% level. We also include other variables to capture demand for improved water services (i.e., the need for more coping) and, therefore, the quantity effect. Our regression suggests that coping costs are higher for households that rely exclusively on community sources such as public taps, stone spouts, public wells, surface water, and neighbors. Coping costs are also higher for households that use water for more activities, including drinking, cooking, bathing, washing, and others. For the most part, these results hold for the overall sample and for the poor and nonpoor subsamples.

5. Conclusions

[49] Our primary goal was to study empirically the coping expenditures related to irregular, unsafe, and insufficient water supply in Kathmandu, Nepal. We estimate the constituents and magnitudes of households' coping costs and evaluate their correlation with household characteristics and WTP for water service improvements. To our knowledge, this is only the second study to combine all of these data for a single study area and to do so in a developing country setting (see *Wu and Huang* [2001] for an example from Taiwan). We find that households in Kathmandu Valley engage in five types of coping behaviors: collecting, pumping, treating, storing, and purchasing. These activities impose coping costs on an average household of as much as US\$ 2.94 per month or about 1% of monthly income and represent some of the hidden but real costs of insufficient public infrastructure. The majority of these costs are attributed to time spent collecting water. While collection costs constitute about 34% of total coping costs for nonpoor households, they constitute approximately 56% of the total for poor households. There is, of course, heterogeneity across households in the sample. Households that are not connected to the water supply network, that rely exclusively on community sources, whose members earn higher wages, and that have greater wealth have higher coping costs.

[50] In general, the distribution of coping costs across income groups and types of users confirms our priors regarding the determinants of coping costs. Comparison with monthly utility bills shows that connected households incur significant costs in addition to the more obvious payments to the water utility. Comparison with WTP estimates using the same data shows that coping costs would substantially underestimate WTP. This result is consistent with the conventional wisdom regarding the lower bound property of coping costs. Unlike previous studies, we find that coping costs are statistically correlated with monthly water bills, WTP, and many of the household characteristics that are correlated with WTP. This consistency across three different data is an encouraging outcome for research on the accuracy and reliability of nonmarket valuation techniques. It validates the credibility of our empirical study because water bills, coping costs, and WTP all reflect a common underlying preference for potable, reliable, and sufficient water supply.

[51] If coping costs are a lower bound for WTP, as suggested by theory and data, what is the policy value of estimating coping costs because these costs cannot be used as a comprehensive measure of the benefits of improved water services? Such lower bound estimates are valuable for two reasons (see *Abrahams et al.* [2000], *Alberini and Krupnick* [2000], and *Abdalla et al.* [1992] for additional discussion). First, the simultaneous estimation and comparison of coping cost and WTP allows us to contribute to developing a calibration factor that can serve as a rule of thumb for estimating comprehensive benefits based on an estimate of coping costs alone. Clearly, repeated tests and evaluation will be necessary before such factors are readily adapted for evaluating specific policies. Calibrations of this type are routine and commonplace in the real world of policy analysis, so applied researchers need to improve the data used in this process.

[52] Second, lower bound estimates of nonmarket benefits, such as those produced by coping cost studies, can serve as a screening tool and minimum threshold for cost-benefit analysis. If the coping costs exceed the supply cost of expanding water the network, we know that the improvement policy passes a cost-benefit test. On other hand, if coping costs are less than the supply cost of investments, it is clear that additional analysis will be needed to determine the extent of the other benefits of water service improvements.

References

Abdalla, C. W., B. R. Roach, and D. J. Epp (1992), Valuing environmental quality changes using averting expenditures: An application to ground-water contamination, *Land Econ.*, 68, 163–169.

Abrahams, N. A., B. Hubbell, and J. Jordan (2000), Joint production and averting expenditure methods for willingness to pay: Do water expenditures really measure avoidance costs?, *Am. J. Agric. Econ.*, 82, 427–437.

Alberini, A., and A. Krupnick (2000), Cost-of-illness and willingness to pay estimates of benefits of improving air quality: Evidence from Taiwan, *Land Econ.*, 76, 37–53.

Babbie, E. (1990), *Survey Research Methods*, Wadsworth, Stamford, Conn.

Bartik, T. J. (1988), Evaluating the benefits of non-marginal reductions in pollution using information on defensive expenditures, *J. Environ. Econ. Manage.*, 15, 111–127.

Choe, K., R. C. G. Varley, and H. U. Bijlani (1996), Coping with inter-mittent water supply: Problems and prospects, report, Res. Triangle Inst., Research Triangle Park, N. C.

Courant, P. N., and R. C. Porter (1981), Averting expenditure and the cost of pollution, *J. Environ. Econ. Manage.*, 8, 321–329.

Dasgupta, P. (2004), Valuing health damages from water pollution in urban Delhi, India: A health production function approach, *Environ. Dev. Econ.*, 9, 83–106.

Dickie, M., and S. Gerking (1991), Valuing reduced morbidity: A house-hold production approach, *S. Econ. J.*, 57, 690–702.

Freeman, A. M. (1993), *The Measurement of Environmental and Resource Values: Theory and Methods*, Resour. for the Future, Washington, D. C.

Halwai, N. (2000), *Demand, Supply and Tariff: Kathmandu Valley Urban Water Supply System*, MEH Consultants, Kathmandu.

Jalan, J., E. Somanathan, and S. Chaudhuri (2003), Awareness and demand for environmental quality: Drinking water in urban India, *Discuss. Pap. 03-05*, Ind. Stat. Inst., New Delhi.

Larson, B. A., and E. D. Gnedenko (1999), Avoiding health risks from drinking water in Moscow: An empirical analysis, *Environ. Dev. Econ.*, 4, 565–581.

Laughland, A., W. Musser, J. Shortle, and L. Musser (1996), Construct validity of averting cost measures of environmental benefits, *Land Econ.*, 72, 100–112.

McConnell, K. (1990), Models for referendum data: The structure of dis-crete choice models for contingent valuation, *J. Environ. Econ. Manage.*, 18, 19–34.

McConnell, K. E., and M. A. Rosado (2000), Valuing discrete improve-ments in drinking water quality through revealed preferences, *Water Resour. Res.*, 36, 1575–1582.

Nepal Water for Health and Water Aid and Water and Sanitation Program (2000), The water supply and sanitation situation of the urban poor in the Kathmandu Valley: Results of a research study, New Delhi.

Pattanayak, S. K., and R. Kramer (2001), Worth of watersheds: A producer surplus approach for valuing drought control in eastern Indonesia, *Environ. Dev. Econ.*, 6, 123–145.

Pattanayak, S. K., and G. Van Houtven (2004), Measuring benefits of the Safe Drinking Water Act: A framework for combining contingent valua-tion and averting expenditure data, working paper, RTI Int., Research Triangle Park, N. C.

Pattanayak, S. K., and J.-C. Yang (2002), Distributional incidence of water tariffs and subsidies in Kathmandu, Nepal, report, Res. Triangle Inst., Research Triangle Park, N. C.

Pattanayak, S. K., J.-C. Yang, D. Whittington, B. Kumar, G. Subedi, Y. Gurung, K. Adhikari, D. Shakya, L. Kunwar, and B. Mahabuhang (2001), Willingness to pay for improved water services in Kathmandu Valley, Res. Triangle Inst., Research Triangle Park, N. C.

Rosen, S., and J. Vincent (1999), Household water resources and rural productivity in sub-Saharan Africa: A review of the evidence, *Dev. Discuss. Pap. 673*, Harvard Inst. of Int. Dev., Cambridge, Mass.

SILT Consultants and Development Research and Training Center (SILT-DRC) (1999), Consumer survey for project on urban water supply and sanitation rehabilitation, report, Kathmandu.

Smith, V. K., and W. H. Desvousges (1986), Averting behavior: Does it exist?, *Econ. Lett.*, 20, 291–296.

Strauss, J. (1986), The theory and comparative statics of agricultural household models: A general approach, in *Agricultural Household Models: Extensions, Applications and Policy*, edited by I. Singh, L. Squire, and J. Strauss, pp. 71–91, Johns Hopkins Univ. Press, Baltimore, Md.

Tiwari, D. (2000), Users' willingness to pay for averting environmental health risks and implications for alternative policy measures for improv-ing water supply facilities in Kathmandu Valley, final report, Dept. of Water Supply and Sewerage, Kathmandu.

Um, M.-J., S.-J. Kwak, and T.-Y. Kim (2002), Estimating willingness to pay for improved drinking water quality using averting behavior method with perception measure, *Environ. Resour. Econ.*, 21, 287–302.

Van Houtven, G., and S. K. Pattanayak (1999), Averting behaviors and willingness to pay for safer drinking water, report, Res. Triangle Inst., Research Triangle Park, N. C.

Whitehead, J. (1995), Willingness to pay for quality improvements: Com-parative statics and interpretation of contingent valuation results, *Land Econ.*, 71, 207–215.

Whittington, D. (2000), Environmental issues, in *Designing Household Survey Questionnaires for Developing Countries: Lessons from 15 Years of the Living Standards Measurement Study*, vol. 2, edited by M. Grosh and P. Glewwe, pp. 5–30, World Bank, Washington, D. C.

Whittington, D., X. Mu, and R. Roche (1990), Calculating the value of time spent collecting water: Some estimates for Ukunda, Kenya, *World Dev.*, 18, 269–280.

Whittington, D., S. K. Pattanayak, J.-C. Yang, and B. Kumar (2002), Household demand for improved piped water services in Kathmandu, Nepal, *Water Policy*, 4, 531–556.

Whittington, D., D. T. Lauria, V. Prabhu, and J. Cook (2004), An economic reappraisal of the Melamchi water supply project—Kathmandu, Nepal, *Port. J. Econ.*, 3, 157–178.

Wu, P., and C. Huang (2001), Actual averting expenditure versus stated willingness to pay, *Appl. Econ.*, 33, 277–283.

Zerah, M. H. (2000), Household strategies for coping with unreliable water supplies: The case of Delhi, *Habitat Int.*, 24, 295–307.

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