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Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination

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ABSTRACT

Public decision-makers require information on the benefits and costs of policies for groundwater quality protection. The averting expenditures method for valuing environmental improvements is examined and used to approximate the economic costs of groundwater degradation to households in a southeastern Pennsylvania community. Regression results indicate that averting expenditures vary with households' knowledge of contamination, perceptions of a contaminant's health risk and presence of young children in the household. The estimates obtained through averting expenditures analysis have a sound basis in theory and are of sufficient empirical magnitude that they merit consideration in federal, state and local groundwater policy decisions.

Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination

I. INTRODUCTION

Groundwater quality management has become an important public policy issue. Groundwater provides drinking water for 53% of the U.S. population and 97% of the rural population (Solley et al., 1988). Recent studies have found that groundwater has been degraded by point or nonpoint sources related to at least 33 different generic classes of human activities (U.S. Congress, Office of Technology Assessment, 1984). The extent and severity of groundwater degradation is not currently well documented. However, available evidence suggests nitrate and synthetic organic chemical contamination is widespread in many areas and that shallow aquifers are likely to be at greatest risk (Moody, 1990). Growing public concerns over possible human health effects from drinking contaminated water and other impacts associated with groundwater quality degradation have led to pressures on policy-makers to protect groundwater. For example, 33 states enacted some form of groundwater protection legislation between 1985 and 1990 (U.S. Environmental Protection Agency, 1990).

Despite the level of concern and legislative activity relating to groundwater contamination, little is known about the economic benefits of groundwater protection. The emphasis in previous research on the costs and benefits of groundwater protection has been on the costs of policies to remedy degraded groundwater. For instance, Raucher (1986) estimated containment costs at three hazardous waste facilities in the U.S. and compared expenditures at each facility in terms of cancer cases avoided. Also, Sarnat et al. (1987) calculated costs of four options for residential wells contaminated with pesticides in Massachusetts. These costs were compared to an estimate of the benefits of avoided health risks calculated using a median value of a statistical life obtained from the literature.

Groundwater protection policies yield a range of possible benefits. These include avoided losses from actual human health effects, such as increased mortality or morbidity from exposure to contaminants, increased fear and anxiety related to groundwater contamination, possible ecological damages, and losses of intrinsic values associated with groundwater resources. One category of economic damages that has received relatively little study is that of averting expenditures, or the costs incurred by households, firms or governments to avoid exposure to a groundwater contaminant.

Researchers who have included avoidance costs in their studies have generally simulated averting behaviors and expenditures based on the assumption that households did in fact engage in such behaviors in response to pollution. For example, Spofford et al. (1989) used pre-specified probability distributions to model households' averting expenditures in a study of groundwater remediation efforts at a federal Superfund site in Massachusetts.

Smith and DesVousges (1986) provided the first empirical evidence of household-level behaviors taken to reduce or mitigate exposure to pollutants. They documented actions to avoid hazardous waste in drinking water and identified factors influencing such behaviors via a survey of households in the suburban Boston area. Harrington et al. (1989) estimated averting expenditures resulting from a waterborne disease outbreak in northeastern Pennsylvania caused by microbiological contamination of a surface water reservoir. Abdalla (1989) documented averting expenditures of households in a central Pennsylvania community using an aquifer contaminated with a synthetic organic chemical.

In this paper averting expenditures are examined and used to approximate the economic costs to households in a southeastern Pennsylvania community affected by groundwater contamination. The analysis begins with a review of the theoretical foundation of the averting expenditures method. The economic estimates obtained are interpreted in light of the underlying theory and implications for water resources policy-making are discussed.

II. THEORETICAL FOUNDATION

Theoretical explanations of averting behavior and analyses of the relationship between averting expenditures and the economic costs of pollution are based on the household production function theory of consumer behavior. This theory is based on the notion that households do not derive utility directly from all purchased goods, but rather may use some or all of these goods and time as inputs to produce services valued by the household (Becker, 1965; Lancaster, 1966). Observed behavior is therefore explained by household production technology in addition to preferences and prices.

In the context of averting behavior models, the household produces consumption goods using various inputs, some of which are subject to degradation by pollution. The household may respond to increased degradation of these inputs in various ways that are generally referred to as averting or defensive behaviors. For example, a household uses water in the production of food and cleanliness. Contamination of the household water source reduces its suitability for such activities. The household may respond with averting activities such as purchase of bottled water for drinking, use of alternative beverages in cooking and installation of home water treatment equipment.

The averting behaviors considered in this study necessitate time input by households. A model that extends Bartik's basic model to include time is presented to establish the theoretical foundation of this study. In this model households produce a level of personal environmental quality and leisure services. The households utility function is

$$U = U(x, q, l) \tag{1}$$

where x is a numeraire good, q is the personal environmental quality produced, and l is leisure services. The utility function is assumed to be increasing, quasi-concave and at least twice continuously differentiable in x, q, and l.

The production function of personal environmental quality is

$$Q(y, t_d, c). \tag{2}$$

where y is a vector of purchased inputs, t_d is household time allocated to producing personal environmental quality, and c is an exogenously determined ambient pollution level. The production function is assumed to be increasing and concave in y and t_d, decreasing in c and at least twice continuously differentiable. The cost function for q is defined contingent upon the amount of time allocated to defensive activities and the pollution level. The cost function is denoted

$$D(t_d, q, c) = \min p_y' y \qquad \text{s.t. } Q(y, t_d, c) \geq q,\ t_d,\ c \text{ and } q \text{ given} \tag{3}$$

where p_y is the price vector for the averting inputs.

The leisure production function is

$$F(z, t_l) \tag{4}$$

where z is purchased leisure inputs and t_l is time allocated to leisure activities. This function is assumed to be increasing, concave and at least twice continuously differentiable. A cost function for leisure services contingent upon t_l is

$$R(l, t_l) = \min p_z'z \tag{5}$$
$$\text{subject to } F(z, t_l) \geq l, \ t_l \text{ and } p_z \text{ given}$$

where p_z is a price vector for leisure inputs.

Income in this model is divided into two components, exogenous income (m) and income obtained from work. Individuals are assumed to work at a constant wage rate of w. Time worked is denoted t_w.

The consumer's utility maximization problem can now be expressed in terms of the expenditure functions and time and income constraints:

$$\max U(q, x, l) \tag{6}$$
$$\text{subject to } m + wt_w = x + D(c, q, t_d) + R(l, t_l)$$
$$\text{and } t = t_w + t_l + t_d$$

where t is the total time available.

The optimality conditions are:

$$\partial U/\partial q - \lambda(\partial D/\partial q) = 0 \tag{7.a}$$

$$\partial U/\partial x - \lambda = 0 \tag{7.b}$$

$$\partial U/\partial l - \lambda(\partial R/\partial l) = 0 \tag{7.c}$$

$$\lambda t_w - \delta = 0 \tag{7.d}$$

$$-\lambda(\partial R/\partial t_l) - \delta = 0 \tag{7.e}$$

$$-\lambda(\partial D/\partial t_d) - \delta = 0 \tag{7.f}$$

where λ is the Lagrangian multiplier (shadow price) of the income constraint and δ is the Lagrangian multiplier (shadow price) of the time constraint.

The indirect utility function is useful for defining the household's cost or benefit from changes in the ambient pollution level. This function is

$$\begin{aligned} V = V(m, c) &= U(x^*, q^*, l^*) \\ &+ \lambda[m + wt_w^* - x^* - D(c, q^*, t_d^*) - R(l^*, t_l^*)] \\ &+ \delta[t - t_w^* - t_l^* - t_d^*] \end{aligned} \tag{8}$$

where *'s indicate optimal values of the choice variables. Totally differentiating the indirect utility function with respect to m and c and setting dV equal to zero we obtain:

$$\frac{dm}{dc} = \frac{-\partial V/\partial c}{\partial V/\partial m} \tag{9}$$

The envelope theorem implies that the RHS of equation (9) is $(\partial D/\partial c)$.

$$\frac{dm}{dc} = \frac{\partial D}{\partial c}. \tag{10}$$

Expressions (9) and (10) give the compensating variation or cost (benefit) of a marginal increase (decrease) in c. From (10) it is evident that the cost (benefit) of a marginal increase (decrease) in c is the increase (decrease) in defensive expenditures necessary to maintain the initial optimal level of personal environmental quality.

The economic cost differs from the change in averting expenditures plus the opportunity cost of the time allocated to averting activities that would be associated with an increase in the ambient pollution level. The change in defensive expenditures is obtained by totally differentiating the defensive expenditure function with respect to c. The opportunity cost of time, in terms of the numeraire good, is the wage rate. Accordingly, the change in observed defensive expenditures associated with a pollution change, including the time costs of household labor used in averting activities is:

$$\frac{\partial D}{\partial c} + \frac{\partial D}{\partial q^*}\frac{\partial q^*}{\partial c} + \frac{\partial D}{\partial t_d^*}\frac{\partial t_d^*}{\partial c} + w\,\frac{\partial t_d^*}{\partial c} \tag{11}$$

The first term of (11) is the economic cost of the increase in the pollution level from expression (10). The second term is the change in defensive expenditures that occurs because the household changes its personal environmental quality level after the pollution increase. The sign of $\partial q^*/\partial c$ is negative as long as q is not a Giffen good. The sign of $\partial D/\partial q$ is positive under assumptions about the production function for personal environmental quality. Thus, the sign of the second term of (11) is negative. The third term is the savings in defensive expenditures resulting from the allocation of household labor to averting activities. The fourth term is the opportunity cost of household labor. Conditions (7.d) and (7.f) imply that the last two terms of (11) cancel out. Accordingly, (11) simplifies to:

$$\frac{\partial D}{\partial c} + \frac{\partial D}{\partial q^*}\frac{\partial q^*}{\partial c} \qquad (12)$$

Since the second term is negative, the change in defensive expenditures, including the value of household time, is less than the economic cost of the increase in c. The change in defensive expenditures can therefore provide a conservative estimate of the cost of ambient pollution increases. This result is the same as Harrington and Portney (1987), Berger et al. (1987) and Bartik (1988), although time used in averting activities was not considered in those earlier works.

The validity of using averting expenditure changes to estimate the benefits or costs of an environmental change is based on assumptions of the household production theory (Dickie and Gerking, 1988). Key assumptions are that averting inputs not exhibit jointness in the production of household outputs and that averting expenditures not involve purchase of durable goods.

III. PROCEDURES

Averting expenditures were used in this study to approximate the costs associated with groundwater contamination. Though groundwater contamination can have many consequences for a community, this study measured only household-level avoidance costs resulting from contamination of groundwater. The theory presented above indicates that these costs can provide a conservative estimate of the true cost of increased pollution levels.

Averting expenditures were measured in a community experiencing a water contamination incident and, as a control group, one that was not. The control community was intended to represent the averting expenditure levels of the community experiencing groundwater contamination before contamination. Furthermore, the use of a control group eliminates the possibility of memory bias associated with asking respondents about their behaviors prior to contamination. Criteria for the community experiencing contamination included a minimum of 500 households connected to a public community water system, an expectation that the contamination incident would continue during the entire study period and public notification of the contamination.

The communities selected were located in Bucks County in southeastern Pennsylvania and served by public water systems relying on groundwater. The borough of Perkasie, which has an estimated 2760 households, was selected as an example of a community affected by groundwater contamination. In late 1987, Trichloroethylene (TCE), a volatile synthetic organic chemical, was detected in the borough's wells. TCE levels were as high as 35 parts per billion (ppb), exceeding the Environmental Protection Agency's maximum contaminant level (MCL) of 5 ppb. Since no temporary solution was available to reduce TCE levels below the MCL, the county health department required the borough to notify customers of the contamination in June 1988. As of December 1989, no solution had been implemented.

Doylestown was chosen as a community that had not experienced any recent water quality problems. The borough of Doylestown has an estimated 2497 households and is located about 15 miles from Perkasie. TCE was detected in one well in 1986 but it was quickly taken out of service. This event received little publicity and the water system has had no additional MCL violations.

Mail questionnaires were chosen as the instrument to elicit information about household averting expenditures and possible influences upon these expenditures, such as risk perceptions, attitudes and demographic factors. A survey instrument was developed and administered following procedures suggested by Dillman (1978).

Based on Kalton (1983), a representative sample of 1733 and 1558 was chosen from Perkasie and Doylestown, respectively. Mailing lists of residential customers were obtained and the survey was administered in September 1989. After three follow-up mailings, 761 and 718 usable questionnaires were received from Perkasie and Doylestown. Adjusting for non-deliverable surveys, the effective response rate was 46.9% for Perkasie and 48.6% for Doylestown.

The response rates obtained were lower than anticipated and it was felt necessary to investigate non-response bias. A telephone interview with a random sample of 50 non-respondents in each community was conducted to determine if respondents and non-respondents were similar in key attributes. Following a method suggested by Snedecor and Cochran (1980), two variables, awareness of TCE contamination and household averting actions taken in response to TCE, were statistically compared for the mail questionnaire sample and the telephone interview sample. The hypothesis that the two samples were different on these attributes was rejected at the .05 level. Consequently, the survey results were considered representative of the two populations.

IV. RESULTS

Averting actions undertaken by Perkasie and Doylestown households and their estimated costs are presented and compared. Regression results are also presented to shed light upon factors influencing averting expenditures.

A. Averting Expenditures

Perkasie residents' averting expenditures included: (1) increased bottled water purchases among households buying it prior to the contamination; (2) bottled water purchases by new buyers; (3) costs of home water purification systems; (4) costs of hauling water from alternate sources; and (5) costs of boiling water. Of the 304 households in the Perkasie sample aware of TCE contamination, 133, or 43.75%, undertook specific actions to avoid exposure after learning of TCE in their water. The costs of these actions were calculated for the sample and extrapolated to the total population of Perkasie residents (Table 1). Total losses from December 1987, when TCE was first detected, to September 1989 ranged from $61,313.29 to $131,334.06, depending on the wage rate used to reflect the value of lost leisure time. The average weekly increase in averting expenditures per household which undertook averting actions in response to the contamination was $0.40.

A total of 210, or 28.9% of Doylestown respondents indicated they were undertaking averting actions relating to water use. Of these, 167 households, or 79.5%, reported bottled water purchases and 65 households, or 31.0%, had purchased a home water treatment system. Expenditures on bottled water and treatment systems were calculated for the sample and extrapolated to the total population of Doylestown households. These expenditures were calculated as a flow of costs.[1] Bottled water costs were estimated at $1,514.55 per week and treatment costs of $191.23 for a total weekly cost of $1,705.78. The average weekly cost per household was $0.68.

The Doylestown averting expenditure level is intended to approximate the Perkasie averting expenditure level before TCE contamination. Adding the averting expenditure level of $0.68 per household per week in Perkasie before the TCE contamination and the calculated average increase of $0.40 per household per week, the average averting expenditure level in Perkasie during the study period was estimated as $1.08 per household per week. In other words, TCE contamination caused average averting expenditure levels in Perkasie to increase about 59%, assuming Doylestown was an appropriate control group.

B. Determinants of Averting Expenditures

Estimated increases in household averting expenditures over the 88-week contamination period were used as the dependent variable for the Perkasie sample. The dependent variable was estimated annual household averting expenditures for Doylestown. The dependent variable was specified in linear and natural logarithmic form for both communities.

The Doylestown regression model using independent variables correlated with the dependent variables at the 0.05 level of significance is presented in Table 2. The RATING OF ENVIRONMENTAL RISKS variable was indexed from nine questions asking respondents to rate the seriousness of the cancer risk associated with different risk values. The scale used for each of the nine questions ranged from 1 (insignificant risk) to 5 (very serious risk). All signs are in the hypothesized directions except for AGE and EDUCATION for which no hypothesis was made.

In the case of Perkasie, fewer independent variables were correlated at the 0.05 level with the dependent variables. Statistical comparisons of the full equations containing all correlated independent variables and restricted equation lead to the dropping of insignificant variables (Table 3).

In all but one of the models, respondents' perceptions of the cancer risk associated with their water had a significant positive relationship with the averting expenditure dependent variable. The presence of children under three years of age in the household influenced averting expenditures in all models. Awareness of water problems, in the Doylestown sample, or other water problems, in the Perkasie sample, positively influenced averting expenditures. The amount of information about TCE health risks and averting actions available to Perkasie residents was positively related to the logarithmic specification of averting expenditures. Income was related to averting expenditures in Doylestown but not averting expenditure changes in response to TCE contamination in Perkasie. Also, education, age and trust in state and local officials had a negative influence on the logarithmic specification of averting expenditures in the Doylestown sample.

In general, the explanatory power of all models was relatively low. The signs of all parameter estimates are in the expected directions. The positive influence of information about environmental contamination received by households upon averting expenditures was also found by Swartz and Strand (1981). Smith and DesVousges (1986) also uncovered a negative relationship between education and household behaviors to avoid hazardous waste in drinking water.

V. CONCLUSIONS

Data on the averting expenditures of households in two Pennsylvania communities was collected to empirically estimate the costs of a groundwater contamination incident. The models developed in this study have indicated that averting expenditures can be theoretically related to willingness-to-pay for changes in environmental quality. Under specific assumptions, the change in averting expenditures associated with a change in environmental quality provides a conservative estimate of the true cost, or benefit, of the environmental change. These assumptions appear to be generally valid to the situation of drinking water contamination.

Average averting expenditure levels in a community affected by groundwater contamination were found to be 58% greater than a similar community unaffected by contamination. The regression results demonstrated that qualitative risk perception is an important determinant of averting decisions. Other factors that influenced averting expenditures included the presence of young children in a household and awareness of water quality problems.

The measures of the economic value of water quality changes obtained via averting expenditures analysis have a sound basis in theory and are of sufficient empirical magnitude that they merit consideration in federal, state and local groundwater policy decisions. Estimates of averting expenditures should be included in cost-benefit analyses of public policies where averting actions are an option for affected individuals. Examples of such policy decisions include: setting of federal Maximum Contaminant Levels (MCLs) for drinking water, establishing state water quality policies and water quality standards, and local decision-making to protect or remediate the quality of water supplies. Failure to consider averting expenditures in water resources decision-making is likely to result in inefficient policies. For example, the costs of groundwater contamination incidents would be understated if averting expenditures were excluded. Understating the costs associated with water contamination would lead to policies which set allowable levels of water contamination too high.

The results indicate that averting expenditures vary with differences in people's perception of the health risk and knowledge of contamination. Risk communication strategies which affect perception of drinking water risks may change the benefits and costs of environmental policies which affect health. Since awareness of contamination influences averting behavior, the policies and procedures for public notification are also important factors affecting costs. The regression results indicate that households may not be equally concerned with health risks posed by contaminants in drinking water. Notification efforts could be intensified towards those groups which appear to be more concerned with water quality. For example, households with young children tend to spend more on averting activities related to water use. Notification programs targeted at parents of young children could be developed, such as through child care centers or pediatricians' offices.

In light of the few studies documenting the existence and nature of behaviors to avoid environmental contaminants, the results are significant. While the averting expenditure method does not encompass all impacts, the method yields theoretically supported estimates of an important category of the costs of groundwater contamination.

References

Abdalla, C. W., Epp, D. J. and B. A. Roach, 1990. Developing Methods to Measure Costs of Averting Behavior in Evaluating Water Quality Improvements. Final Project Completion Report to US EPA, Office of Policy Planning and Evaluation, Cooperative Agreement # CR-815412-01-0, (February).

Abdalla, C. W., 1989. "Measuring the Costs of Groundwater Contamination: An Empirical Application Using Averting Behaviors." Agricultural Economics and Rural Sociology Staff Paper No. 161, Penn State University, University Park, PA, (April).

Bartik, T. J., 1988. Evaluating the Benefits of Non-marginal Reductions in Pollution Using Information on Defensive Expenditures. Journal of Environmental Economics and Management 15(1988): 111-127.

Becker, G. S., 1965. "A Theory of the Allocation of Time." The Economic Journal 75: 493-517.

Berger, M. C., G. C. Blomquist, D. Kenkel and G. S. Tolley, 1987. Valuing Changes in Health Risks: A Comparison of Alternative Measures. Southern Economic Journal 53(4):967-984.

Dickie, M. and S. Gerking, 1988. Benefits of Reduced Soiling from Air Pollution Control: A Survey. Migration and Labor Market Efficiency, ed., H. Folmer. Amsterdam: Martin Nijhoff.

Dillman, D. A., 1978. Mail and Telephone Surveys: The Total Design Method. New York: John Wiley, 1978.

Harrington, W. and P. R. Portney, 1987. Valuing the Benefits of Health and Safety Regulation. Journal of Urban Economics 22: 101-112.

Harrington, W., Krupnick, A. J. and W. O. Spofford, Jr., 1989. "The Economic Losses of a Waterborne Disease Outbreak." Journal of Urban Economics 25: 116-137.

Kalton, G., 1983. Introduction to Survey Sampling. Beverly Hills: Sage Publications.

Lancaster, K. J., 1966. "A New Approach to Consumer Theory." Journal of Political Economy 74: 132-157.

Moody, D. W., 1990. "Groundwater Contamination in the United States." Journal of Soil and Water Conservation 45(2): 170-179.

Raucher R. L., 1986. "The Benefits and Costs of Policies Related to Groundwater Contamination." Land Economics 62(Feb.): 33-45.

Sarnat, C. L., C. E. Willis, and C. R. Harper, 1987. "Choosing Alternatives to Contaminated Groundwater Supplies: A Sequential Decision Framework Under Uncertainty." Northeast Journal of Agricultural and Resource Economics 16:102-112.

Smith, V. K. and W. H. DesVousges, 1986. "Averting Behavior: Does it Exist?" Economics Letters 20: 291-296.

Snedecor, G. W. and W. G. Cochran, 1980. Statistical Methods. Ames, Iowa: The Iowa State University Press.

Solley, W. B., C. F. Merk, and R. R. Pierce, 1988. Estimated Use of Water in the United States in 1985, Circular 1004, US Geological Survey, Reston, VA.

Spofford, W. A., Krupnick, A. J., and E. F. Wood, 1989. "Uncertainties in Estimates of the Costs and Benefits of Groundwater Remediation: Results of a Cost-Benefit Analysis." Discussion Paper QE89-15. Washington, D.C.: Resources for the Future.

Swartz, D. G. and I. E. Strand, Jr., 1981. "Avoidance Costs Associated with Imperfect Information: The Case of Kepone." Land Economics 57(May):139-150.

U.S. Congress, Office of Technology Assessment, 1984. Protecting the Nation's Groundwater from Contamination, OTA-O-233, Washington, DC, (October).

U.S. Environmental Protection Agency, 1990. Progress in Groundwater Protection and Restoration. EPA 440/6-90-001, Office of Water, Washington, DC, (Feb.).

Footnote

1. The costs of home water treatment systems was converted to flow of costs by assuming that the useful life of such a system was 10 years. Specific procedures, assumptions and data sources used in cost calculations can be found in Abdalla, et al. (1990).

Table 1 - Estimated Costs of the TCE Contamination Incurred by Perkasie Households from December 1987 to September 1989

Category of Cost	Low Estimate ($)[1]	High Estimate ($)[2]
1. Increased purchases of bottled water[3]	11,134.54	11,134.54
2. New purchases of bottled water	17,341.95	17,341.95
3. Home water treatment systems[4]	4,691.46	4,691.46
4. Hauling water[5]	12,512.76	34,031.48
5. Boiling water[6]	15,632.58	64,134.63
Total	61,313.29	131,334.06

1 - Low estimate values lost leisure time at minimum wage ($3.35 per hour).

2 - High estimate values lost leisure time at the estimated hourly wage. To estimate hourly wage, the median value of the income category checked by each respondent was used as an estimate of yearly income. Then, yearly income was divided by 2,080 hours to obtain an estimated hourly wage.

3 - An average bottled water cost of $0.83 per gallon was obtained by contacting several retail grocers in the Perkasie area.

4 - The useful life of a home water treatment system was assumed to be ten years (520 weeks). Since the 88-week study period represented 0.169 of a ten-year period, only 0.169 of the purchase price of each water treatment system was included in the estimate. This estimate does not include any regular maintenance costs or filter disposal.

5 - Information was asked in the survey regarding the number of trips per week to haul water, round-trip distance and how often the trip was for the sole purpose of hauling water. The average travel speed was assumed to be 35 miles per hour and the American Motor Vehicle Manufactures Association indicates a vehicle operation cost of 32.6 cents per mile.

6 - Respondents were assumed to use an electric stove for eight minutes to boil one-half gallon at a time. The electricity cost in Perkasie was 5.5 cents per kilo-watt hour.

Table 2. Doylestown Regression results

	Specification of Dependent Variable	
	Annual Averting Expenditures	Log of Annual Averting Expenditures
Independent Variable	Parameter Estimate	Parameter Estimate
Intercept	-27.989	-1.862
	(-0.540)	(-1.290)
AWARENESS OF WATER PROBLEMS	42.635***	1.067***
(0=not aware, 1=aware)	(5.240)	(4.681)
PERCEIVED CANCER RISK FROM WATER	10.513**	0.390***
(1=insignificant to 5=very serious)	(2.531)	(3.373)
HOME OWNERSHIP	38.678	2.123**
(0=rents, 1=owns or buying)	(1.278)	(2.521)
EDUCATION	2.197	0.170**
(1=grade school to 7=grad. school)	(0.677)	(1.882)
AGE	-0.478	-0.016**
(actual age in years)	(-1.750)	(-2.071)
CHILD BETWEEN AGE 0-3	27.238**	0.551*
(0=no, 1=yes)	(2.517)	(1.829)
TRUST IN STATE/LOCAL GOVERNMENT	-1.450	-0.113*
(1=not at all to 5=alot)	(-0.599)	(-1.676)
INCOME GREATER $50,000	13.995**	0.201
(0=no, 1=yes)	(2.155)	(1.114)
CHILD BETWEEN AGES 3-17	-3.580	-0.006
(0=no, 1=yes)	(-0.507)	(-0.032)
FAMILIARITY WITH CHEMICALS	5.076	0.090
(1=not at all to 5=very familiar)	(1.196)	(0.760)
PROBLEM OF TOXIC CHEMICALS	-2.090	-0.016
(1=insignificant to 5=very serious)	(-0.444)	(-0.125)
RATING OF ENVIRONMENTAL RISKS	0.186	0.009
(9=insignificant to 45=very serious)	(0.344)	(0.615)
FREQUENCY OF EXERCISE	3.247	0.098
(1=never to 5=5+ per wk.)	(1.396)	(1.512)
PROBABILITY OF FUTURE PROBLEMS	-8.411*	
(1=very high to 5=very low)	(-1.874)	
Number of Observations:	463	463
R-Squared:	0.1633	0.1972
Adjusted R-Squared:	0.1380	0.1730
F-Value:	6.455	8.125

(Both models are significant at 0.01 level)

Note: t-values are in parentheses

*** - statistically significant at the 0.01 level
** - statistically significant at the 0.05 level
* - statistically significant at the 0.10 level

Table 3. Perkasie Regression Results

Independent Variable	Increase in Averting Expenditures: Parameter Estimate	Log of Increase in Averting Expenditures: Parameter Estimate
Intercept	-43.747** (-1.927)	-1.140* (-1.773)
PERCEIVED CANCER RISK OF TCE WATER (1=insignificant to 5=very serious)	24.779*** (3.480)	
CHILD BETWEEN AGES 3-17 (0=no, 1=yes)	49.711*** (2.678)	
CHILD BETWEEN AGE 0-3 (0=no, 1=yes)	36.385** (2.385)	1.313*** (4.036)
AWARENESS OF OTHER WATER PROBLEMS (0=no, 1=yes)	45.230** (2.336)	
INFORMATION ABOUT TCE HEALTH RISK AND AVERTING ACTIONS (1=none to 5=alot)		0.297*** (2.541)
PERCEIVED CANCER RISK OF WATER PRIOR TO TCE CONTAMINATION (1=insignificant to 5=very serious)		0.454*** (3.040)
GENDER (0=female, 1=male)		0.536** (1.984)
Number of Observations:	266	280
R-Squared:	0.1257	0.1255
Adjusted R-Squared:	0.1126	0.1130
F-Value:	9.562	10.048

(Both models are significant at 0.01 level)

Note: t-values are in parentheses

*** - statistically significant at the 0.01 level
** - statistically significant at the 0.05 level
* - statistically significant at the 0.10 level