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Estimating Willingness to Pay for River Amenities and Safety Measures Associated with Shale Gas Extraction

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This paper utilizes a Contingent Valuation Method survey of a random sample of residents to estimate that households are willing to pay an average of US$12.00 per month for public projects designed to improve river access and US$10.46 per month for additional safety measures that would eliminate risks to local watersheds from drilling for natural gas from underground shale formations. These estimates can be compared with the costs of providing each of these two amenities to help foster the formation of efficient policy decisions.
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INTRODUCTION

The Susquehanna River watershed extends for over 500 miles from the interiors of New York and Pennsylvania to the Chesapeake Bay in Maryland. The north and west branches of the Susquehanna meet in the Susquehanna Valley of central Pennsylvania — a region known for rural landscapes and small river towns. Historically, the economies of these river towns relied upon the river system to transport natural resources such as timber, coal, and produce to support agricultural and industrial activities. Today, river-town economies either struggle in the face of the national decline in manufacturing or rely upon a large service institution such as a university or regional hospital for employment and economic growth.

A question facing all river towns in the Susquehanna Valley region is how best to utilize the Susquehanna River watershed to promote economic and social development. Young professionals employed by regional universities and medical facilities may value increased recreational opportunities along the river. Alternatively, recent developments in the technology of extracting natural gas from shale rock formations, technological processes that require large quantities of water, have ushered in a rapid increase in gas exploration and extraction within the watershed. Shale gas extraction could improve river-town economies, but could threaten the environmental quality of the river. These two potential uses of the river system — for recreation and gas extraction — may not be compatible.

This paper estimates both the value residents of the Susquehanna Valley place on improved access to the Susquehanna River and additional safety measures that would protect the local watershed from contamination by the process of shale gas extraction. These values are estimated using the Contingent Valuation Method (CVM) — a process that involves surveying a random sample of residents. A sample of 186 valley residents were each asked whether or not they would pay a randomly assigned monetary value for improved river access and additional safeguards against contamination. Results suggest households are willing to pay an average of US$12.00 per month for public projects designed to improve access to the Susquehanna River and US$10.46 per month for additional safety measures that would eliminate risks to local watersheds from drilling for natural gas from underground shale formations. These estimates can be compared with the costs of providing each of these two amenities to help foster the formation of efficient policy decisions.

The next section of this manuscript provides a background of the region and the recent developments in extraction of shale gas. The subsequent section summarizes the economics literature devoted to river quality and environmental safety. The section after that describes the data gathered for this research, and section after that explains the econometric approach for estimating willingness to pay (WTP). The penultimate section provides the empirical results, and the final section suggests results under three alternative scenarios.

BACKGROUND

The Susquehanna Valley region of Pennsylvania features wide rural valleys containing farms, small agricultural villages, and several river towns along the two main branches of the Susquehanna River. River towns in this region share much in common. All have human populations of less than 20,000 persons. Some have a large university or hospital as the primary employer, and thus attract young professionals to the region.

Lewisburg is one such river town — situated on the western side of the Susquehanna River's West Branch. Lewisburg is recognized for its vibrant downtown and preserved historical character. Bucknell University, home for 3,400 students, is located along on the southern edge of Lewisburg. Lewisburg residents access the river at only a few locations. The Soldier Park is adjacent to the river, but its design does not encourage interaction with the river. A smaller park, rustic boat launch, and wooded walking trail are available a few blocks south for canoes and kayaks, but poor signage makes these access points illusive to many visitors. The river water itself is shallow during many parts of the year making it ill-suited to power boating.

Selinsgrove is also a small university town located along the west bank of the Susquehanna River just below the confluence of the west and north branches of the river. Selinsgrove's population consists of over 5,000 residents and approximately 2,000 undergraduate students from Susquehanna University. The river adjacent to Selinsgrove is wide and tranquil, but the riverbank is privately owned except for a public boat ramp. The nearby Isle of Que is formed by the confluence of the Susquehanna River and Penns Creek. This island features a small neighborhood and agricultural fields, and a river road that contains scenic views of the river.

Danville is populated by approximately 5,000 residents. Historically, the town was active in the extraction of iron, and the first iron T-rail in the United States was

produced in Danville. Today, Geisinger Health Systems, a large regional hospital, is Danville's largest employer. Danville's local levee system, which protects the majority of the town from flooding, serves as a barrier between Danville and the Susquehanna River.

Other river towns in the valley include Milton, Watsontown, Sunbury, and Bloomsburg. Of these, only Bloomsburg features a large institutional employer (Bloomsburg University). The economies of the other river towns are based on small-scale manufacturing and retailing services.

Marcellus Shale is a black shale formation in the deep underground parts of Pennsylvania, New York, West Virginia, and Ohio believed to contain trillions of cubic feet of natural gas — an amount that when combined with other shale gas plays may result in the United States one day becoming a net exporter of natural gas. Extracting this gas was recently made economical by the development of horizontal drilling and hydraulic fracturing. Hydraulic fracturing involves large amounts of water taken out of local waterways and mixed with sand and other various chemicals. Each gas well requires 1–8 million gallons of fresh water from local waterways. This water, known as slickwater, is injected into the shale formation to pulverize the shale and free the natural gas. Once this process is complete, the used water (known as fracwater or flowback) resurfaces and is heavy in sodium, calcium, chlorine, strontium, barium, and is mildly radioactive. This fracwater must be re-injected into gas wells, stored, or transported and disposed into other deep wells. If the fracwater were to leach into the local watershed it could create widespread environmental damages. Over 400 wells were drilled in Pennsylvania in 2009.

If all goes as planned, then shale drilling can be a safe operation. However, with any large extractive operation there are risks involved. For example, in the summer of 2010, a faulty valve in Clearfield County caused a gas well to spew natural gas and fracwater 75 feet in the air. Containment ditches and pumps were put in place immediately following this accident to catch the released fluids. The site was secured approximately 16 hours after the accident, and the environmental impact to local streams and springs was minimal. Estimating the WTP by the regional population for protection against these types of accidents represents one focus of this paper.

A REVIEW OF THE RELEVANT LITERATURE

This research contributes to two areas in the economics literature. The first literature estimates WTP for various forms of improved river quality. The second focuses on WTP to avoid environmental risks and damages. Both of these literatures demonstrate that households are willing to pay for quality surface water and for protection against environmental dangers. This literature employs various techniques for conducting CVM surveys, including the use of open-ended, close-ended, and choice-based methods.

WTP for river amenities

Loomis et al. [2000] uses the close-ended CVM survey approach to estimate household WTP to increase ecosystem services in a 45-mile area of the Platte River in Colorado. Such ecosystem services include the dilution of wastewater, the natural purification of water, erosion control, improving habitat for fish and wildlife,

and recreation. Results suggest households are willing to pay US$26.59 per month, or US$7.09 per mile of river, for increased ecosystem services.[1] This estimate suggests all households are willing to pay US$23.48 million for improved river quality. Improving the river may require the United States Department of Agriculture to idle 300,000 acres of farmland (at a cost of US$15.58 million) and lease additional water (at a cost of US$1.43 million) for a total government cost of US$17.01 million. If lost agricultural output is the only cost of restoring the Platte River, then the benefits to households exceed these costs.

Holmes et al. [2004] took a similar approach. Here, researchers studied costs and benefits of riparian restoration projects along the Little Tennessee River in western North Carolina. On the basis of household WTP survey results, the present value of public benefits of full restoration was estimated at US$3,273,000, or US$5.24 per household per mile, and similar in value to Loomis et al. [2000]. Researchers also note a "super additive" effect is exhibited where the value of total restoration is greater than the sum measured for partial restoration programs, although the partial programs still have value.

Bockstael et al. [1989] used a similar survey method to establish how much people are willing to pay for changes in water quality to improve the recreational use of the Chesapeake Bay. Using a variety of valuation methods, including the travel cost method, researched estimated total WTP for a moderate improvement in the Chesapeake Bay's water quality to be somewhere between US$17.60 and US$175.95 million.

Asking open-ended WTP questions is another CVM option. Respondents are asked how much they are willing to pay, but are expected to come up with a value on their own. Garrod and Willis [1996] use this approach to estimate the costs and benefits of enhancing flow on the River Darent (UK) to enhance recreational uses. Respondents were estimated to be willing to pay US$37.74 (residents) and US$29.90 (visitors) to improve current flow levels in any of the 40 rivers presently subject to low water flows.

Green and Tunstall [1991] also used an open-ended WTP question to estimate recreational benefits from improvements in river quality in the Mersey Basin in the United Kingdom. Annual benefits resulting from improvements in a 5.9 km section of the River Bollin are estimated at about US$402,370 per year.

Two studies combine dichotomous choice and open-ended methods within the same survey. A study done by Andrews [2001] found the value of enhancing water quality in the Brandywine watershed in Pennsylvania by establishing riparian buffers. The survey results indicate that households would be willing to pay on average between US$41.86 and US$59.10 per year. When multiplied by the number of households, this estimate amounts to between US$5.54 and US$7.76 million per year. The conservative estimate (which assumes that those who did not respond had zero values) states a total WTP between US$1.48 and US$2.22 million per year. Ojeda et al. [2008] estimate the economic value of the environmental services that would be produced by restoring flows in the Yaqui River Delta in Mexico. The mean household WTP is US$5.52 per month. Variables affecting WTP include income, education level, number of children, and the level of information about the environmental situation in the area.

Weber and Stewart [2009] asked respondents to rank various scenarios for river restoration projects along the Rio Grande River in central New Mexico. WTP for complete restoration was estimated at US$159.17 per household per year, or US$9.36 per mile of river. The researchers believe that answers to CVM questions

may have been influenced by previously posed CVM questions, and suggest splitting the sample as a better approach.

Bateman et al. [2006] uses both these methods (CVM and choice experiment) in establishing the value of improving water quality in the River Tame in the United Kingdom. Surveys defined three levels of river quality improvements. After excluding protest bids, annual WTP is estimated at US$22.89 for small improvements, US$36.34 for the medium improvements, and US$54.58 for large improvements.

Collins et al. [2005] also asked respondents choice questions about various attributes of Deckers Creek, in West Virginia, to determine the economic value of restoration. The three most important attributes were defined as aquatic life, swimming ability, and scenic quality. Each survey asked four choice questions (which varied survey to survey). Respondents believed the top three problems were trash, unnatural colors, and lack of aquatic life. The mean WTP for these attributes is estimated at US$14.41 per respondent per month. Assuming that those who declined to respond to the survey do not value restoration, the watershed population of 35,719 households are estimated to be willing to pay just under US$2.12 annually for restoration.

Paulrud and Laitila [2004] took a different approach to estimate the use value associated with fishing. In this study, respondents were presented with various options and asked to choose their preferred alternative. Total WTP for a change from the current "catch and release" scenario to the "natural" scenario is estimated at US$2.65 million per 2 years. A change from catch and release to over-fished decreases total WTP by US$1.76 million per 2 years. Results also indicated one large fish is valued 18 times more than one small fish.

Zhongmin et al. [2003] estimate the total economic value of restoring ecosystem services in the Ejina region, China. Respondents chose their own maximum WTP amount from a list of values. The median WTP is estimated at US$3.62 per household per year in Hei Valley, US$3.88 in the Main Valley, and US$3.06 in the Surrounding District. When adopting a discount rate of 15 percent, the resulting median annual WTP is US$0.86 million for the Main Valley and US$0.79 million for the Surrounding District. On the basis of these estimates, the aggregate present value of the benefits to the region is US$10.33 million, which can be compared with total costs of restoring the Ejina ecosystem total in the amount of US$112 million.

Two valuation studies have been conducted in the Susquehanna Valley. The first examines local and statewide economic benefits from abandoned mine drainage remediation of the West Branch Susquehanna River [Hansen et al. 2008]. Here, a CVM survey was sent through the mail. Respondents were presented with many possible programs for improving the environment (such as preserving farmland, protecting open spaces, maintaining state parks). Of all options offered, cleaning up polluted rivers and streams was the most common choice. The estimated WTP was a one-time payment of US$22.28 for respondents residing inside the watershed and US$36.46 for respondents residing outside of the watershed (the authors explain this result by noting that education levels are higher for respondents residing outside the watershed than inside and suggesting that respondents residing inside the watershed have a strong familiarity with the problems of polluted river waters and may have a adopted a greater acceptance of it). Total WTP to clean Pennsylvania's rivers and streams across the population was estimated at US$74.54 million.

The second study on the Susquehanna researched public opinion on establishing a greenway along 500 miles of the Susquehanna River [Toole 2003]. The survey was conducted via mail and direct telephoning. The survey results suggest that most Susquehanna Valley residents held a positive impression of the river, but that

awareness and use of the river was low. Over 50 percent of the respondents thought their community should be more attached to the water, and 55 percent of respondents indicated an interest of achieving a balance of conservation and resource protection with economic development. Recreation, protection for water quality, and conservation of natural resources were the residents' top concerns. Approximately 61 percent of respondents indicated support for the creation of the Susquehanna Greenway. The top perceived benefit of the Greenway was found to be improving the quality of life and spurring the local economy. Promoting the greenway and building a strong public identity appears to be the biggest challenge. The top five activities are enjoying river views, scenic drives, enjoying nature, time with family and friends, and enjoying peace and quiet.

WTP for avoiding environmental risk

Following the Exxon Valdez oil spill in 1989, a large-scale CVM study was administered to estimate the harm it caused to average Americans [Carson et al. 2003]. The WTP question asked respondents to place a value on preventing a future accident similar to the Exxon Valdez spill. The researcher asked respondents a simple dichotomous choice question. The in-person interviews used photos of the accident as visual aids. After performing various statistical adjustments, researchers estimated the median household WTP to prevent an Exxon Valdez type oil spill was US$56.88 per person per year. This estimate translates to a total estimated WTP of 8.52 billion by the United States population.

Hurley et al. [1999] specifically studied rural residents' perceptions of risk to water quality from large-scale livestock production facilities. Respondents were asked their WTP to delay nitrate contamination in their water for 10, 15, and 20 years. The bid values were held constant for the three questions on the survey, but varied across the surveys. The estimated annual median WTP was US$67.68 per person for a 10-year delay, US$84.34 for a 15-year delay, and US$107.17 for a 20-year delay. Researchers found that education level and income both positively affect the median WTP and male respondents were less likely to pay than female respondents.

Irvin et al. [2007] estimate the WTP for additional protection of Ohio surface waters. Ohio taxpayers were given hypothetical opportunities to pay for the monitoring and enforcement costs. Results suggest a WTP of US$43.70 to remove 25 percent of pollutants in all of Ohio's surface water, US$40.05 for 50 percent, US$47.37 for 75 percent, and US$45.62 for 100 percent.

Riddle and Shaw [2003] researched the value of protecting future generations from the health risks of nuclear waste storage in the Yucca mountain region. Residents of southern Nevada were given the option to accept a tax rebate to relocate to a safer distance from the site. Results suggest the total ex ante social cost associated with health and safety risks associated with proximity to a nuclear waste storage facility at US$20.298 per household per year. Over half of this amount is associated with a desire to protect future generations.

Hammitt and Zhou [2005] surveyed residents in China to find the value of preventing adverse health effects of air pollution. Researchers studied three health effects including colds, chronic bronchitis, and fatality. Respondents were asked how much they would be willing to pay to (1) prevent a cold in the next few days, (2) to reduce their lifetime chance of getting chronic bronchitis, and (3) to reduce their probability of death from 0.007 to 0.001. Respondents are estimated to be willing to

pay between US$3.35 and US$6.70 to prevent a cold, US$558 to US$1,117 to prevent a case of bronchitis, and US$4,466 and US$18,980 to prevent death.

Both literatures surveyed above demonstrate a WTP on the part of households in various regions of the world for access to quality surface water and for protection against environmental harms. This paper contributes to these literatures by estimating the WTP by households in the Susquehanna Valley for improved access to the river and for security against threats to water from extraction of gas from the Marcellus shale. The next section explains the CVM data gathering process.

THE CONTINGENT VALUATION SURVEY DATA

All Pennsylvania drivers are required to renew their driver's license each 4 years during the month of their birthday. As part of this renewal process, each driver must appear at a branch office of the Department of Motor Vehicles (DMV) to have a new photograph taken and then receive an updated license. The three branch offices available to drivers of the central Susquehanna Valley area of Pennsylvania are in Lewisburg, Danville, and Selinsgrove. DMV branch offices in Pennsylvania maintain limited hours of operation. The DMV offices in Lewisburg and Danville are open only on Fridays and Saturdays from 8:30am to 4:15pm. The DMV office in Selinsgrove is open on Tuesdays, Wednesdays, Fridays and Saturdays from 8:30am to 4:15pm.

With advanced permission from the main DMV office in Harrisburg, interview stations were established at these three branch offices for one complete weekday (Friday for Lewisburg and Danville and Tuesday for Selinsgrove) and one complete Saturday during June and July of 2010. The intention was to gather as random a sample of Pennsylvania drivers as might be possible, including those that are too busy to visit the DMV during the week or on weekends. To avoid oversampling teenagers and drivers recently moving to Pennsylvania, only Pennsylvania drivers that were *renewing* licenses were surveyed. Thus, the sample contains no adults under the age of 20.[2] Drivers were approached with a request to complete a survey after they completed the renewal process at the DMV.[3] A total of 302 individuals were approached with a request to complete the survey. Of these, 186 completed the survey indicating a positive response rate of 61.6 percent (as a crude comparison, the response rate to the 2010 United States as of April 27, 2010 was 72 percent).[4] Of these 186 respondents, complete income and demographic information useful to the estimation was obtained from 177 individuals.

The survey process began with a brief introduction followed by two general questions about the respondent's use of the Susquehanna River. Respondents spent an average of 39.76 days per year along the river. Among respondents that enjoy visiting the Susquehanna River, approximately 38 percent go to relax and enjoy nature, about one-fifth exercised (walked, jogged, or biked), 28 percent went to fish or hunt, and another 28 percent use the river for boating.

The survey also gathered information on each respondent's household and demographic characteristics. Table 1 provides definitions and summary statistics of all variables obtained in the survey. To determine how representative our sample is of the local population, sample means of income and demographic characteristic can be compared to county-wide data obtained by the 2010 United States Census. This comparison is summarized in Table 2, where average incomes and demographic characteristics are reported for the four counties in the central Susquehanna River

Table 1 Variable definitions and descriptive statistics

	Description	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
FREQUENCY	Days spent on or along the river per year	39.76	91.389	0	365
RELAX	To relax and enjoy nature near the river	0.38	0.486	0	1
DOG	To walk the dog on the river trails	0.12	0.324	0	1
EXERCISE	To walk, jog, or bike along the river	0.22	0.416	0	1
FISHHUNT	To fish and hunt along the river	0.28	0.450	0	1
BOATING	To boat on the river	0.28	0.450	0	1
RIVER FEE	Offered WTP amount for river access	8.49	5.065	2	16
SAFETY	1—Responder would pay the river fee 0—Responder would not pay river fee	0.60	0.492	0	1
RIVER TAX	Offered WTP amount for safety measures	9.20	6.441	2	20
RIVER	1—Responder would pay the safety fee 0—Responder would not pay safety fee	0.59	0.494	0	1
RURAL	Respondent lives in a rural area	0.54	0.500	0	1
RENTER	Respondent rents primary residence	0.20	0.404	0	1
CHILDREN	Number of children under the age 18	0.76	1.153	0	3
AGE	Respondent's age (measured in years)	46.48	14.578	25	70
COLLEGE	Respondent has obtained college degree	0.42	0.495	0	1
INCOME	20—Household income less than 25K 50—Household income between 25 and 75K 100—Household income above 75K	60.38	29.050	20	100
MALE	Respondent is a male	0.52	0.501	0	1

Table 2 A comparison of the sample to the 2010 United States Census

	Sample	*Montour county*	*Northumberland county*	*Snyder county*	*Union county*
INCOME:					
Less than US$25,000 (%)	16.1	23.8	31.9	25.3	25.5
US$25,000–US$75,000 (%)	51.4	47.4	50.3	52.1	51.0
Over US$75,000 (%)	32.4	28.8	17.8	22.6	24.4
RURAL* (%)	54.1	54.4	37.0	71.3	45
RENTER (%)	20.4	25.3	27.1	24.7	25.9
CHILDREN (%)	39.2	31.0	28.1	33.3	30.5
AGE (years)	46.5	43.0	42.7	38.7	37.4
COLLEGE (%)	41.9	25.5	13.5	15.0	21.6
MALE (%)	51.6	51.9	49.6	49.4	55.0

*Data from 2000 US Census.

valley. Sample income data were obtained in broad categories (under US$25,000, US$25,000–US$75,000, and over US$75,000). The comparisons of incomes in Table 2 suggest an oversampling of high-income earning households and an undersampling of low-income households. Apparently, non-drivers and those under the age of 20 earn on average incomes that are lower than for drivers.

The more troubling comparison is the percentage of those over 25 with a college education. The percentage of respondents with a college education is much higher in our sample (41.9 percent) than in the four area counties. Perhaps college educated individuals felt less threatened by the survey process and were therefore more likely than non-college graduates to accept the invitation to participate in the survey. Or, respondents lacking a college degree may have overstated their educational

attainment while being interviewed by self-identified college students. Because the sample contains a sufficient number of respondents both with and without a college education, WTP can be estimated as a function of the education level. The population WTP (estimated below) is estimated using average levels of education in the population (not the sample), and therefore the estimate will not be biased by an oversampling of educated individuals.

The average age in our sample exceeded that of the average resident in the area. This difference is expected since we only sample adult drivers over the age of 20.[5] The other four demographic variables (gender, the percentage of households with children under the age of 18, rural, and ownership status) appear to be roughly the same in our sample as in the Susquehanna Valley.

Each respondent was read a brief background paragraph about drilling for natural gas in the Marcellus Shale. Included in this background is a brief summary of an accident in Clearfield County that had occurred about a month prior to the surveying.[6] People were then asked the following question:

> We are interested in learning how dangerous you perceive these risks to be. Suppose all risks to area waterways could be eliminated with the implementation of public safety measures around gas wells (such as the installation of containment ditches). Do you value such extra safety measures? Would you, for example, be willing to pay an extra fee of _____ per month to your electricity bill for the secure knowledge that an accident would never occur?
>
> YES NO

The extra fee could take on a value of US$2, US$4, US$8, US$16, or US$20 and varied randomly across survey respondents. As displayed in Figure 1, 76 percent of respondents were willing to pay an extra US$2 on their electricity bill for the secure knowledge that an accident would not occur with the Marcellus Shale drilling. However, only 30 percent would be willing to pay an extra US$20 per month.

Guidelines issued by the National Oceanic and Atmospheric Administration for conducting contingent valuation survey methods suggest that an effective survey will have a "clear and believable description of the status quo and change." The ideal survey instrument would provide respondents with a specific list of expected environmental consequences to wildlife, human health, and the natural environment from shale related contamination. Respondents would then know what dangers exist and could make a choice over how much they value safety from these risks. But little is known regarding the potential threats to water from the shale gas industry, nor is it known how often contamination might occur. Any efforts to make a "clear" description of the potential change to the status quo from contamination necessarily diminish "believability," since specific threats are largely unknown.

Therefore, rather than presupposing a specific but purely hypothetical list of environmental costs and contamination likelihoods, some of which have already been well estimated in the literature cited above, this process purposefully keeps things vague. At measure is the current state of individual perceptions of the risks. Bockstael et al. [1989] took a similar approach when stating, "perceptions of water quality are not easily linked to objective measures, and because individuals do not easily understand these scientific measures, the gauge in acceptability in this analysis rests with the individual." Even though the risks imposed by the shale gas industry cannot be yet specified, current perceptions of these risks are developing,

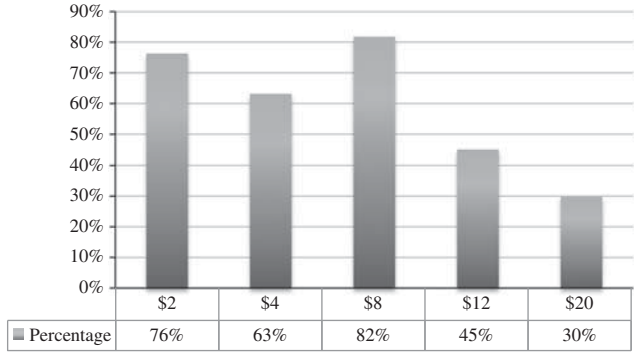

Figure 1. WTP for safety measures.

may be affecting public policy, and can be measured. An estimated positive WTP for safety measures suggests the perception of risk is not zero.

Each respondent was then read the following statement:[7]

> Several projects have been planned by local governments and environmental organizations to increase access to the Susquehanna River for public use and enjoyment. For example, Columbia, Montour, and Union counties are looking to develop a trail system connecting regional parks with river communities. The project will benefit the local business and encourage healthy living style for people of all age. Other projects may include recreation enhancement, education, community revitalization, and economic development.

followed immediately by this question:

> Do you support such projects? Would you be willing to pay _____ per month in additional taxes for increased river access?
> Yes No

The question is hypothetical in nature, and is meant to capture whether or not respondents value broadly defined access to the river.

The extra tax could take on a value of US$2, US$4, US$8, US$12, or US$16, and varied randomly across survey respondents. Figure 2 summarizes responses to this question. Eighty-five percent of those surveyed indicated that they would pay a monthly tax of US$2, but only 37 percent reported a WTP for a tax of US$16 per month.

ECONOMETRIC MODEL

The research question at hand is what value households in the Susquehanna Valley place on increased access to the river and for increased safety measures to protect the quality of the river from contamination from hydraulic fractioning process associated with shale gas extraction. This value is represented by the maximum an individual would be willing to pay for either issue. Following Cameron and James [1987], let Y_i^* denote this maximum WTP for the issue by household i ($i = 1, \ldots, N$). Assume the maximum WTP is a linear function of various household characteristics such as income, education level, gender, and others. Call these

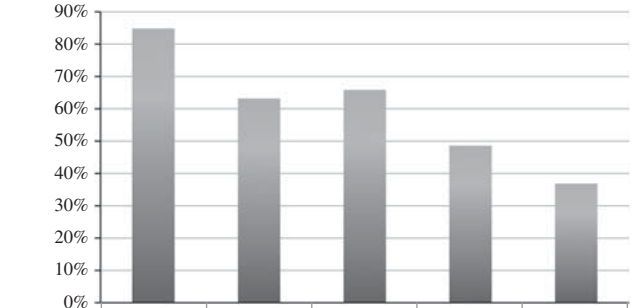

Figure 2. WTP for river access.

demographic characteristics X_1, X_2, and so forth up to X_K. That Y_i^* is a linear function of these demographic variables suggests $Y_i^* = \alpha + \beta_1 X_1 + \cdots + \beta_K X_K + \mu_i$, where u_i represents unobserved variables that could affect WTP. The mean value of these unobserved effects across the sample of individuals (μ_i) is zero with constant variance of σ^2. Assume the role these unobserved variables play in determining a household's maximum WTP are drawn from a normal distribution and are independently and identically distributed.

We do not observe actual WTP (Y_i^*), and instead only observe whether or not the individual responded yes or no to a hypothetical option to pay some randomly determined value t_i. Let $y_i = 1$ if household i responded agreed to pay the sum t_i, and $y_i = 0$ if the household did not. Assuming rational individuals respond accurately to the hypothetical offer, y_i will equal 1 only if $Y_i^* > t_i$. More generally, the probability that any household's y_i is equal to 1, $Pr(y_i = 1)$ is,

$$\begin{aligned} Pr(y_i = 1) &= Pr(Y_I^* > t_i) \\ &= Pr(\alpha + \beta_1 X_1 + \cdots + \beta_K X_K + \mu_i > t_i) \\ &= Pr(\mu_i > t_i - \alpha - \beta_1 X_1 - \cdots - \beta_K X_K) \\ &= Pr(\mu_i/\sigma > t_i/\sigma - (\alpha - \beta_1 X_1 - \cdots - \beta_K X_K)/\sigma), \end{aligned}$$

where μ_i/σ is a standard normal random variable. Therefore we can write

$$Pr(y_i = 1) = Pr(1 - \Phi(t_i/\sigma - (\alpha - \beta_1 X_1 - \cdots - \beta_K X_K)/\sigma))$$

and

$$Pr(y_i = 0) = Pr(\Phi(t_i/\sigma - (\alpha - \beta_1 X_1 - \cdots - \beta_K X_K)/\sigma))$$

where Φ denotes the standard normal cumulative density function.[8]

Unbiased estimates of α and the β's can be found be first running an ordinary Probit model where the offered amount, t_i, is included as an independent variable in the non-linear regression of y_i on t_i, X_1, X_2, …, and X_K. This regression will provide estimates of $\delta_1 = -1/\sigma$, $\delta_2 = \alpha/\sigma$, $\delta_3 = B_1/\sigma$, and so forth. Note that from this regression it is easy to solve for $\sigma = -1/\delta_1$, $\alpha = \delta_2\sigma$, $\beta_1 = \delta_3\sigma$ and so on. Asymptotic standard errors of these estimated parameters can be obtained using a Taylor Series approximation as described in Cameron and James [1987].

These estimated coefficients can then be applied to predict the WTP by the average resident of the Susquehanna Valley region (Y_i^*). We identify the average resident as having the mean population value of each demographic characteristic in the model (the X's). The standard error for the predicted WTP is derived using a process outlined in Cameron [1991].

RESULTS

Two separate estimations were conducted. The first estimates the WTP for improved access to the Susquehanna River. The second estimates WTP for additional safety measures around Marcellus shale well drilling sites.

Improved river access

On the basis of survey results, the respondent with mean values on income and demographic characteristics is estimated to be willing to pay US$12.00 per month for public projects to improve recreational opportunities along the Susquehanna River. The 95 percent confidence interval of this predicted WTP is within the interval bounded by US$8.41 and US$15.59. The US$12.00 mid-point estimate can be multiplied by the total number of households in Montour (7,405), Northumberland (38,647), Snyder (14,085), and Union (13,748) counties to predict the annual benefits to Susquehanna River valley households of public projects to improve access to the river at nearly US$10.64 million per year.[9] Assuming the river project has a 25-year life span and assuming a social discount rate of 2 percent, the discounted benefits of river access projects in central Susquehanna region are US$207.73 million. If instead the improvement project is designed for enjoyment by a localized population such as the residents within a single river town or county, then estimated benefits are US$2,811 per household served by a river project with a 25-year life span. Multiply this per-household amount by the number of affected households to obtain the local benefits to households from the local river access project.

Other variables gathered by the survey allow us to estimate how the predicted WTP varies with changes in household income and demographic characteristics. The estimated coefficients on these demographic characteristics are provided in Table 3. The standard errors allow for a test on whether the statistical relationship

Table 3 Willingness to pay for river access projects

Variable	*Coefficient*	*Standard error*	*Significance*
Constant	14.521	5.854	5% level
FREQUENCY	−0.009	0.0116	—
INCOME	0.047	0.053	—
RURAL	−3.252	2.574	—
RENTER	1.948	3.290	—
CHILDREN	−0.173	1.144	—
AGE	−0.144	0.098	—
COLLEGE	2.583	2.989	—
MALE	3.791	2.830	—
σ	11.645	2.791	1% level

$N = 177$; Log likelihood of original regression = −92.416.

observed in the sample between each characteristics and the WTP is sufficient to confidently reject the possibility of no such relationship in the overall population. The high standard errors relative to the estimated coefficient do not allow for the rejection of no relationship. None of the variables are themselves statistically different than zero, but a few are discussed here.

Holding constant all other household characteristics, the estimated WTP per month in the sample decreases by an average of 0.9 cents for each day per year the respondent visits the river. For example, a person that visits the river twice per week (104 times per year) would be willing to pay US$0.47 less per month for public projects designed to improve access to the river than a person that visits the river only once per week. These respondents might prefer to leave the river in its current state. The extra crowds attracted by the river project might interfere with a familiar use of the river. Controlling for other variables, the amount a person in the sample is willing to pay each month for the project increases for renters (relative to home owners), college graduates, those with higher incomes, and males. WTP in the sample decreases for rural residents, residents with children, and older residents. For example, a respondent decreases reported WTP by an average of US$1.44 for each decade of age.

The estimated coefficient on σ is statistically significant. This result implies that the likelihood a respondent agreed to pay a specified amount for improved river access decreases with the value of that amount.

Safety measures

On the basis of survey results, the average Pennsylvanian is estimated to be willing to pay US$10.46 per month for added safety measures to secure the environment from well accidents. The 95 percent confidence interval for this estimate is within the US$6.73 to US$14.19 interval. On the basis of the four-county population in the region, the total value households place on these safety measures in US$9.27 million per year. If the life span on these measures is 25 years, then repeated benefits to households for the next 25 years are valued at US$180.98 million given a social discount rate of 2 percent.

Table 4 provides the estimated coefficients predicting how each household demographic characteristic affects the sample WTP for additional safety measures. WTP increases by 1.6 cents for each day of a respondent visits the river. Comparing

Table 4 Willingness to pay for safety measures

Variable	*Coefficient*	*Standard error*	*Significance*
Constant	5.511	6.679	—
FREQUENCY	0.016	0.015	—
INCOME	−0.053	0.062	—
RURAL	0.353	2.862	—
RENTER	6.287	4.083	—
CHILDREN	7.480	3.316	5% level
AGE	0.018	0.105	—
COLLEGE	8.467	3.903	5% level
MALE	1.222	2.939	—
σ	13.865	3.122	1% level

$N = 177$; Log likelihood of original regression = −105.736.

these results with those above suggests that although frequent river visitors in the sample are less supportive of improved river access, they are more supportive of safety measures designed to protect the watersheds from frac water. Reported WTP in the sample is roughly equivalent for rural versus urban households, males versus females, low income versus high income, and young versus old. Renters in the sample are unexpectedly estimated to pay more than owners for the safety measures. None of these results, however, are statistically significant — these patterns that emerge in the sample cannot confidently be extended to support statistical relationships for the regional population.

Two household demographic characteristics are statistically significant, suggesting sample responses are consistent enough to make confident predictions about trends in the population. First, having an additional child under the age of 18 is estimated to increase a respondent's WTP by US$7.48 per month. Perhaps, these respondent's fear the consequences on their children's health from a gas well accident. Second, respondents completing college are estimated to pay US$8.48 more than those not completing college. Perhaps educated individuals are more aware of the environmental threat posed by the drilling process. The low estimated standard errors on these two coefficients suggest that across the entire regional population, having young children and earning a college degree positively affect WTP at the 95 percent confidence level.

The estimate of σ is once again positive and statistically significant. This result once again suggests that the likelihood that a survey respondent said "yes" to an offered payment decreased with the value of that payment.

ALTERNATIVE SPECIFICATIONS

Starting point bias

Two separate versions of the surveys were issued to respondents at the three area DMV's. The only difference between the two versions of the survey was the ordering of the two WTP questions. The concern, well established in the literature, is that the amount offered to the respondent for first question may serve as a starting point bias affecting responses to the second question [Weber and Stewart 2009]. For example, if two respondents were provided with separate amounts to the first question (US$2 and US$16, for example) and were both were presented with an US$8 amount for the second question, then the household facing the initial US$16 may be more inclined to say yes to the comparatively low US$8 value than the household facing the comparatively high US$8 value. In addition, individuals facing repeated WTP questions can suffer fatigue in the sense that they are less willing to pay for follow up questions after saying yes to earlier question. Alternatively, individuals might also be more inclined to say yes after an initial "no" to please the surveyor.

Any of these behaviors could potentially distort estimates of WTP for river access and safety. Although we have no way of knowing how the behavior of any given respondent might be affected, by varying the order of the questions we are able to control for these problems. First, the percentage of households saying yes to the river access question was 57 percent if this question was asked first and 59 percent if asked second. The percentage of respondents stating "yes" to the safety question was 59 percent if asked first and 58 percent if asked second. These comparisons support no major bias, but to further test for starting point bias, we estimated the model again using only the subset of responses that were given first, and deselected all data points

where the question was answered second. The average predicted WTP for river access decreased from US$12.00 to US$10.01 per respondent per month. This result suggests households may have been slightly more inclined to hypothetically pay the stated amount for improved river access if this question was asked second rather than first. The average predicted WTP for safety measures to avoid risks from shale drilling decreased only slightly from US$10.46 to US$10.11 per household per month. Responses here were rather robust to the ordering of the question. As a whole, these results suggest that starting point bias may not be problematic in these data.

Protest votes

Another issue that arises with WTP surveys is the possibility of a protest vote [Bateman et al. 2006]. Some individuals might decline an offer to pay a given amount because of reasons unconnected to the value the individual might place on the attribute. To explore for this possibility, those respondents that were unwilling to pay the stated amount were asked to indicate why. The survey provided several possible reasons such as limited income levels or the lack of concern for the issue. But six (6) households indicated they were unwilling to pay an amount because they believe that only the industry should actually pay for the added safety measures. These respondents might indeed value the added safety measures, but refuse to reveal this value. We re-ran the safety regression again while removing these six protest votes. The average estimated WTP is expected to increase after removing negative responses. In this case, the average estimated WTP increased only slightly from US$9.19 to US$9.51 per household per month. Protest voters did not appreciably affect the estimated WTP.

Including those that refused to respond to the survey

Several studies in the literature assume that all individuals that refused to respond to the survey would have responded negatively to the WTP question because by not participating they are revealing the fact that they do not care about the issue. This self-selection bias would be particularly problematic if the survey teams approached each individual with a statement such as "would you take a few minutes to respond to a survey *about the Susquehanna River*." Those with no interest in the river might have no desire to participate in the survey — the sample would not represent the regional population. Our survey teams avoided this strategy and instead simply introduced themselves as university students conducting a survey.

But if we assume that individuals refusing the survey would have responded negatively, then the estimated WTP for improved river access and additional safety measures decrease from US$12.00 to US$7.39 and from US$10.46 to US$6.44 per household per month, respectively. These lower predicted values have been interpreted in the literature as representing a lower bound [Andrews 2001; Zhongmin et al. 2003; and Collins et al. 2005].

CONCLUSION

This paper estimated household WTP for two issues related to the Susquehanna River and its watershed. A random sample of 186 drivers suggested that respondents are willing to pay an average of US$12.00 per month (with a lower bound of

US$7.39) for public projects designed to improve access to the Susquehanna River and US$10.46 per month (with a lower bound of US$6.44) for additional safety measures to eliminate risks to local watersheds from drilling for natural gas from underground shale formations.

Both of these results can help inform cost-benefit analyses. If the net present value of the costs to construct and maintain 25-year river access projects available to all area residents is less than US$204.61 million, then the project has positive net benefits. If instead the improvement project is designed for enjoyment by a localized population such as a single river town or county, then the benefits are US$2,881 per household. If the gas extraction industry is able to implement additional safety measures that would reduce to zero the likelihood of an accident for the next 25 years for a cost of less than US$178.25 million, then the benefits to households make such safety measures economically efficient.

Notes

1. All reported WTP values from the literature have been converted to 2010 dollars to facilitate comparison across studies.
2. A 20-year old would be renewing a license originally issued at the age of 16 — the legal minimum age to drive in Pennsylvania.
3. The survey was first tested door-to-door on a group of 30 households. Revisions to the survey were made based on experiences gained during this pilot effort.
4. http://www.census.gov/ (accessed July 3, 2010)
5. As a courtesy, we only asked individuals to report age in terms of decades, and used the median of decades to represent testers' age. For example, if a gentleman indicated he was in his 40s, we would enter 45 as his age. With a sufficiently large sample size, this process will not bias the average age in our sample.
6. Clearfield County is in the Susquehanna watershed approximately 130 miles west of the confluence of the north and west branches of the Susquehanna River.
7. A complete survey instrument is available from the authors on request.
8. This econometric model departs from the common Probit model by the introduction of t_i. See, Cameron and James [1987] for additional details of the model or the estimation method.
9. The number of households in each country is obtained from the 2010 US Census.

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