Effects of Uncertainty on Support for Water Quality Improvement Programs

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1. Introduction

Privately owned residential onsite wastewater treatment systems (OWTS), or septic systems, are gaining attention as a source of waterborne contaminants. While OWTS were originally intended for low-density, rural communities, high concentrations have emerged in suburban metropolitan areas across the United States. For example, in 2004, 50% of new homes in Michigan were built with septic systems; the 15 counties surrounding Atlanta, GA, contain more than a half million septic systems, with 12,000 being added each year (MNGWPD, 2009). The impact of these systems on water quality and quantity is an important water resource issue for urbanizing landscapes (Burns et al., 2005; Landers and Ankcorn, 2008). While it is understood that malfunctioning septic tanks contaminate surface and/or groundwater, recent studies indicate that even properly functioning septic tanks can contribute significant quantities of pollutants, especially after high precipitation events (Arnade, 1999; Habteselassie et al., 2009). The principle contaminants are pathogens, organic pollutants (e.g., hormones), and nutrients, each of which pose a significant threat to human and wildlife health, and ecosystem function.

Microbial contamination of water bodies is commonly associated with OWTS. In Georgia, over 600 stream segments are listed as impaired by fecal coliforms (GDNR, 2011), with OWTS identified as one of the non-point sources of fecal contaminants (GDNR, 2002). Lipp et al. (2001) used cluster analysis to demonstrate that sampling stations close to high density OWTS were exposed to high risk of fecal pollution and enteric viruses. Using antibiotic resistance analysis for source tracking, Carroll et al. (2005) found that the percentage of human *E. coli* isolates increased significantly in the surface water of urban areas where there were high density OWTS compared to rural areas where the source of contamination was mainly nonhuman. Further, research has shown other pathogens emerging from OWTS. For example, using viral tracers DeBorde et al. (1998), Paul et al. (2000),and Scandura and Sobsey (1997) have shown that viral pathogens can travel quickly from OWTS to nearby coastal surface and ground waters posing health risks to people and animals.

A second significant issue from the expanding number of OWTS in urbanized areas is the contamination of waters from hormones, a contaminant of emerging concern (Hale and La Guardia, 2002). A number of steroidal estrogens (17ß-estradiol (E2), estrone (E1) and estriol (E3)) are harmful to aquatic life and humans because of their potential to impact endocrine systems, affecting reproduction and development (Ying et al., 2002). The occurrence of male vitellogenesis (secretion of a female specific protein called vitellogenin) and intersexuality in wild fish (feminization of male fish) is associated with the presence of hormone steroids in waters impacted by sewage effluent (Jobling et al., 1998). Concentrations as low as 1 ng $L^{-1}$of E2 are enough to cause vitellogenesis in male trout (Hansen et al., 1998). This is alarming considering that steroid hormones (including E2) have been detected in sewage effluents (Ternes et al., 1999), streams (Kolpin et al., 2002), and groundwater (Peterson et al., 2001) at concentrations higher than 1 ng L^{-1}. Studies have also linked chronic ingestion of endocrine disrupting chemicals to cancer (Jobling et al. 1998). Humans are a major source of hormones and septic tanks contain steroid hormones in significant concentrations (Swartz et al., 2006). Studies have shown that OWTS do not achieve complete removal of these hormones or other endocrine disrupting surfactant metabolites before releasing wastewater to the environment (Desbrow et al., 1998; Swartz et al., 2006; Conn et al., 2006; Conn et al., 2010).

The primary nutrient concern with OWTS has been elevated nitrate concentrations in ground or surface waters that can cause blue baby syndrome (Beal et al., 2005). Many studies have shown that nitrogen losses from OWTS can cause elevated nitrate concentrations in groundwater immediately below or down gradient of these systems (Bernhardt, et al., 2008; Gold et al., 1990; Kaushal et al., 2006; Postma et al., 1992). Several studies have attributed nutrient contributions to OWTS at the watershed scale (e.g., Harman et al., 1996; Hatt et al., 2004; Gill et al., 2009; Maizel et al., 1997), but only a few have confirmed the origin of the nutrients using source tracking techniques (Aravena et al., 1993; Silva et al., 2002). More recently, nitrogen of any form has become a concern in surface waters where eutrophication is an issue. Although surface waters are most sensitive to phosphorous, nitrogen also stimulates algal growth and the threshold concentrations can be quite low. For example, in the draft EPA standards for total nitrogen in Florida waters, the critical concentrations range from 0.51 to 1.87 mg L^{-1}, depending on the type of water body and region (USEPA, 2011). A Total Maximum Daily Load (TMDL) developed for Lake Allatoona, a large reservoir just north of Atlanta, includes nitrogen and phosphorous limits and attributes part of the nutrient load to OWTS (GDNR, 2009).

Given the emerging recognition that there is a significant public health and ecosystem threat from existing privately owned OWTS in urbanized areas, several costly approaches to reducing contamination of waters exist. An effective solution would be to expand sewer service to more residential areas in order to replace the use of OWTS. However, this approach is hindered by high costs and regulatory hurdles such as existing wastewater treatment facility discharge permits that are often prohibitive. In lieu of supplanting existing residential OWTS, previous studies have explored the feasibility of methods such as riparian buffers, constructed wetlands, and fertilizer restrictions for reducing contaminant levels in watersheds (Ribaudo et al., 2001; Kramer et al., 2006).

A third approach, which is the focus of this study, is improving the performance of existing septic systems by retrofitting upgrades to reduce pollutant loads. While upgrading residential OWTS has the potential to reduce watershed contamination and associated health risks, there are two major policy hurdles to implementing the upgrades: public financing design and uncertainty. Current septic system owners are legally responsible for maintaining their systems, but requiring them to upgrade otherwise well-functioning tanks is outside the scope of current regulations. An incentive structure is necessary to induce private homeowners to invest in OWTS upgrades that deliver both private benefits for homeowners with existing septic tanks in addition to the positive externality for the wider public and environment. The question for policy makers is how these private incentives should be financed, and whether public support can be garnered.

Complicating this decision is the issue of uncertainty, which arises from several sources. First, the probability of failing to meet water quality standards (hereafter referred to as the "probability of failure") under current conditions is dependent on a variety of factors, some of which are stochastic, and largely unknown. Second, the ability of a particular policy intervention, such as septic system upgrades, to affect the probability of failure is also unknown. This is true in many areas of environmental policy, from water quality to air quality to climate change. While actual damages associated with degradation of environmental quality may follow a continuous marginal damage function, water quality standards in the United States are demarcated by designated uses that are either met or not met. As such, policy options, particularly at the state and local level, are often designed around the goal of meeting water quality standards. There is, in effect, a policy-oriented damage function in which the risk of not meeting a standard is of particular interest.

In order to assess the acceptability of different public financing mechanisms for upgrading privately owned OWTS in a setting with uncertain benefits, a choice experiment was conducted with current homeowners in Gwinnett County, GA. The choice experiment focused on three attributes critical for the design of a publicly financed water quality improvement policy. . These include how funds are collected (e.g., property tax vs. household water bills), how the burden of the cost is split (e.g., equal vs. unequal cost sharing between septic and sewer households), and the uncertainty surrounding policy efficacy, namely, how the upgrade would affect the probability of water quality standards not being met. Understanding the weight the public places on these attributes is essential to effective policy design, communication of policy objectives, and, ultimately, securing public support for and cooperation with policy implementation.

The remainder of the paper is organized as follows. In the next section the survey design, sampling procedures, and choice experiment attributes are described. Then, the following section presents regression estimates for responses in the choice experiment. In the final section we conclude with a discussion of the policy implications of the choice experiment results.

2. Survey Design and Data

To assess the willingness of homeowners to use public financing mechanisms to partially defer the cost of upgrading privately owned septic systems, an internet survey and choice experiment was administered in the spring of 2013 to a random sample of Gwinnett County, GA residents. The survey consisted of three key components: (1) prior knowledge and attitudinal questions regarding water quality in Gwinnett County, (2) a choice experiment over alternative policy solutions for uncertain water quality improvement, and (3) basic socio-demographic questions. With the assistance of Survey Sample, International, a panel of 2,096 eligible residents was constructed. Individuals were contacted via telephone and asked whether they would be willing to participate in the web-based survey. Of the 1,165 individuals who agreed and either provided an email address or asked for a direct link to the survey, 334 individuals completed the entire web-based survey yielding a response rate of 15.9%.

Table 1 provides a summary of the characteristics of the survey respondents compared to Gwinnett County residents. The sample has slightly higher income, is older, more educated, and more Caucasian than the county as a whole.

Thirty-seven percent of the sample lived in residences with septic systems, but only 35% of them reported pumping their septic tanks every 1-6 years; the recommended pumping frequency is every 5 years. Despite the infrequent pumping, only 26% have experienced problems with their septic systems.

The majority of survey respondents (59%) rated water quality in the area as “good” or “very good,” with 90% of homeowners stating water quality is at least adequate compared to 70% of renters who felt that way. Nonetheless, on average the sample respondents felt there is a 48% chance that local streams will fail to meet water quality standards. Industrial discharges and runoff from roadways were identified as the most likely contributors to water quality impairments.

The study location, Gwinnett County, Georgia, was selected specifically for this study for several reasons. Gwinnett is the second largest county in Georgia, part of the greater Atlanta metropolitan area, and has experienced tremendous population growth between 1970 and 2010 from about 70,000 to over 800,000 residents (CITE CENSUS). Accompanying the rapid population expansion in Gwinnett County has been widespread installation of residential septic systems (see figure 1) and water impairment issues. Elevated levels of fecal coliform are responsible for 85% of the impaired streams in the county.

Given the size and density of Gwinnett County and the significant number of installed septic systems, all policy options to improve water quality are costly. Estimates suggest that depending upon the retrofit technology and installation costs upgrading all septic systems in Gwinnett County could cost between $400 million and $1.2 billion.

Table 1.Descriptive statistics of the sample and the Gwinnett County

	Sample	**Gwinnett County**
Sample size	241	n/a
Male (%)	48.4	49.3
Median age (18+)	62.33	40-44
Household has at least one child (%)	49.51	45.6
White/Caucasian (%)	65.97	53.3
Education		
Less than HS diploma(%)	0	12.9
High school or equivalent(%)	9.9	23.2
Some college or associate's degree (%)	31.23	29.3
College graduate or higher (%)	58.85	34.7
Income		
Median income category	$75,001-$100,000	$70,258
Homeowners (%)	84.51	70.4
Member of environmental organization (%)	7.81	n/a
Septic users (%)	37.09	n/a
Sewer users (%)	62.48	n/a

Stated probability of failure (mean value, %)	47.41	n/a
% of people who believed probability of failure is >50%	39.46	n/a
Probability their Opinions could Influence Local Policy (PROBInfluence) (mean value, %)	21.58	n/a
% of people who believed PROBInfluence is >50%	18.41	n/a

*Education data from U.S. Census Bureau, 2007-2011 American Community Survey.

**Demographic data from 2010 U.S. Census.

3. The Choice Experiment

The core component of the internet survey was the choice experiment designed to elicit individual preferences for alternative policy options. Choice experiments, which are commonly employed in the environmental literature (e.g., Hanley, wright, and Adamowicz 1998; Revelt and Train 1998; MORE), entail presenting respondents with a series of scenarios in which they must make a choice between alternative options with varying attributes. In each scenario, respondents were asked to make a choice between two different policy options for upgrading septic systems or staying with the current status quo. Attributes for the different options of upgrading existing septic systems were selected based upon consultations with Gwinnett County officials, water quality experts, and existing estimates of program costs. The attributes and respective levels of the upgrades are listed in table 2 and discussed below.

Table 2. Choice Scenario Attributes and Levels

Attributes	**Levels**
Policy Options	
Payment Vehicle	Water bill flat fee, property tax flat fee, SPLOST revenue
Cost Share (Septic/Sewer)	50/50, 70/30, 30/70
Total Cost of Upgrade Program	\$200 million, \$300 million, \$400 million
Decrease in Probability of Failure Under Action Alternatives	10%, 50%, 90%
Status Quo	
Probability of Failure Under Status Quo	20%, 50%, 90%

Rather than specify one payment vehicle for all scenarios, payment vehicle is included as an attribute in the survey. From discussions with Gwinnett County, it was determined that a property tax increase, a water bill fee, and a Special-Purpose Local Option Sales Tax (SPLOST) referendum are three likely payment vehicle options. A property tax or water bill increase may be levied for county residents, and the amount of the additional fee may vary depending on whether the homeowner has a septic system or not. Alternatively, a SPLOST may be levied which would accrue funds from county residents and non-county residents. We later test the hypothesis that SPLOST will be most preferred because it is the only vehicle where part of the funds would come from non-resident shoppers, lowering the cost share paid by county residents.

Cost share levels denote the division of costs between households with septic systems versus households on sewer, and include 50-50, 70-30, and 30-70 (septic-sewer). For example, at the 70-30 level, septic users pay 70% of the total costs and sewer users pay 30%. We test the hypothesis that individuals will prefer alternatives where their group (septic or sewer users) pay a lower share of the program costs.

The total estimated cost attribute has three levels: $200 million, $300 million, and $400 million. The highest total cost level, $400 million, reflects the minimum cost of retrofitting all septic systems in the county and was calculated based on estimated costs for the septic retrofit and the estimated number of septic systems in the county. The lower cost levels are intended to reflect the costs of retrofitting a subset of septic systems. The choice set design assigns a total estimated cost level, cost share level, program effectiveness level, and payment vehicle to each action alternative in each choice set. To calculate the total cost to each household for a particular choice set alternative, the total estimated cost for that alternative is divided among septic users, sewer users, and out-of-towners according to the specified cost share level and payment vehicle level. Our initial hypothesis is that individuals will prefer alternatives where the cost to them is lower. Because the total cost per household was high and may cause sticker shock, costs were broken up into annual payments over a period of 2-5 years. Costs are the same for each model due to the uncertainty of the upgrade program's efficacy. Even if the highest level of implementation is chosen, there is uncertainty about the degree to which water quality will improve.

To allow for a continuous variable and account for uncertainty, water quality is defined as the probability that streams in Gwinnett County will fail to meet water quality standards (probability of failure). To incorporate uncertainty about the current state of water quality in Gwinnett County, we considered three different status quo probabilities of failing to meet water quality standards, 20%, 50%, and 90%.

The water quality improvement attribute for the septic system retrofit policy alternatives is defined as a percentage decrease in the probability of failure from the baseline status quo probability of failure. The levels of the actual attribute are the same for each model – a 10%, 50%, and 90% decrease in probability of failure – but the calculated probability of failure varies according to the baseline probability of failure for each model.

To reduce the cognitive burden for respondents, the attributes and levels presented in table 2 were converted into a straightforward breakdown of costs for participants under each of the three different status quo states considered. Table ### presents a summary of the attributes, levels, and status quo features presented to respondents. Figure ### presents an example choice scenario that was displayed for individuals to make their decision.

Table 2. Choice Scenario Attributes and Levels

Attributes	**Status Quo**	**Levels for Septic System Upgrades**
Chance of Meeting Water Quality Standards	20%	2%, 10%, 18%
	50%	5%, 25%, 45%
	90%	10%, 45%, 80%
Certain Costs: How Certain Costs are Paid	N/A	INSERT, Flat fee added to annual property tax bill over 5 years, Revenue from 2-year SPLOST referendum (1% sales tax),
Certain Costs: How Certain Costs are Shared	N/A	50/50/0, INSERT
Certain Costs: Annual Cost to Septic Users	$0/household	
Certain Costs: Annual Cost to Sewer Users	$0/household	
Uncertain Costs: Costs to All Residents if Water Quality Standards are Not Met	$1500/household	

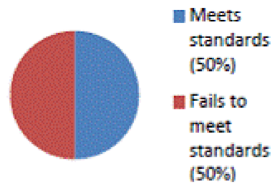
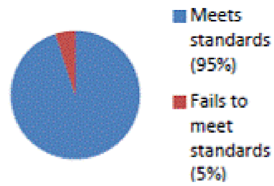
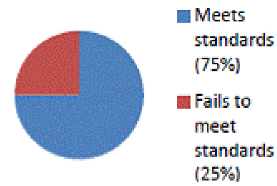
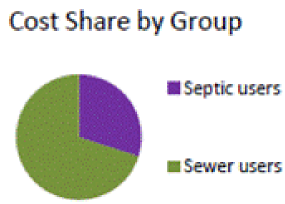
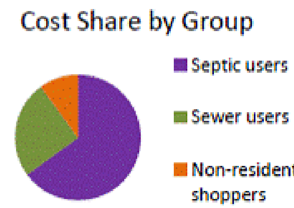
Characteristic	Option A	Option B	Option C
Action	Do nothing	Septic System Upgrade	Septic System Upgrade
Chance of Meeting Water Quality Standards			
Certain Costs: How Certain Costs Are Paid	No certain costs to pay	Flat fee added to annual property tax bill over 5 years	Revenue from 2-year SPLOST referendum (1% sales tax)
Certain Costs: How Certain Costs Are Shared	No certain costs to share		
Certain Costs: Annual Cost to Septic Users	$0/household	$100/household for 5 years	$600/household for 2 years
Certain Costs: Annual Cost to Sewer Users	$0/household	$140/household for 5 years	$400/household for 2 years
Uncertain Costs: Costs to ALL Residents if Water Quality Standards Are Not Met	$1500/household total	$1500/household total	$1500/household total

Figure ###. Example Choice Scenario

Ngene was used to generate orthogonal, main-effects-only fractional factorial designs. Taking into consideration the trade-offs between D-efficiency and number of choice sets per respondent, a 12 set design was selected with a D-error of 0.138. To further minimize the cognitive burden on participants, the 12 choice sets were randomly blocked into four blocks of three choices each. Each choice set contained one status quo alternative and two different septic upgrade programs (action alternatives). In the next section, three separate models will be estimated, each corresponding to a different "status quo" water quality level. Each model had the same design, and so each participant saw three choice sets for each model, a total of nine choice sets.

4. Data Analysis

To model responses to the choice experiment, three separate conditional logit models were estimated, one model for each status quo probability of failure. In each model, the variables presented in table ### were included.

Variable	Description
COST	Total cost of the septic upgrade program to each household, continuous variable ranging from $400 to $1800
PROBFAIL	Probability that county streams will not meet water quality standards, continuous variable ranging from 2% to 90%
PTAX	=1 if total cost is paid via a flat fee added to the household's annual property tax bill over 5 years
WBILL	=1 if total cost is paid via a flat fee added to the household's water bill over 5 years
IPAYLESS	=1 if respondent's group (septic or sewer) pays a smaller proportion of the total program costs
IPAYMORE	=1 if respondent's group (septic or sewer) pays a larger proportion of the total program costs
SQ	=1 if status quo alternative

	Model 1 Estimates SQ PROBFAIL=.90	Model 2 Estimates SQ PROBFAIL=.50	Model 3 Estimates SQ PROBFAIL=.20
COST	-0.0006***	-0.0011***	-0.0004**
	(0.0002)	(0.0002)	(0.0002)
PROBFAIL	-1.1382***	-3.3961***	-5.4215***
	(0.2512)	(0.4375)	(1.0372)
PTAX	0.3494**	0.0343	0.2931*
	(0.1676)	(0.1639)	(0.1690)
WBILL	0.3269**	0.0872	0.1940
	(0.1512)	(0.1450)	(0.1495)
IPAYLESS	-0.4894***	-0.1190	-0.3029*

	(0.1618)	(0.1574)	(0.1552)
IPAYMORE	-0.6716***	-0.3402**	-0.4795***
	(0.1724)	(0.1656)	(0.1592)
SQ	-1.2069***	-0.7599***	-0.0244
	(0.2464)	(0.2416)	(0.2381)
Sample size	2115	2169	2169
Log-likelihood	-641.2157	-695.0222	-739.6808
Pseudo *R*	0.1721	0.1250	0.0688
Correct predictions (overall)	74.75%	71.60%	68.83%
Status quo	85.67%	76.76%	70.12%
Alt 1	70.50%	68.19%	69.16%
Alt 2	68.09%	69.85%	67.22%
IIA Test (Chi-sqrd value)			
Status quo dropped	10.85*	3.76	14.54**
Alt 1 dropped	12.68**	2.63	15.74**
Alt2 dropped	7.73	5.36	2.95

Standard errors in parentheses.

***p<.01, **p<.05, *p<.10

Payment vehicles relative to SPLOST.

Cost shares relative to equal share, or 50/50.

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