The Structure of Farmers' Perceptions of Ground Water Pollution

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Abstract

Data from a 1992 Georgia Farm Practices survey are used to examine the structure of farmers' perceptions of ground water pollution and their support of regulations to protect ground water. Estimates of the influence of farm and farmer characteristics on pollution perceptions and support for pollution control were computed using a multiple-indicator model. Results show that the willingness to change farm practices to protect ground water is positively related to how an operator perceives the seriousness of the pollution problem. Regulatory policies that negatively affect farmers' income are likely to be opposed by farmers.

Key Words: factor analysis, latent variable model, water quality.

Agricultural activity can adversely affect ground water quality through the leaching of nitrogen fertilizers and pesticides (Keeney). At the same time ground water is a source of drinking water for almost 50 percent of the U.S. population, with over 90 percent of rural households drinking water from underground sources (Sarnat, et al; Walker and Hoehn). Further, nearly one-fourth of the U.S. population relies on ground water pumped from areas with a significant chemical use (Lee and Nielsen).

The U.S. Environmental Protection Agency (USEPA) revealed that more than 50 percent of the nation's wells contain traces of nitrate (Rahm). The survey, which was conducted in 1988-89, collected data from 1,300 wells in all 50 states. The survey results showed 19 million people are exposed to nitrates in wells with 1.5 million facing nitrate concentrations above the 10 parts per million (ppm) contamination level. The survey also found that 85 million additional people are exposed to nitrates in their community water systems, with three million experiencing nitrates over 10 ppm. Although only about 1.2 percent of the nation's community wells and 2.4 percent of its rural wells contain nitrates in amounts above the Federal maximum contaminant level the percentage is high in some parts of the country. For example, out of 191 rural drinking wells tested in southern Michigan, 34 percent exceeded the maximum contaminant level (Vitosh). In Massachusetts, more than 110 public wells have been closed (Sarnat, et al).

Over 500,000 private wells in Georgia are not under federal, state or local regulations for testing. Of these wells, 25 percent are shallow (less than 75 feet deep) and are at the highest risk for nitrate contamination (USEPA). Thus, drinking-water from 125,000 private wells throughout Georgia is a potential health hazard. In Georgia, 2.6 million people, or about one-third the state's population in 1986, obtain their water from ground water sources. Domestic wells in rural areas in the southern part of the state supply about one million people (Clarke and McConnell). A study conducted in 1990 (Tyson and Isaac) sampled 896 private wells in Georgia (343 shallow wells and 553 deep

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wells). The tests were to determine the percentage of wells above the U.S. EPA's primary and secondary drinking water standards. Primary standards included tests for lead, cadmium, chromium and nitrate-nitrogen. Secondary standards included iron, manganese, copper and zinc. The study found that 50 percent of the shallow wells in the Southern Coastal Plain of the state had levels of contaminants above the EPA's primary standards. The most prevalent contaminants were nitrates. Nearly 60 percent of the wells exceeded the secondary standards statewide, while 14 percent of shallow wells exceeded the primary standards.

Although progress has been made in reducing water pollution from point sources, policies directed toward non-point sources of pollution are needed. Agriculture is considered a major contributor to non-point source pollution. Formulation of successful policies to protect ground water against pollution from agriculture, requires the farmers' support. Therefore, it is important to understand farmers' perceptions of ground water quality and their preferences for policies to protect ground water. The objective of this paper is to study the structure of farmers' perceptions of ground water pollution and their support of ground water protection policies using data from a statewide survey of Georgia farmers.

Conceptual Model

Although ground water pollution may be objectively measured, there is always a difference between expert assessment of an environmental problem and public perceptions. Perceptions of ground water pollution will vary from one individual to another depending on the individual characteristics (such as education, income, age, etc.) and the environment in which he/she lives (i.e, information and personal observations can influence perceptions.)

Here we assume that farmers do not know the exact quality of their drinking water but have formed subjective perceptions of quality. We also assume that the farm's utility depends on water quality (WQ) and farm's profit (π). Both variables will be affected by the farmer's practices such as applications of fertilizers and pesticides. The farmer chooses those practices that maximize his/her utility. There is a tradeoff between WQ and π: while applications of fertilizers and pesticides increase profit, they may cause deterioration of water quality. Any regulatory policy on the use of fertilizers and pesticides will be looked at by the farmer from that angle. A farmer's support for such a policy will increase, ceteris paribus, as farmer's perceptions of risk from ground water increases. On the other hand, the farmer's support for the policy will depend on how it will affect his/her profit. For example, the farmer's production costs may increase or he/she may have to buy new equipment to reduce ground water contamination.

In mathematical notation we can write "pollution perceptions - from ground water" (η_1), and "support for regulatory policies - to protect ground water" (η_2) as:

$$\eta_1 = f(X_1;\alpha) \tag{1}$$

$$\eta_2 = g(X_2,\eta_1;\beta) \tag{2}$$

Where X_1 includes variables that describe the farmer such as education, age, income, knowledge of water pollution, etc.; X_2 includes farm characteristics and variables that describe farmer's beliefs about how changes in practices (regulatory policies) will affect his/her farm's profits; and α and β are unknown parameters to be estimated. In choosing which variables to include in X_1 and X_2, we were guided by other studies. Napier and Brown carried out a similar survey of Ohio farmers and their model is a basis for the choice of X_1 and X_2. Other studies that focus on farmer's perceptions of water quality (or environmental quality) and farmer's opposition to government regulations were also consulted (Dunlap and Van Liere; Ferris, 1983, 1985; Gillespie, Jr., and Buttel; Lichtenberg and Lessley; Napier, Camboni, and Thraen). table 1 gives the definitions and descriptive statistics for X_1 and X_2.

Generally, these variables fall into three categories. The first category contains variables that describe the farmer's beliefs about how changes in farming practices will affect (1) ground water pollution, and (2) the farmer's well-being. The first group of variables in this category (Farmer's

Beliefs-I in table 1) will affect the farmer's perceptions of ground water pollution. The second group (Farmer's Beliefs-II) will affect the farmer's support of regulations to protect ground water. The hypothesis here is: if farmers believe that practice changes will negatively affect their farm incomes, they will become less supportive of regulations.

The second category contains variables that describe the farmer (Farmer's Characteristics - table 1). Included in this category are variables such as age, education, income, and farmer's knowledge about ground water pollution. Most of the variables in this category are expected to influence both the farmer's perceptions of ground water pollution and support of regulations. Previous research has shown that older and less-educated people are more likely to be less supportive of regulations (to protect the environment) than younger and more-educated people (Gillespie and Buttel; Napier, Camboni, and Thraen). Napier and Brown have argued that financially successful farmers possess the ability to internalize regulation costs, and therefore are more likely to support regulations than less fortunate farmers. Gillespie and Buttel argue that off-farm work may be inversely related to regulations because it could make the economic implications of regulations less salient. Variables that measure a farmer's concern about drinking water (*OWNWELL*, *PROTECT*) are expected to positively influence both the farmer's perceptions of pollution and support of regulations.

Table 1. Definition and Description of Variables Used in Analysis

Variable name	Description	Mean
Farmer's Beliefs - I:		
NO_REDUC	Reduction of fertilizer application rates on my land would not reduce ground water pollution in this area. Likert scale: 1 if "strongly disagree" to 5 if "strongly agree."	3.7
Farmer's Characteristics:		
AGE	Age in years.	54 (50)[a]
EDUCATION	Years of formal education completed.	12 (13)
INCOME	Income categories: 1 for ≤ $5,000 to 27 for ≥ $130,000/per year in increments of $4,999.	6.57
OWNWELL	1 if has a water well for household consumption on farm, zero otherwise.	0.81 (0.90)
INFO	Number of information sources from which operator has received information about ground water pollution (choose from a list of 12 e.g., radio, tv, extension agent, etc.).	3.2 (3.8)
PROTECT	Number of ways used to protect family members from consuming contaminated water: bottled water, osmosis filtering, drill a new well, water from city/county system; equal one if respondent checked one used.	0.32
KNOWLEDGE	How knowledgeable operator believes he is about ground water pollution in county. Likert scale: zero for "no knowledge" to 10 for "very knowledgeable".	3.8 (4.3)
IPM	1 if operator ever participated in an integrated pest management program, zero otherwise.	0.08
OPERATE	Years has been operating farm.	22 (25)

Table 1. (continued)

Variable name	Description	Mean
FERT_PRO	Operator's feeling about participating in educational programs to reduce fertilizer rates while maintaining productivity. Likert scale: zero for "very unwilling" to 10 for "very willing".	7.1
Farmer's Beliefs - II:		
OFF-FARM	Days/year operator and spouse work off farm for wage.	183[b] (65)
PEST_PRO	Operator's feeling about participating in educational programs to reduce pesticides rates while maintaining productivity. Likert scale: zero for "very unwilling" to 10 for "very willing".	7.0
NEW_EQUIP	Adoption of farming practices that will improve ground water quality often requires purchase of new farm equipment. Five-category Likert scale: 1 if "strongly disagree" to 5 if "strongly agree."	3.0
LOWER_INC	Reduction of nitrogen application rates on my land would probably lower my net farm income. Five category Likert scale: 1 if "strongly disagree: to 5 if "strongly agree."	3.8
PRO_COST	How operator believes production costs would change if his/her farm was operated in a manner that would protect ground water from being polluted by farm chemicals. Likert scale: zero for "large decrease" to 10 for "large increase."	4.9 (5.0)
LOW_PEST	Most farmers in this area would reduce the amount of pesticides applied without significantly reducing productivity. Likert scale: 1 if "strongly disagree" to 5 if "strongly agree."	2.9 (3.3)
CUL_ACRE	Acres of land usually cultivated.	102.3 (536.2)
GRAINS	Percent of farm's income from grains during last 3 years (corn + wheat + soybeans.)	14
DEBT	Debt-to-asset ratio: 1 for ≤ 10 percent to 10 for 91-100 percent in increment of 10	2.50[c] (27.5)
GOVT_PRO	Number of government programs operator participated in during last 3 years. Respondent chose from a list of 9 programs.	1.00
IRRIGATED	Equal one if irrigation is used, zero otherwise.	0.19

[a] Numbers in parentheses are the averages from Napier and Brown - if reported and applicable.
[b] Napier and Brown reported Days\years for operator alone.
[c] Napier and Brown reported the percentage. To compare statistics, using midpoints our estimate would be 20 percent.

The third category contains variables that describe the farm (Farm Characteristics - table 1). This type of variables has been found to influence farmers' acceptance of regulations (Gillespie and Buttel). The effect of these variables will depend on how they relate to farm practices. For example, irrigated farms use more fertilizers and are more technology-intensive than non-irrigated farms. Therefore, irrigated farm operators can be expected to be less supportive of regulations than non-irrigated farm operators. Previous research has found farm size to be positively related to "opposition" to regulations of agricultural substances such as pesticides (Hoiberg and Bultena). Farmers with high debt-to-assets ratios are likely to oppose regulations because such regulations will add to their financial burden (Napier and Brown).

Finally, as noted earlier, "pollution perceptions" and "control support," in equations (1) and (2), are unobservable (or latent) variables. Indicator responses were needed to measure perceptions and preferences. Responses to a single question will not be appropriate for deriving such constructs because of the measurement problem associated with survey data (Kalton and Schuman). Most previous empirical analyses of public preferences have been based on responses to a single question (Ferris 1983; Gramlich and Rubinfeld; Hewitt; and Schokkaert). In this paper, observed responses to multiple questions were modeled as imperfect indicators of the true constructs (perceptions of ground water pollution and support of ground water protecting policies). This approach was used to reduce the measurement problem. The underlying constructs were then related to the observed farm's and farmer's characteristics using the linear structural relationships (LISREL) approach, as explained below. Responses to the indicator variables are summarized in table 2.

Data and Variables

This paper was based on a survey of Georgia farmers administered in the spring of 1992. The survey was designed to explore both the farmers' perceptions of ground water quality and how farm practices affect ground water quality in Georgia.

The survey was conducted in conjunction with a similar survey in Ohio and other midwestern states (Napier and Brown). Assisted by the Georgia Agricultural Statistics Service (GASS), systematic sampling was used in March 1992 to survey 1,000 of the 46,000 farmers in Georgia. It was followed by a reminder card in April 1992. A third mailing in May included another copy of the questionnaire. Of the 1,000 surveys, 60 were returned because recipients were no longer farming and 36 were returned as undeliverable or bad addresses. Therefore, the effective sample was 904. Out of these 904, 352 were returned completed, for a response rate of about 39 percent.

Although it might be low, such a response rate is not uncommon in mail surveys. Moreover, comparing some of our sample statistics with corresponding statistics from census data (Georgia Agricultural Statistics Service - GASS) indicates that our sample was representative. For example, the average farm size in Georgia in 1992 survey year) was 263 acres (GASS). Our sample produced an estimate of 221 with a standard error of 28. Therefore, the 95 percent confidence limits from our sample (i.e., 165 to 277) contain the GASS estimate. Similarly, the 95 percent confidence limits for the average farm income from our sample ranged from \$23,806 to \$36,894 which contain the GASS estimate of \$24,506. Also our estimate of the debt-to-asset ratio was 20 percent compared to 19.4 percent from GASS. Further, comparing our econometric results with those of Napier and Brown gave us more confidence in our sample.

The survey asked farmers asked about their perceptions of ground water pollution, fertilizer and pesticide use and the threat to the ground water supply, as well as sources of information regarding ground water pollution problems. The survey also sought information on the farm's and farmer's characteristics believed to have influenced farmer's perceptions of ground water pollution and preferences for action to control it.

Responses to eight statements related to ground water pollution are summarized in table 2. Respondents registered the intensity of their responses on a five-category Likert scale ranging from strongly agree to strongly disagree. Numerical values were assigned to the responses. Five was assigned to "strongly agree," four to "agree," three

Table 2. Views About Ground water Pollution: 1992 Georgia Farm Survey[a]

	Percent Respondents			
	Agree	Neither agree or disagree	Disagree	Mean (1 to 5)
1. Ground water pollution is an important environmental problem in my area	44 (39)[b]	34 (25)	22 (36)	3.3 (3.1)
2. Ground water pollution is not a problem on my farm	75	18	7	2.1
3. Agricultural fertilizers have significantly polluted ground water in my area	3 (7)	41 (24)	56 (68)	2.2 (2.2)
4. Pesticides do not contribute to ground water pollution in this area	40	41	19	2.8
5. Farmers should be forced to reduce application rates of farm chemicals to protect ground water resources	42 (28)	29 (25)	29 (46)	3.1 (2.7)
6. Farmers should be required to periodically test levels of ground water pollution on their farm	41 (40)	28 (30)	31 (31)	3.0 (3.0)
7. Farmers should be forced to change fertilizer application rates to reduce ground water pollution	30 (23)	34 (32)	36 (46)	2.8 (2.7)
8. Farmers who contribute to ground water pollution should not be permitted to participate in government farm programs	49 (43)	34 (36)	17 (20)	3.3 (3.3)

[a] For ease of exposition, the categories "strongly agree" and "agree" were combined into "agree", while "strongly disagree" and "disagree" were combined into "disagree." However, the analysis used all categories.

[b] Numbers from Napier and Brown - if reported and applicable.

to "neither agree nor disagree," two to "disagree," and one to "strongly disagree" for statements 1, 3, and 5 to 8. Therefore, agreement with these statements increases along the Likert scale. The scoring has been reversed for statements 2 and 4 as disagreement with these statements reflects perceptions of ground water pollution as a problem.

Exploratory Analysis

Ground water pollution is the unifying concept underlying the eight statements in table 2. However, the statements differ in wording, content, and focus. The eight statements can be classified into two groups. The first four statements measure the respondent's perception of ground water pollution or "pollution perception." An agreement with the first and third statements or a disagreement with the second and fourth statements indicates that the respondent perceived ground water pollution as a problem.

The second group (statements 5 to 8) measures the respondent's preferences for an action against farmers to protect ground water quality. We call the latent variable underlying these statements "control support." An agreement with these statements suggests that the respondent supports regulations to protect ground water.

Because the two constructs "pollution perceptions" and "control support" were unobservable variables (latent factors), factor analysis was used to study the relationship between the observed indicators (the eight statements) and the underlying latent factors. First, a principal factor analysis (PFA) (Harman) was conducted to help identify the number of latent variables. Results showed that only two factors had eigen values greater than one. Maximum likelihood factor analysis also suggested that only two factors had eigen values greater than the average of all eigen values. These two factors explained about 90 percent of the total variance. Moreover, a chi-squared (χ^2) test rejected a one-factor model as satisfactory with a $\chi^2(20)$ of 72.82, while a two-factor model could not be rejected with a $\chi^2(13)$ of 19.37. Therefore, two factors were retained and a varimax rotation of the factors was carried out (Harman). The rotated factor pattern revealed a structure similar to the grouping of the statements as suggested above (table 3). This structure is shown by loadings of 0.35 (or greater) for the statements on the two factors.

Econometric Method

Although the two hypothesized constructs are unobservable (i.e., latent variables), their effects on measurable (manifest) variables are observable and can be studied. A class of models that handles this type of variables is called latent variable models. A general model that involves multiple indicators of unobservable variables is the linear structural relationships (LISREL) model, and is used in this study (Joreskog and Sorbom, 1985; 1986; 1989).

The LISREL model consists of two parts, the measurement model (MM) and the structural equation model (SEM). The MM specifies how the unobservable variables (η) relate to the observed variables (y):

$$y = \Lambda \eta + \varepsilon \qquad (3)$$

where y and η are q x 1 and L x 1, respectively, Λ is a q x L matrix of loadings, and ε is a q x 1 vector of measurement errors. The SEM specifies the relationships among the η's and other explanatory variables, x (Px1 matrix):

$$\eta = B\eta + \Gamma x + \zeta, \qquad (4)$$

where $\zeta' = (\zeta_1, ..., \zeta_L)$ is a vector of residuals representing both errors in equations and random disturbance terms, the matrices B (LxL) and Γ (LxP) are regression weights to be estimated.

The following assumptions were made:

(a) $E(\zeta) = E(\varepsilon) = 0$

(b) ε is uncorrelated with η; ζ is uncorrelated with η and x, and ζ and ε are mutually uncorrelated.

(c) $B^* = (I - B)^{-1}$ is non-singular, where I is L x L identity matrix.

The variance-covariance matrices are defined below:

$$E[xx'] = \Phi \text{ (PxP)}$$
$$E[\zeta\zeta'] = \Psi \text{ (LxL)}$$
$$E[\varepsilon\varepsilon'] = \Theta \text{ (qxq)}$$

Given equations (3) and (4) and the above assumptions, the predicted variance-covariance matrix of y and x, Σ, is given by

$$\Sigma = \begin{bmatrix} \Lambda B^{*}[\Gamma\Phi\Gamma' + \Psi]B^{*\prime}\Lambda' + \Theta & \Lambda B^{*}\Gamma\Phi \\ \Phi\Gamma' B^{*\prime}\Lambda' & \Phi \end{bmatrix} \qquad (5)$$

The above LISREL model can be estimated by full information maximum likelihood (FIML) by fitting Σ to the observed covariance matrix, S, of y and x (Joreskog and Sorbom, 1985; 1986.) The FIML method gives consistent and efficient estimates of the model's parameters B, Γ, Λ, Ψ, Φ, and Θ. Assumptions and hypothesized relations between variables can be specified as restrictions on the model's parameters.

Imposing the restrictions implied by the relationships between the indicators (y-variables) and the two constructs (table 3), we write Λ' in the following form:

$$\Lambda' = \begin{bmatrix} \lambda_{11} & \lambda_{21} & \lambda_{31} & \lambda_{41} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \lambda_{52} & \lambda_{62} & \lambda_{72} & \lambda_{82} \end{bmatrix} \qquad (6)$$

while B is assumed to have the form:

$$B = \begin{bmatrix} 0 & 0 \\ 0 & B_{21} \end{bmatrix} \qquad (7)$$

Equation (7) implies that a person's perceptions of pollution can influence his/her preferences for pollution control. Equation (4) is thus a recursive system of simultaneous equations. For model identification and to ease interpretation, the scales of the constructs were fixed according to the

Table 3. Factor Analysis Results After Varimax Rotation

Statement No[a]	Rotation Results		Eigen Values Results	
	Factor 1	Factor 2	Factor	Eigen Value
1	0.30	0.41*	1	5.48
2	-0.05	0.54*	2	0.97
3	0.28	0.38*	3	0.42
4	0.20	0.51*	4	0.32
5	0.71*	0.25	5	0.11
6	0.66*	0.14	6	0.04
7	0.84*	0.13	7	-0.04
8	0.36*	0.08	8	-0.17
Explained variance percent[b]	76.8	13.6		7.13[c] (0.89)

[a] Statement numbers correspond to those in table 2.
[b] Percentage of total variance explained by the factor.
[c] 7.13 is the total of the eigen values and 0.89 is their average.
* Indicates that loading ≥ 0.35.

restrictions: $\lambda_{11} = \lambda_{52} = 1$, while Ψ and Θ were assumed to be diagonal matrices.

Empirical Results

The LISREL model was estimated using the full information maximum likelihood method (Joreskog and Sorbom, 1989). Goodness-of-fit statistics and parameter estimates are presented in tables 4 and 5.

The measurement model fitted the data well as indicated by the significance of the estimated parameters and the goodness-of-fit statistics (table 4). Another test that all coefficients on the x-variables (Γ) were equal to zero was conducted. The restricted model was called the null model (NM), while the unrestricted model was called the full model (FM). A significant reduction in chi-squared (of 370.56 with 31 degrees of freedom) occurred when moving from the NM to the FM (table 4).

Because the model in equation (4) was recursive, the independent variables, x, would have both direct and indirect effects on "control support," η_2. The sum of the two effects was the total effect. The total effect of x on η was given by $(I-B)^{-1}\Gamma$. For the stability of the system, a sufficient condition is that the largest eigen value of BB' should be less than one (Joreskog and Sorbom, 1989). Table 4 shows that the system was stable with an stability index of 0.309.

The total effects of the explanatory variables (see table 1) on the two constructs, "pollution perception" and "control support," are presented in table 5. Although the model formulation is different, the results could be compared to Napier and Brown[1]. Most of the statements in Napier and Brown (table 2, p 434) fall in the category "control support." Therefore, their results (Napier and Brown, table 8, p 438) were compared to the total effects of the explanatory variables on control support. In this regard, we found that all coefficients (except *AGE*, *INCOME*, and *GRAINS*) had the same sign as in Napier and Brown. Some variables were significant (at 10 percent or better) in explaining variation in control support, while they were not in Napier and Brown. These variables included *AGE*, *EDUCATION*, *INCOME*, *PROTECT*, and *GOVT_PRO*. Further discussion of these results follows.

Because we analyzed the correlation matrix, the coefficient estimates were standardized and can be compared in magnitude. Variables that were significant in explaining the variation in pollution perceptions were *NO_REDUC*, *OWNWELL*, *INFO*, *KNOWLEDGE*, and *IPM*, while *INCOME* and *OPERATE* had t-ratios greater than one in absolute value. Results showed that *NO_REDUC* and *KNOWLEDGE* were the most important variables in explaining farmers' perceptions. Farmers who agreed that reduction of nitrogen application rates on their farms would not reduce ground water pollution (*NO_REDUC*),

Table 4. Estimate of Constant Loading and Model Goodness-of-fit Statistics

Parameter	Estimate	Asymptotic t
λ_{11}	1 000[a]	-
λ_{21}	1.027**	5.282
λ_{31}	1.409**	6.119
λ_{41}	1 595**	6.335
λ_{52}	1.000[a]	-
λ_{62}	0.951**	12.618
λ_{72}	1.286**	16.469
λ_{82}	0.482**	6.300
Number of observations = 319		
Measurement R^2 = 0.962		
Structural R^2 = 0.766		
Goodness-of-fit index = 0.891		
Adjusted goodness-of-fit index = 0.690		
Root mean square residual = 0.050		
Chi-squared for full model with 164 degrees of freedom = 971.99		
Chi-squared for null model with 195 degrees of freedom = 1342.55[b]		
Stability Index = 0.309		

[a] Loading is restricted to one for model identification.
[b] The null model sets all the Γ coefficients equal to zero.
** Indicates significance at the 5 percent level.

Table 5. Total Effects of Explanatory Variables on the Constructs

Variable[a]	Pollution Perception (η_1)		Control Support (η_2)	
	Effect	Asym. *t*-ratio[b]	Effect	Asym. *t*-ratio
NO_REDUC	-0.16533**	-4.765	-0.09184**	-4.413
AGE	-0.02153	-0.688	-0.10476**	-2.688
EDUCATION	-0.00510	-0.196	0.05010*	1.806
INCOME	-0.04596	-1.545	0.13781**	3.523
OWNWELL	0.06077**	2.004	0.59989**	11.411
INFO	0.06201**	2.205	0.02018	0.627
PROTECT	-0.01458	-0.540	0.46717**	9.893
KNOWLEDGE	-0.11421**	-3.551	-0.08141**	2.550
IPM	-0.07171**	-2.369	0.17252**	4.294
OPERATE	-0.04603	-1.418	-0.08268**	-2.221
FERT_PRO	-[c]	-	-0.09034**	-2.496
PEST_PRO	-	-	0.36757**	8.357
OFF-FARM	-	-	-0.07693**	-2.721
NEW_EQUIP	-	-	-0.03814	-1.435
LOWER_INC	-	-	-0.09466**	-3.361
PRO_COST	-	-	-0.15126**	-5.351
LOW_PEST	-	-	0.09227**	3.307
CUL_ACRE	-	-	-0.09964**	-2.850
GRAINS	-	-	0.05465*	1.927
DEBT	-	-	-0.48426**	-9.503
GOVT_PRO	-	-	-0.20815**	-5.224
IRRIGATE	-	-	-0.36001**	-7.159
Perception, η_1	-	-	0.55551**	4.715

[a] For variable definitions see table 1.
[b] "Asym. *t*-ratio" means asymptotic t-ratio
[c] Means not applicable (variable not used)
*,** Indicates significance at the 10 and 5 percent level, respectively

perceived pollution as less of a problem than farmers who disagreed (table 5). Apparently, such farmers might not have considered the aggregate effect of their practices over time. An implication of this result is that farmers should be made aware of the build-up effect of their current practices.

Farmers who stated that they were knowledgeable about ground water pollution in their counties (*KNOWLEDGE*), did not perceive water pollution as a problem. On the other hand, farmers obtaining information about ground water pollution (*INFO*) from external sources (e.g., extension agents, universities, TV, ..etc.), were likely to perceive a problem with ground water pollution. The policy implication of these results is that external sources of information will be useful if the potential for ground water pollution is accentuated.

Table 5 also shows that a farmer who participated in an integrated pest management (*IPM*) program perceived ground water pollution as less of a problem than a one who did not. Farmers obtaining water from own wells (*OWNWELL*) were more likely to perceive ground water pollution as a problem than their counterparts. This result could be due to the higher degree of uncertainty about water quality for people using their own wells water compared with those using city\county water systems.

The total effects of the explanatory variables on "control support" are presented in table 5. All coefficients (except *INFO* and *NEW_EQUIP*) were significant at the ten or five percent level. Results showed that farmers acted in a manner that guards their self-interest. Farmers who believed changes in practice would negatively influence their utilities had less "control support." Farmers who believed that reducing fertilizer application rates on their farms would not reduce ground water contamination (*NO_REDUC*) were less supportive of regulations to control pollution. The policy implication is that understanding the objective consequences of farmers' practices is important for a full support of any agriculture policy. Results also showed that older and less-educated farmers (*AGE* and *EDUCATION*) were less supportive of regulations than their counterparts. Previous research has shown that old and less educated people were less likely to support regulations to protect the environment (Gillespie and Buttel; Napier, Camboni, and Thraen).

As it has been hypothesized, *INCOME* had a positive effect on "control support." This result indicated the ability of the financially successful farmers to internalize the costs of any pollution control. A further support to this conclusion was provided by the negative effect of the DEBT variable on control support. Farmers who were in debt were less likely to support pollution control since that would add to their financial burden.

Farmers who were using different devices to protect their family members from consuming contaminated water (*PROTECT*), were supportive for pollution control. Action that protects ground water would reduce costs incurred by this group when using these protective devices. Similarly, farmers who obtained drinking water from their own wells (*OWNWELL*) were more supportive of action to protect ground water. These farmers apparently want to make sure that the source of their drinking water is safe. These results again supported the self-interest behavior hypothesis.

The negative influence of *KNOWLEDGE* on control support could be because currently there is no widespread ground water pollution problem in Georgia. However, EPA has ranked Georgia second in the nation for potential ground water problems. The positive effect of IPM participation on control support is an indication of the possible success of such programs in elevating the level of farmer's awareness about environmental issues.

The effect of the number of years a farmer had been operating the farm (*OPERATE*) on control support was negative. The result could be due to the usual resistance for change (changes of practices) if a technology had been in operation for a long time. While willingness to participate in fertilizer programs (*FERT_PRO*) had a negative effect on control support, the effect of willingness to participate in pesticides programs (PEST_PRO) was positive. The results might indicate that farmers were more comfortable using fertilizers than pesticides.

The effect of OFF-FARM work on control support was negative. This result was in contrast to Gillespie and Buttel's conjecture that off-farm work might be inversely related to opposition of government regulations because it might make the economic implications of regulations less salient. The result could be due to the exposure off-farm employment provides to people and issues beyond agriculture.

For farmers to change practices to protect ground water, the effect of this change on farm's income will be important. The variables *NEW_EQUIP*, *LOWER_INC*, *PRO_COST*, and *LOW_PEST* measure how farmers believed farm income would be affected by changing practices to protect ground water. Results indicated that if the farmer believed that (1) changes in practices would require the purchase of new equipment (*NEW_EQUIP*), (2) reduction of nitrogen applications would reduce net farm income (*LOWER_INC*), (3) farm production costs would increase due to changes in practice (*PRO_COST*), or (4) productivity would significantly decline due to a reduction of pesticides applied (*LOW_PEST*), then such a farmer would be less supportive of regulations (note the scoring of *LOW_PEST* - table 1). Therefore, for a policy to be successful, the effect on farm income must be acceptable by farmers.

The effect of the usually cultivated acreage (*CUL_ACRE*) on control support was negative. The result conforms with previous findings where Hoiberg and Bultena reported a positive relationship between farm size and "opposition" to regulations. An interesting result was the positive effect of *GRAINS* on control support in contrast to the negative effect found by Napier and Brown. Grains in Ohio are major crops and the midwest is considered a primary user of fertilizers (Ward, et al) and has the highest fertilizer leaching scores (Kellog, Maizel, and Goss). In contrast, grains in Georgia do not constitute a major part of farm income. Farmers in Georgia may be more concerned with the use of chemicals and fertilizers for other crops such as pecans, cotton, and fruits. The effects of poultry and livestock production on ground water pollution should also be more of a concern than the effects of grains. The result also contrasts with that of Pease and Bosch where they concluded, for some parts of Virginia, that crop farmers feel more threatened by the increasing societal concern about water pollution than do livestock farmers. On the other hand, irrigated farm operators (*IRRIGATE*) were less likely to support regulations than were their counterparts. The result could occur because irrigated farms use more fertilizers than non-irrigated farms. Moreover, irrigated farms are more technology-intensive than non-irrigated farms and therefore, irrigated farm operators would be less willing to adopt changes to protect ground water (see also Napier and Brown, p. 434).

Participation in government programs (*GOVT_PRO*) had a negative influence on control support. The direction of the effect was the same as in Napier and Brown (although it was not significant in Napier and Brown.) Finally, an important result was the positive and significant relationship between "pollution perceptions" and "control support." For farmers to support any policy that protects ground water, they first had to perceive a pollution problem.

Conclusions and Policy Implications

In this paper data from a statewide survey of Georgia farmers were used to study farmers' perceptions of ground water pollution and their preferences for actions to protect ground water. Although a large percentage of farmers realized that ground water pollution was an important environmental problem, most farmers did not think it was a problem on their farms; a result supporting previous findings (Lichtenberg and Lessley; Pease and Bosch). Most of the farmers also did not believe that reducing fertilizer application rates on their farms would reduce water pollution. Also, most farmers did not believe that water contamination was a problem in Georgia and therefore did not support any protection policy. Although that may be true, Georgia has been ranked second in the nation in potential ground water contamination, especially from agriculture. This type of information needs to be conveyed to farmers. Results also showed that farmers who got more information from external sources (such as universities, extension agents, and TV) were more supportive of regulatory policies on fertilizers and pesticides. These sources of information, therefore, must accentuate the potential for ground water pollution in Georgia. Also, farmers must understand the objective consequences of their practices as this seems to be an important factor that influences farmers' support of agricultural policies.

Results also showed that farmers acted in a way to guard their self-interest. Therefore, if changes in practices to protect ground water would lower net farm's income, farmers were unlikely to support such a policy. The study also pinpointed the target group that needs to be motivated to support water protecting policies. Older, less-educated, non-grain producing, and irrigated-farm operators should be targeted in extension programs to protect ground water. Results also suggested that farmers who were under financial stress were not in support of policies that would protect ground water, especially if these policies would deprive them from some benefits such as government programs. An implication is that if practices to protect ground water would involve high costs by farmers, these policies are likely to be opposed especially by farmers who are in debt. Also, government programs should be designed to provide incentives for farmers to protect the environment. Results showed the success of programs such as integrated pest management in motivating farmers to support regulations to protect ground water. It also seems that farmers in Georgia were more concerned about the use of pesticides than fertilizers. Extension programs should take that into account.

It also seems that most farmers obtained their drinking water from farm wells that were not tested to insure the safety and purity of water. This group of farmers would be supportive of water protecting policies if they perceived any risk from water consumption. Therefore, we believed that well testing is important since the identification of a problem would encourage farmers to act in a self-interest way and change their practices to protect themselves.

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Endnotes

1. The dependent variable in Napier & Brown's model, the groundwater pollution index (GWPI), measures two concepts : (1) perceived importance of groundwater pollution and (2) action options needed to prevent it (Napier and Brown, p. 435). Here we decompose the GWPI into its two components as in equations (1) and (2). We also used more explanatory variables than did Napier and Brown. Note also that most of our statistics compare favorably with those from Napier and Brown (see tables 1 and 2.)