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On how environmental stringency influences adoption of best management practices in agriculture

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Abstract

There are relatively few Federal environmental regulations that influence agricultural production in the US. However, many local and state environmental rules may influence the management practices on US farms as might interactions between urban population centers and agricultural producers. Detailed analysis of corn farms gives insight into these relationships and suggests that stringent environmental regulations could increase the likelihood of adoption of certain conservation practices, all else being constant, but that the interaction between urban populations has less of an effect on the adoption decisions.
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1. Introduction

Agricultural production affects the environment in many ways. Some impacts are positive—pleasant vistas and provision of wildlife habitat. However, many impacts are not positive—chemical and sediment runoff into lakes, streams, and estuaries. At the state and federal level policies seek to encourage the positive impacts of crop production and to lessen its negative impacts. These typically rely on voluntary conservation programs, which provide education, technical assistance, and incentive payments to farmers for such things as retiring environmentally sensitive lands or adopting best management practices (BMPs) on land that remains in production. BMPs such as comprehensive nutrient management planning are designed to reduce the potential for pollution runoff from cropland.

Voluntary approaches can succeed when farmers' concerns over environmental quality reflect those of society. When this is not the case and production decisions are based solely on private benefits, then farmers could under-invest in conservation if the costs of implementing and managing conservation practices are higher than expected returns, including conservation incentive payments.

To the best of our knowledge, there are few studies that analyze the impact of a state's environmental stringency and interaction with non-farm populations on the use of BMPs. In this paper, we examine whether evidence suggests that farmers in states with relatively strong environmental laws are adopting environmental-quality protecting management practices at higher rates than elsewhere, even when the environmental laws are not aimed directly at crop production. This could be an indication that information about impaired environmental quality and the perceived likelihood of possible regulation in the future could spur farmers to adopt practices they ordinarily might not. Moreover, we examine whether proximity to urban areas influences the production practices of the farmers. Demand for environmental quality at the rural–urban fringe, expressed through citizen complaints over farming practices and local ordinances to reduce rural–urban conflicts, might spur the adoption of BMPs as a means of reducing potential conflicts with non-farm residents.

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Accordingly, the main hypothesis we test is whether farmers in states with relatively strong environmental laws or where there is a higher interaction with urban population centers are more likely to adopt BMPs at higher rates than elsewhere. We examine this question in light of the fact that farmers are likely to bundle one or more management practices from a larger set of available BMPs. Our paper starts with a literature review of environmental stringency, urban proximity, agricultural production and adoption of BMPs. Then, using data on corn production from the 2001 Agricultural Resource Management Study (ARMS) survey of USDA, we utilize a multivariate probit model to estimate the likelihood of the farmers' adoption of BMPs. This estimation procedure enables the identification of correlations between BMP choices. We conclude with a discussion of the results and implications for future research.

2. Environmental stringency

The influence of environmental regulations on production in manufacturing and some other industries has been studied by various researchers (e.g., Becker and Henderson, 1999; Sun and Zhang, 2001). The impacts of environmental regulations on agriculture production have also been analyzed. Isik (2004) assessed the relationship between environmental regulation and spatial structure of the US dairy sector. His study concludes that counties with strict environmental regulations are likely to lose dairy inventories to the ones with less strict regulations. In addition, findings of panel analysis by Herath et al. (2005) suggest that regions with less stringent environmental policies have increased their shares for hog and diary production in the US. Parallel to the pollution haven hypothesis, the study also suggests that state environmental regulations can indirectly or directly impact the size of the animal industry in the state by increasing the relative abatement costs of livestock producers.

Similarly, Metcalfe (2000) proposed that state water quality regulatory stringency on hog production in the US has a negative impact on the production of small hog feeding operations. Additionally, Metcalfe (2002) determined that stricter environmental regulations in the US will have a minimum effect on the international competitiveness of hog producers in the US while more stringent EU regulations might harm the international competitiveness of the hog producers in Europe.

However, environmental regulations might have different impacts on livestock and crop producing industries, because compared to crop producers, animal feeding operations can change their production locations. That is, in contrast to capital and labor, land is an immobile factor of production, so crop producers cannot move their production facilities from one region to the other. Thus, crop producers might face greater adaptation costs from new environmental regulations compared to livestock producers.

In 1997, the Environmental Law Institute published a report that analyzed the differences in the enforceable state laws used for controlling non-point source water pollution, such as pollution runoff from cropland. Such differences in state environmental policies have important implications for the states whose economies depend heavily on its resource base.[2]

Another potential source of pressure to adopt environmentally friendly production practices is potential conflict with non-farm populations. In the suburban–rural fringe that is expanding in many parts of the country, people are moving into closer proximity to farms. This has given rise to citizen complaints about noise, odors, and other factors common to farm operations (Clayton, 2005; Bergstrom and Centner, 1989; Duke and Malcolm, 2003). Even if there are no regulations addressing these issues, farmers may face citizen complaints and lawsuits. Farmers may respond by implementing practices for reducing the potential for conflicts over environmental quality issues. Such practices would be an indication that farmers are taking due care in their operations, thereby protecting themselves from any civil actions (Centner, 2002).

3. Data

In our analysis we use farm-level agricultural and economic data from the 2001 USDA Agricultural Resource Management Survey (ARMS) collected from corn producers (Banker et al., 2001). Corn was planted on approximately 76 million acres of land base in 2001, and generated approximately $19 billion in returns for farmers (USDA-ERS, 2003). Because of both the coverage and the relative intensity of production on corn acres, the environmental management practices of corn producers may have a significant bearing on the overall environmental performance of US agriculture.

The 2001 ARMS target farms within the 48 contiguous states, where a "farm operation" is defined as an establishment that sold or would normally have sold at least $1000 of agricultural products in a year (see USDA-ERS, 2006a). Surveyed farms have unequal probabilities of being selected for ARMS, and multiple sampling frames, using stratification and clustering procedures, are used to gather sufficient sample sizes to achieve reliability of the estimates. Full consideration of the sample design of ARMS is given to the estimates included herein. The 2001 ARMS gathered detailed data on production practices for corn, including the use of management practices and detailed costs and returns of the corn enterprise. The survey includes 1542 observations. These observations are weighted in such a way that they expand to represent 94% of all acres planted to corn for grain (full coverage is not possible because detailed corn data was drawn from the 19 highest producing states, rather than the entire contiguous US).

[2]See for example the case of Florida's rules regarding phosphorus runoff and the Everglades (Environmental Law Institute, 1997).

Table 1
Sample means[a]

Variable	Variable name	Estimate	CV	Units
Observations		1542		
Share with highly erodible fields	*hel*	0.19	6.40	0 or 1
Field drainage used	*drain*	0.38	3.90	0 or 1
Yield goal for field	*yieldgoal*	140.94	0.90	bushels
Share of planted acres owned	*ownshare*	0.5284	3.2000	0 or 1
Share of ag in state	*agshare*	1.53	2.00	0 or 1
Share receiving costs	*costshare*	0.03	26.00	0 or 1
Share using irrigation	*irrigate*	0.09	22.90	0 or 1
Field size	*aplfield*	42.12	4.00	acres
Crop insurance as percentage of total expenses	*cropins*	0.04	2.00	%
Share in heartland	*heart*	0.58	2.10	0 or 1
Value of production	*valprod*	1.94	4.60	$100,000's
Population interaction index	*pnew*	0.85	5.20	index
Stringency index	*index2000*	3.69	0.90	index
College graduate	*educ*	0.15	10.70	0 or 1
Fulltime farmer	*oper*	0.76	2.00	0 or 1

[a]Estimate column on the table refers to the mean of each variable. We use the delete-a-group jackknife procedure, a replication-based method (Kott, 1998), to calculate the reported standard errors rather than the classical variance formula. Many national surveys, including ARMS, facilitate the use of replication-based variance estimation methods. The general idea of replication methods is to draw repeated subsets of the sample, calculate the estimator for each subset, and then estimate the variance based on how much the estimates vary across the subsets (Dubman, 2000). Coefficient of variation (CV) is calculated as (StandardError/Estimate) $*$ 100.

To examine the decision to implement BMPs, we consider farm, farmer, and management variables (see Table 1) that have also been shown to influence the adoption of conservation technologies. Land tenure is an important determinant in the adoption of conservation practices. Soule et al. (2000) found that renters (both cash-renters and share-renters) are less likely than owner-operators to adopt a bundle of practices (grassed waterways, strip-cropping and contour farming) that provide benefits over the longer term because of their shorter planning horizon. In our study, land tenure is captured by the percentage of land owned by the farmer (*ownshare*).

We consider how farmer attitude towards risk might influence the adoption of BMPS. The impact could be positive or negative. If conservation practices are perceived to increase financial risks due to their short-term high costs, then risk averse farmers would not be likely to adopt them. However, if conservation practices are seen as a means of avoiding potential conflicts with environmental laws or with non-farm residents, a farmer that is risk averse may be willing to incur the cost of BMPs. We represent the risk attitude of farmers with a variable (*cropins*), measured as expenditures for crop insurance as a percentage of total expenditures. We would expect that higher levels of *cropins* to be positively correlated with higher levels of risk aversion.

If a farm uses manure (*manure*) as a fertilizer, it might be subject to greater regulatory scrutiny (Herath et al., 2005), particularly at the rural–urban fringe. Concerns over manure led to new EPA Clean Water Act regulations in 2003 (Ribaudo et al., 2003), and odors and insects associated with animal operations are a major source of citizen complaint. Such scrutiny could thereby increase the probability of employing a nutrient management plan. Such a plan could be used as evidence that the farm is exercising due care in its management of manure.

The farmer's yield goal (*yieldgoal*) might also affect costs of production and conservation adoption—higher yield goals would likely result in more intensive farming practices, which may not be consistent with some of the adoption technologies we consider (Johansson et al., 2004).

Whether the primary occupation of the farmer is as a fulltime operator (*oper*) and whether he or she has graduated from college (*educ*) have been shown to be important in explaining farm management and technology adoption (Fernandez-Cornejo et al., 2005).

To capture the potential impact of economies of scale on management choices, we use total farm value of production (*valprod*) as a proxy to farm size. Larger farms may be more likely to invest in new practices, due to internal economies of size (Robinson and Napier, 2002).

We consider how the share of crop and animal production in total state GDP[3] (*agshare*) might capture external factors that impact the likelihood of BMP adoption. Higher *agshare* indicates the overall importance of agriculture to the state and could indicate an increased overall acceptance of agricultural externalities—one might expect that attitudes towards agriculture in states with higher *agshare* might be in general more sympathetic to farmers.

We account for climate and soil conditions optimal for corn production using a dummy variable for farms located in the Heartland (*heart*), where more than half of corn farms are located and more than 70% of corn is produced

[3]Gross domestic product.

(Foreman, 2001). The Heartland encompasses all of Iowa, Illinois, Indiana, and the nearby corn-producing counties in Arkansas, Ohio, Minnesota, Kentucky, Nebraska, and South Dakota (USDA-ERS, 2006b). Fields located on highly erodible land (*hel*) are expected to have higher rates of BMP adoption because of the conservation compliance provisions (Claassen et al., 2004). Other geographically determined farm production and conservation practices that may affect conservation practice adoption include the use of irrigation (*irrigate*) and field drainage (*drain*). Irrigated farms have been found to be more likely to adopt nutrient-management related practices (Lambert et al., 2006). Similarly, fields that require drainage may be less amenable to conservation tillage techniques (University of Minnesota, 2002).

In addition, we expect that farms located in counties with increased interaction between agricultural land use and urban-related activities face different pressures than farms located elsewhere. Proximity to the urban areas may increase the probability that state-level environmental rules would be more rigorously enforced and increase the probability that farmers adopt BMPs because there is a higher potential of conflicts between farmers and urban residents. Soule et al. (2000) find that urban proximity[4] increases adoption of certain practices[5] by owner-operators and share-renters.

We use "population-interaction indexes" (PII) and the "population-interaction zones for agriculture" codes (PIZA) developed by ERS (USDA, ERS) to represent areas of agricultural land use, where urban-related activities affect the economic and social environment of agriculture (USDA-ERS, 2005). PII's are designed to provide a measure of the potential interaction between nearby urban-related population and agricultural production activities in five-kilometer grid cells across the contiguous 48 states. PII is derived from a gravity model of population density. Essentially, the PII provides a continuous measure of proximity to nearby population concentrations, accounting for both local population size (within a grid cell), nearby population size (surrounding cells), and distance to the nearby population (distance to surrounding cells). The index increases as local population increases, and/or as distance to nearby population decreases.

The continuous PII does not identify which grid cells are rural and which are subject to the effects of urban-related population interaction. To classify each grid cell into a "rural" zone or a "population-interaction" zone, ERS developed the PIZA. PIZA were established based on PII levels in the most rural areas of each of the 20 USDA Land Resource Regions (LRR). In each LRR, the distribution of PII values was divided into four parts such that the lowest part reflected levels of population that would likely exist in the absence of urban-related population interaction. Each successive part of the distribution was meant to reflect increasing rural–urban population interactions. The cutoff values of PII used to establish PIZA were allowed to vary regionally due to expected differences in the productivity of farmland and the level of associated industries that support agriculture. The resulting PIZA**'s** therefore consist of a four-category classification:

- 1 rural (does not contain any part of a town of 2500 or more residents and the primary commuting pattern was to sites within the tract);
- 2 population interaction, low;
- 3 population interaction, medium;
- 4 population interaction, high.

We create a new variable (*pnew*), which is a county-level, continuous representation of the four PIZA categories. It is created by normalizing the PIZA score for the grid-cell at the county centroid on the highest county PII score of all counties in the same PIZA category. High values represent areas of agricultural land use in which urban-related activities are most likely to affect the economic and social environment of agriculture. In these zones, interactions between urban-related population and farm production activities are assumed to increase the potential for conflict over environmental quality.

The data to measure regulatory stringency are limited; and several different indexes are used to measure it. Although different indexes use different criteria to measure the stringency, their main focus is to address states' attempts to decrease environmental pollution. In our study, we use the stringency index (*index2000*) for the year 2000, developed by Herath et al. (2005). This index is formed for each state according to the presence or absence of seven regulations, which are aimed at managing the farm-level livestock operations. These include:

- *anti-corporate*—prohibition of corporations owning farmland or engaging in confined livestock operations;
- *moratoria*—limits on total animal production or the number of operations;
- *local control*—local administration and enforcement of environmental regulations affecting confined livestock operations;
- *bonding*—financial assurance requirement to pay for costs of clean up of any spills;
- *cost share*—cost sharing or incentive programs in a state to encourage compliance with regulations;
- *nutrient standards*—restrictions on the timing and applications of manure; and
- *set-backs*—(minimum manure application distance to water resources $*$ average farm price)/maximum setback measure.

[4]To measure urban proximity, they use an index of population within 50 miles of the sampled farm, weighted by the inverse of the inverse of the squared distance from the sampled farm.

[5]The bundle of practices (grassed waterways, stripcropping and contour farming) examined provide benefits over the longer term.

Ideally, stringency would reflect regulations aimed at corn production. Lacking such an index, we assume that the Herath et al. index serves as a proxy for environmental stringency towards agriculture in general.

While we are examining if adoption of conservation practices are influenced by state-level environmental stringency or local-level interactions with urban populations, some BMPs will be adopted for other financial reasons. For example, participating in a voluntary conservation program and receiving cost-share payments (*costshare*) is likely to be correlated to adoption of conservation practices (Robinson and Napier, 2002; Lambert et al., 2006). (Note that our data did not specify which practices were being supported, only that the farmer received a cost share payment.)

4. Model

Our estimation examines a set of interrelated conservation practices, where it is likely that the decision to adopt one practice is correlated to other conservation management decisions. Here, we examine the use of conservation tillage, or having residue cover of at least 30% at the time of planting (*residue*); building grassed waterways (*grass*), which help filter field runoff from drainage channels; use of filter strips at the edge of the corn field (*strip*), which helps reduce runoff from farm fields; testing the field for nitrogen and phosphorus content (*test*), which enable more efficient applications of commercial and manure nutrients; and using a yield monitor on harvesting equipment (*precag*), which also enhances the efficiency of input use on the field. We also consider how conservation planning (erosion plan—*eros*; manure management plan—*manman*; and commercial fertilizer plan—*fert*) might be affected by environmental stringency and urban influences (see Table 2). Corn farms show a range of adoption rates—ranging from 34% of farms employing conservation tillage to 7% of corn farms with filter strips on the edge of the corn field.

For our model, we estimated the following multivariate probit regression model for each farmer i using conservation practice j,

$$y_{ij}^* = \beta_j' X_{ij} + \varepsilon_{ij}, \quad i = 1, \ldots, n \text{ and } j = 1, \ldots, 8,$$

$$y_{ij} = 1 \quad \text{if } y_{ij}^* > 0 \text{ and 0 otherwise.}$$

Here **X** is the matrix of independent variables hypothesized to influence BMP adoption (i.e., *agshare*, *valprod*, *heart*, *drain*, *hel*, *yieldgoal*, *educ*, *oper*, *irrigate*, *cropins*, *ownshare*, *manure*, *costshare*, *index2000*, and *pnew*). ε_{ij} denotes the error terms with multivariate normal distribution where each has a mean of zero and variance of 1. The variance-covariance matrix of error terms includes potentially non-zero correlations off the main diagonal. We have eight equations where all of the equations are individual probit models with the same functional form and the same set of independent variables and y represents the likelihood of adopting different, possibly interrelated, conservation practices. The error terms of conservation practices are assumed to be related to each other. In this sense, a multivariate probit model is a system of eight seemingly unrelated probit models.

Table 2
Conservation management practices[a]

Variable	Variable name	Mean	CV	Units
Conservation tillage	*residue*	0.34	6.30	0 or 1
Yield monitors used	*precag*	0.16	8.20	0 or 1
Grassed waterways used	*grass*	0.27	11.40	0 or 1
Commercial fertilizer plan	*fert*	0.09	11.70	0 or 1
Manure management plan	*manman*	0.04	18.90	0 or 1
Erosion plan	*eros*	0.25	7.00	0 or 1
Soil nutrient test	*test*	0.30	8.70	0 or 1
Filter strips used	*strip*	0.07	20.90	0 or 1

[a]We use the delete-a-group jackknife procedure, a replication-based method (Kott, 1998), to calculate the reported standard errors rather than the classical variance formula. Many national surveys, including ARMS, facilitate the use of replication-based variance estimation methods. The general idea of replication methods is to draw repeated subsets of the sample, calculate the estimator for each subset, and then estimate the variance based on how much the estimates vary across the subsets (Dubman, 2000).

The simulated maximum likelihood technique (SML) is used to estimate our model. As Greene (2002) emphasized, SML estimation has been used by a growing number of studies (e.g., Cooper, 2001; Belderbos et al., 2004). Following Cappellari and Jenkins (2003), our multivariate probit models are estimated using Geweke–Hajivassiliou–Keane (GHK) simulator in Stata. Eight dimensional normal probability distribution functions are simulated to evaluate multivariate probit likelihood functions. Multivariate normal probabilities are calculated at each iteration of the simulation using the GHK simulator. Similar to maximum likelihood estimator, SML estimator is asymptotically consistent. Simulation bias will be minimized as the number of observations and the numbers of random draws increase (Cappellari and Jenkins. 2003).[6]

5. Results

The Wald test suggests that our estimated model is significant (Table 3), and the likelihood ratio test supports our model assumption that the choices of BMPs are not independent of each other (Table 4). Most of the variables had the expected signs.

Estimation results from the multivariate probit model (Table 3) suggest that share of agricultural production in

[6]In initial simulations we used 5, 20, 50 and 100 random draws. Estimated coefficients and their standard errors from each regression were very similar to each other. Results from our final estimations are based on 20 random draws for the multivariate probit model.

Table 3
Multivariate probit results[a]

Variable	Residue		Test		Grass		Eros	
	Coef.	$P>\|z\|$	Coef.	$P>\|z\|$	Coef.	$P>\|z\|$	Coef.	$P>\|z\|$
agshare	0.17	0.00	0.08	0.05	0.03	0.52	0.03	0.60
costshare	0.42	0.17	0.46	0.09	0.55	0.07	0.81	0.03
valprod	0.01	0.30	0.01	0.21	−0.01	0.38	−0.01	0.65
heart	−0.08	0.45	0.02	0.88	0.28	0.02	0.10	0.44
drain	−0.03	0.80	0.39	0.00	0.07	0.58	−0.13	0.36
hel	0.50	0.00	−0.14	0.27	0.66	0.00	1.45	0.00
yieldgoal	0.00	0.02	0.00	0.01	0.00	0.10	0.01	0.00
educ	0.09	0.49	0.20	0.11	−0.02	0.91	0.20	0.15
oper	−0.25	0.04	0.26	0.04	0.21	0.12	0.12	0.41
irrigate	−0.15	0.53	0.93	0.00	−0.20	0.68	−0.84	0.00
cropins	0.12	0.37	0.01	0.95	−0.34	0.05	−0.09	0.57
ownshare	−0.10	0.46	0.07	0.60	−0.09	0.60	0.38	0.00
manure	−0.21	0.11	0.01	0.92	0.01	0.96	−0.02	0.89
index2000	−0.01	0.74	−0.01	0.90	0.17	0.00	0.16	0.00
pnew	0.02	0.72	−0.05	0.42	−0.18	0.02	0.05	0.47
Constant	−1.06	0.00	−1.84	0.00	−1.84	0.00	−3.28	0.00
	Manman		Fert		Percag		Strip	
	Coef.	$P>\|z\|$	Coef.	$P>\|z\|$	Coef.	$P>\|z\|$	Coef.	$P>\|z\|$
agshare	0.06	0.38	0.01	0.92	0.08	0.04	0.06	0.34
costshare	0.52	0.12	0.48	0.16	−0.57	0.22	1.44	0.00
valprod	0.02	0.00	0.00	0.73	0.02	0.04	−0.02	0.46
heart	0.16	0.40	0.34	0.03	0.14	0.27	0.10	0.57
drain	−0.09	0.65	0.09	0.59	0.14	0.26	0.45	0.01
hel	0.03	0.89	0.02	0.89	0.18	0.20	0.08	0.65
yieldgoal	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.70
educ	0.11	0.56	−0.22	0.23	0.37	0.01	0.19	0.28
oper	0.86	0.00	0.41	0.05	0.24	0.11	0.22	0.25
irrigate	−0.40	0.17	−0.14	0.49	−0.18	0.42	−0.45	0.15
cropins	0.04	0.79	−0.11	0.53	0.38	0.01	−0.10	0.63
ownshare	0.21	0.33	0.21	0.23	−0.13	0.34	−0.12	0.55
manure	1.04	0.00	0.05	0.75	−0.37	0.02	0.00	1.00
index2000	0.04	0.59	0.06	0.27	−0.04	0.33	−0.06	0.31
pnew	0.07	0.53	−0.13	0.12	−0.05	0.51	−0.02	0.83
Constant	−4.93	0.00	−3.75	0.00	−3.13	0.00	−1.59	0.00

[a]A Wald test from chi-square statistics with 120 degrees of freedom rejects the null (that there is no effect of the independent variables on the probability of BMP adoptions) at the 0.0001 level.

total GDP of a state (*agshare*) tends to increase the probability of adoption of conservation tillage, nutrient soil testing, and yield monitoring. Farms with higher total value sales (*valprod*) show an increased use of a yield monitor on harvesting equipment and use of manure management plans, perhaps capturing the impact of increasing manure management requirements for large livestock operations (Metcalfe, 2000). Having a field classified as highly erodible (*hel*) increases the probability of the farm using conservation tillage, managing grass waterways, and an erosion plan. These practices could be required under the Conservation Compliance provisions of the 1985 Food Security Act as a condition for receiving program benefits. Setting higher yield goals (*yieldgoal*) is likely to increase the use of all conservation management practices except for filter strips.

Table 4
Correlation matrix for conservation practices[a]

	Residue	Test	Grass	Eros	Manman	Fert	Precag	Strip
Residue	1.00							
Test	0.08	1.00						
$P>\|z\|$	0.21							
Grass	0.07	−0.01	1.00					
$P>\|z\|$	0.21	0.14						
Eros	0.15	0.09	0.25	1.00				
$P>\|z\|$	0.30	0.23	0.39					
Manman	−0.05	0.21	0.33	0.35	1.00			
$P>\|z\|$	0.16	0.40	0.52	0.52				
Fert	0.26	0.37	0.21	0.42	0.63	1.00		
$P>\|z\|$	0.42	0.50	0.37	0.58	0.75			
Precag	0.05	0.13	0.06	0.09	0.10	0.13	1.00	
$P>\|z\|$	0.18	0.27	0.21	0.25	0.31	0.29		
Strip	0.26	0.10	0.24	0.27	0.31	0.08	0.01	1.00
$P>\|z\|$	0.46	0.28	0.44	0.44	0.54	0.36	0.25	

[a]A likelihood ratio test from chi-square statistics with 28 degrees of freedom rejects the null hypothesis (that the choice of BMPs are independent of each other) at the 0.0001 level.

A farmer that has graduated from college (*educ*) is more likely to use yield monitors when harvesting his/her crop, but is no more or less likely to employ the other conservation practices that we examined. Full-time farmers (*oper*) are more likely to have nutrient management plans and soil tests (*manman*, *fert and test*) and less likely to use conservation tillage (residue).

Irrigated farms (*irrigate*) are more likely to be tested for soil nutrient content, but less likely to have erosion plans. Farms with tile drainage are also likely to be tested for soil nutrient content and to use filter strips. Farms using manure nutrients as fertilizer (*manure*) are more likely to have a manure management plan, but less likely to use a yield monitor while harvesting. While most farms report having some type of crop insurance, those that spend relatively more on crop insurance are less likely to use grassed waterways, but more likely to use yield monitors. Farmers with a higher ownership percentage (ownshare) on the fields are more likely to develop erosion plans. This suggests that those farmers that rent a relatively high proportion of their operation might be a group to target for adoption of this BMP, which is highly correlated to other conservation practices.

Looking at explicit carrots (receipt of conservation incentive payments) and possible sticks (close interaction with urban populations and state-level environmental stringency), we find that receiving cost-share payments (*costshare*) positively affects the probability of using nutrient testing, managing grassed waterways, developing erosion plans, and use of filter strips. In addition, those farms located in states with a higher environmental stringency, all else being constant, are more likely to have grassed waterways and erosion plans. However, having a closer interaction with urban populations is found to have relatively little influence over the adoption of BMPs, with the exception of grassed waterway.

6. Discussion

Turning to our hypotheses that environmental stringency or contact with non-farming populations increases BMP adoption we find in our results only partial confirmation. The results suggest that the adoption of only two practices, grassed waterways and an erosion plan, were influenced by state-level environmental stringency as represented by *index2000*. Grassed waterways are an effective practice for filtering sediment and chemicals for field runoff, thus protecting water resources. It is generally not a practice that increases productivity, so its use constitutes a pure cost to the farmer.

Adoption of an erosion plan could be for protecting soil productivity, a private benefit. However, an erosion plan also addresses offsite impacts of erosion, and is often implemented in conjunction with other practices, such as nutrient management. Table 4 indicates that there is significant correlation between an erosion plan (*eros*) and all other types of conservation practices included in the analysis, indicating that an erosion plan is complementary to the other practices. The results could be an indication that environmental stringency is influencing the adoption of practices that address particular problems. However, since problems vary across states, only the erosion plan, which is often implemented in conjunction with other practices, is significant in the multivariate probit model.

The use of manure (*manure*) was a significant variable in explaining the adoption of a manure management plan (*manman*) and yield monitors (*precag*). Because the use of manure receives such scrutiny, farmers using manure may be adopting these practices to minimize their risk from regulatory exposure or citizen complaint, as hypothesized. This could be considered a response to environmental stringency.

Having a field classified as highly erodible (*hel*) increases the probability of the farm using conservation tillage, managing grass waterways, and development of an erosion plan. These practices could be used to meet the Conservation Compliance provisions of the 1985 Food Security Act as a condition for receiving program benefits. This result is an indication that farms will respond to environmental concerns when economic consequences of not doing so are clear.

Proximity to urban areas did not have the expected influence on practice adoption. The only equation in which it was significant was adoption of grassed waterways, but with the negative sign.

7. Conclusions

Our analysis concludes that environmental stringency could influence the adoption of some conservation practices. However, while environmental stringency could accelerate the adoption of environmental-quality protecting practices, we cannot say whether it provides enough of an incentive for policies based on voluntary adoption to adequately protect water quality. The level of adoption necessary to achieve water quality goals may not be possible without stronger incentives.

In our study, we did not analyze the change in the structure of the crop industry. Instead, assuming no change in the production locations and using cross-sectional farm data, we tested the hypothesis that state and local environmental stringency as measured by an index (Herath et al., 2005) had a positive impact on the adoption of two conservation technologies—grassed waterways and the development of farm erosion plans. Related to this question is the result that many conservation technologies are treated by producers as a bundle of management decisions, which are not independent of each other. Developing an erosion plan is positively related to both environmental stringency and the adoption of all other conservation practices examined.

One of the main drawbacks in our study is that it does not capture the timing difference between the creation of environmental regulations and the adoption of conservation practices. Since we do not have time series data, it is not possible to evaluate the impact of regulations on the behavior over time. For example, it could be possible that farmers could adopt the BMPs in anticipation of future regulations. Therefore, a logical next step in this research would be to assess these relationships over time. Since the ARMS survey samples different farms in each collection year, it is impossible to create a panel. On the other hand, a pseudo panel could be created from data in different years for panel regressions. It is likely that there is an endogenous relationship between stringency and past adoption practices, difficult to discern using cross-sectional data. Similarly, tracing the impact of these conservation practices by reductions in soil and chemical runoff would enrich the conclusions we might draw from our analysis. Moreover, rising energy prices might cause the farmers to use more energy-conserving practices. An analysis of the impacts of rising energy prices on BMP adoptions is an avenue for future research.

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