Do Farmers Have Heterogeneous Preferences for the Environment and Does It Matter?

A Latent-Class Approach to Explaining Field-Level Tillage Choices

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Agricultural practices can affect soil erosion, nutrient runoff, water quality, wildlife habitat and other ecosystem services and, in turn, many policies can influence these agricultural practices. Voluntary, incentive-based programs dominate U.S. policy approaches and, in most cases, voluntary farmer adoption has not been sufficiently widespread to obtain the desired changes in ecosystem services. Existing studies of farmer decision making focus on the relative profitability of crop choices and management practices, the risk associated with alternative choices, the diffusion of new cropping and management practices and programs that alter the profitability and riskiness of farmer choices (Wu et al. 2004). Other studies have considered how these decisions impact ecosystem services (Wu et al. 2004, Langpap 2008, Swinton et al. 2011). At the core of policy analysis is the development of appropriate models of farmer decision making processes. This paper adds to this literature by allowing for heterogeneity of farmer decision making processes concerning field-level tillage choices and for assessing farmer motivation by using a scale in which farmers assign weights to different motivations that might drive these decision making processes, including motivations such as profitability and environmental stewardship. Our results reveal two latent classes of farmers in the Maumee River watershed in Ohio who make choices concerning tillage practices in distinct ways and have different levels of motivation concerning environmental stewardship. The latent class that chooses tillage practices that leave greater levels of crop residue is composed of individuals that assign a higher average weight to environmental stewardship and a similar average weight to profitability.

Concern for environmental degradation has led to the enactment of a number of conservation programs and other efforts (CRP, EQUIP, WRP etc.) which provides incentives to farmers to engage in environmentally friendly agricultural practices. Some of the possible land use changes include to remove land from production to buffers or idling, changing crop choices or rotating crops and taking up environmentally friendly management practices (including choices like no-till or conservation-till). The existing literature correctly appreciates the need to consider the spatial heterogeneity of land while evaluating the efficacy of any of these programs in reducing environmental degradation. Our results suggest that motivational heterogeneity may also be important in evaluating the efficacy of such programs.

This work is distinct from the existing literature in several ways. First, we focus on field-level tillage decisions and control for field-specific characteristics including soil type, crop and quality. As many policies focus on enrolling particular parcels of land rather than entire farms, a focus on how field-specific attributes influence tillage choices are advantageous. Second, we ask farmers to assess the relative importance of several goals, including profitability and environmental stewardship, in their farming practices decisions. This helps us understand the source of tillage choice heterogeneity in a way that may be useful for targeting farmers for future policy programs.

Literature

Policy recommendations range from those of development impact fees to those which pay for conservation practices or reforestations. Langpap and Wu (2008) estimate a multinomial logit model to analyze the effect of the determinants (returns to land use, land use regulations etc.) of land use which is then linked with a species habitat association matrix to assess the impact of different land use policies on the habitat of terrestrial vertebrates. The results suggest that local land acquisition policies, incentive based policies and policies that increases the returns to forest land have a positive impact on habitat abundance. Hascic and Wu (2006) conclude that the amount of land devoted to intensive agriculture and urban development has a preponderant effect on conventional water pollution while that devoted to transportation and mining has a huge impact on toxic water pollution. Westra, Zimmerman and Vondracek (2004) compare CRP and CSP and ask the question whether performance based payment criteria would be more effective. They contend that the success of such programs crucially depends on the ability to target the program towards the actual resource concern of interest to the people in a watershed.

A number of these papers analyze two pieces of the puzzle separately, the economic model of individual decisions and the environmental/ecological/ecosystem model, and link them up together to measure the effect of individual decision on a particular (or multiple) environmental attribute(s).

Wu et al. (2004) analyzes micro level data starting with an economic model that covers a large geographic region (incorporating spatial heterogeneity). Individual farmers make crop and tillage choices simultaneously so as to maximize utility. Crop choice depends on variables like expected profitability. The cost differential between alternative management practices influences the tillage choice of individual farmers. A multinomial logit framework is employed to model farmer choices of crop and tillage. They employ a site specific environmental production function to determine the impact of conservation payments on the nitrate runoff, leaching, water and wind erosion. Their results seem to suggest that conservation payments may increase crop rotation and conservation tillage in the region.

Wu et al. (2008), estimate a multinomial logit model of land use choices which depends on returns on different land uses and links it to an econometric model of land use and watershed health, using three measures of watershed health: conventional water pollution, toxic water pollution and number of aquatic species at risk. Land uses have differential impacts on the health of the watershed. It might be more efficient from a policy perspective to target land uses which have the maximum impact on watershed health.

Methodology

We assume the tillage choice for a particular field is the outcome of a utility maximization process in which the farmer decides how much residue to leave on a field after considering the attributes of the field, the crop chosen and his or her preference parameters. Residue levels map ordinally into particular styles of tillage with approaches that leave less than 30% of residue on the field considered conventional tillage, between 30 and 90% of residue on the field as conservation tillage and more than 90% of residue on the field called no-till.

We allow individual farmers to have heterogeneous preferences by estimating a finite-mixture or latent class model. The core assumption is that different groups of farmers exist and that each group has homogeneous preferences or decision processes for determining tillage practices. However, the researcher is unable to observe which group a particular farmer belongs to or to observe the number of distinct groups. However, additional variables may be used to model class membership. The complete model, which involves parameters determining the ordinal choice of tillage practice and the discrete assignment to class membership, is estimated via maximum likelihood estimation in Latent Gold 4.5.

Sampling and Data Collection

The target population for this research was corn and soybean farmers in the Maumee watershed in northwest Ohio. Land use in the Maumee, which drains into Lake Erie, is between 60% and 80% agricultural, with corn and soybean production making up the primary farming activities. Further, the environmental impacts from agricultural non-point source runoff have become a significant issue in Lake Erie due to phosphorus concentrations and subsequent large algal blooms. The majority of the phosphorus loading into Lake Erie is from agricultural sources, particularly from farms in the Maumee and Sandusky watersheds (Ohio EPA, 2010). Consequently, results of this study have implications not only for residents in the Maumee watershed, but also for everyone who is impacted by the water quality in the Great Lakes. Finally, topological and soil conditions within the Maumee watershed are relatively homogenous, allowing analysis of heterogeneity to largely focus on preference heterogeneity rather than gross physical variation.

We conducted a mail survey of 2000 farmers with postal addresses in counties within the Maumee watershed following a modified version of Dillman's Tailored Design method (Dillman, 2000). Mailings included an announcement letter, a survey packet, a reminder letter and a replacement packet for non-respondents. Farmers who completed the survey were entered into a raffle to receive one free pair of football tickets to an Ohio State Buckeyes football game.

Survey Development and Operationalization of Variables

The survey was pilot tested several months before distributing the surveys with farmers recruited by local extension educators. Two key features of the survey include a question asking farmers the following:

> "If you had 100 points to assign to these five goals to demonstrate their relative importance when making farm management decisions, how would you do that? For example, someone who places equal weight on making a profit and maintaining a farming lifestyle, but no weight on the remaining goals would assign 50 points to profit and 50 points to lifestyle, and 0 to the rest. Assign the points in the way that best reflects the importance of each goal to you. Be sure that the total points assigned add up to 100."

The five goals were (i) Making a Profit, (ii) Being an Environmental Steward, (iii) Protecting Human Health, (iv) Ensuring Farm Viability for My Children and (v) Maintaining a Farming Lifestyle.

The other unique aspect of the survey was that farmers were prompted to "Consider one of your fields where runoff is a potential problem.." For this field they were asked to report the type of tillage they employed last year with the options being conventional tillage, conservation tillage or no-till. Each option was denoted with the bounds of residue coverage associated with each type of tillage (30% residue or less, 30 – 90% residue, 90% residue or more). Other details collected about the field include the crop last planted, the yield for this last crop, the crop rotation maintained for the field, the expected fair market rental rate and the soil type (clay, clay loam, silty loam, loan, sand, sandy loam). Moreover farmers are asked whether they are aware about the algae issues in the Grand Lake St. Marys and Western Lake Erie Basin. Key descriptive statistics appear in Table 1.

Results

A two latent-class model was chosen as the most appropriate model for this sample by consulting the Akaike Information Criteria statistic for models that involved 1 to 4 classes. Differences between the classes are articulated in the last two columns of Table 1. The first class represents approximately 72% of the sample and contains farmers who choose tillage practices that leave more residue on the field. Specifically, the modal tillage choice among this class is no-till (47%), followed by conservation tillage (33%) and conventional tillage (20%). The remaining 28% of farmers fall in latent class two and choose tillage practices that leave less residue on the field. For this class, conventional tillage is the modal choice (46%), followed by conservation tillage (33%) and no-till (21%).

Several hypothesized drivers of tillage choice are significant in this model and work in opposite directions for the two classes (Table 2). For example, crop choice is a highly significant driver of tillage choice in both classes ($p < 0.001$). In the first latent class, farmers leave more residue when planting soybeans or wheat than when planting corn. However, among the second latent class, the opposite holds, with farmers leaving less residue when planting soybeans or wheat compared to corn. Hausman tests suggest that crop choice is not endogenous, which is not surprising given that we are considering single-year field-level crop choices and that most farmers report that the field is in an established rotation.

The presence of livestock on a farm and the size of the farm are also both highly significant drivers of tillage choice and are also work in distinct directions between latent classes. In the first latent class, small livestock farmers leave less residue than large farms without livestock, perhaps being indicative of farms that utilize the residue for livestock fodder. In the second latent class small livestock farmers leave more residue than large farms without livestock, suggesting different approaches to meeting livestock feed and bedding needs between the two classes. Finally, the reported yield in the field (normalized to the sample's crop-specific median) is also a significant driver of tillage choice. Farmers in latent class one leave more residue in productive fields while farmers in latent class two leave less residue in such fields.

The determinants of class membership are presented in Table 3. Compared to the high-residue first latent class, farmers in the second latent class, who are most likely to choose conventional tillage, tend to assign a lower weight to environmental stewardship. However, both classes weight profit maximization equally. This is not surprising as the profitability of tillage choices can be highly field and farm specific and may hinge on elements that were not observed as part of this survey, such as farm equipment availability and specific knowledge of farm tillage practices. Older, more highly educated farmers were more likely to be members of the low-residue second latent class as were first generation farmers with less awareness of local algae blooms. The fact that more highly educated farmers tend to be in the class that leaves less residue may reflect that recent research has suggested that continuous no-till tillage choices may leave fields at a certain disadvantage from both a fertility point of view, as occasional deep tillage may be needed to reinvigorate soils, and from an environmental point of view, as excessive crop residue may aid transport of phosphorous to local surface water sources.

Conclusion

Addressing emerging environmental challenges may require policy interventions that target particular agricultural management practices. An enhanced understanding of farmers' decision making processes concerning such management practices can aid in the design of educational and incentive-based policies that are commonly employed in this sector. However, farmers are not a homogeneous group, and an improved understanding of different motivations and decision processes can help policy makers target educational and incentive based interventions.

We survey farmers in a single Ohio watershed that drains into Lake Erie and ask them to assign weights to various farming motivations, including profit maximization and environmental stewardship, and then use this information to see these differences in motivation affect the way they choose tillage practices in a single field they deem at greatest risk of nutrient runoff. We find the weight they assign to environmental stewardship to be a positive significant driver of membership into the latent class of farmers that choose tillage practices that leave the greatest amount of crop residue on the field. Latent class membership is not driven by profit motivation, but is also driven by awareness of local environmental issues, age and education.

Within each class, the amount of crop residue left is determined in a distinct manner. For example, for the latent class that generally leaves more residue, large farms with no livestock that plant their chosen field to soybeans or wheat are the most likely to choose the no-till option, in which more than 90% of crop residue is left on the field. In the latent class that generally leaves less residue, small farms with livestock that plant low-yielding loam-soil fields to corn are most likely to choose the no-till option. Such detail provides guidance to educators who may wish to target certain types of farmers with information about the relative benefits of no-till approaches or to policy makers who wish to target certain size farms or farms with certain profiles for particular incentive based programs.

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Table 1. Summary Statistics (N=549)

Variable	Mean	Std. Dev.	Class 1	Class 2
Tillage Category				
Conventional	0.27		0.20	0.46
Conservation	0.33		0.33	0.33
No-till	0.40		0.47	0.21
Crop Planted				
Corn	0.36			
Soybean	0.42			
Wheat	0.13			
Other	0.09			
Livestock on Farm?	0.32			
Farm Gross Receipts				
<$50k (=1)	35.5			
$50 – 100k (=2)	17.8			
$100 – 250k (=3)	13.3			
$250 – 500k (=4)	9.9			
>$500k (=5)	23.5			
Field's Fair Market Rent				
Normalized Yield	1.12	0.67		
Soil Type				
Clay	0.18			
Clay loam	0.51			
Silty loam	0.14			
Loam	0.04			
Sand	0.03			
Sandy loam	0.10			
Subjective Weighting of…				
Making a Profit	36.10	19.27	35.73	36.91
Being an Env. Steward	18.35	11.99	19.18	16.16
Crop Rotation				
Corn/Soybean	0.28		0.28	0.26
Corn/Soybean/Wheat or Forage	0.34		0.36	0.32
Other	0.29		0.29	0.27
Not in a Rotation	0.09		0.07	0.15
Awareness of local algae blooms				
Not aware at all (=1)	0.13		0.07	0.26
Somewhat award (=2)	0.42		0.37	0.55
Very aware (=3)	0.45		0.56	0.19
Age	52.45	14.06	51.22	55.56
# generations farm in family				
One (=1)	0.19		0.14	0.34
Two (=2)	0.19		0.21	0.13
Three (=3)	0.61		0.65	0.52
Education				
< HS (=1)	0.02		0.02	0.02
HS or equivalent (=2)	0.45		0.48	0.42
Some College (=3)	0.20		0.10	0.10
Associate's Degree (=4)	0.11		0.09	0.06
Bachelor's Degree (=5)	0.15		0.24	0.26
> Bachelor's Degree (=6)	0.07		0.04	0.10

Table 2. Ordinal Model of Tillage Choice, 2-Latent Classes

	Latent Class 1		**Latent Class 2**		**Wald Statistics**	
Variable	*Coefficient*	*Z-stat*	*Coefficient*	*Z-stat*	*Variable Significance*	*Distinct Classes*
Crop Planted					23.48***	15.15***
Corn	--	--	--	--		
Soybean	0.96***	3.60	-1.14*	-1.76		
Wheat	1.07***	2.89	-5.28**	-2.15		
Other	-0.70	-1.38	0.34	0.40		
Livestock on Farm Dummy	-0.95***	-3.62	1.46**	2.11	16.15***	9.91***
Farm Gross Receipts	0.001***	2.65	-0.01**	-1.98	10.75***	9.31***
Field's Fair Market Rent	-0.002	-0.81	0.009	1.44	2.30	2.30
Normalized Yield	0.20	0.77	-1.16*	-1.88*	5.00*	4.89**
Soil Type					13.31	10.79*
Clay	--		--			
Clay loam	-0.17	-0.56	0.65	0.93		
Silty loam	-0.36	-0.91	3.01***	2.78		
Loam	-0.67	-1.35	3.14***	2.36		
Sand	0.02	0.02	-4.14	-0.70		
Sandy loam	-0.62	-1.41	0.86	1.08		
N	353		141			
Pseudo-R^2	0.27		0.52			

Notes: Dependent variable is ordinal value of amount of residue left on field where <30% (conventional tillage) is coded as a '1', 30 – 90% residue (conservation tillage) is coded a '2' and >90% residue (no-till) is coded as a '3'. The first Wald statistic tests for joint significance of each variable across all latent classes of the model while the second Wald statistic tests for differences in variable coefficients between the latent classes.

Table 3. Ordinal Model of Tillage Choice, Model of Latent Class Membership

	Prob(Latent Class 2)		
Variable	*Coefficient*	*Z-stat*	*Wald*
Intercept	2.21	1.42	2.03
Subjective weighting of making a profit	-0.003	0.22	0.05
Subjective weighting of being an environmental steward	-0.069**	-2.25	5.06**
Crop Rotation			
No Rotation	--	--	3.05
Corn/Soybean	-0.36	-0.39	
Corn/Soybean/Wheat or Forage	-0.94	-1.06	
Other	-1.66	-1.51	
Awareness of local algae blooms	-1.89***	-3.52	12.40***
Age	0.04**	2.20	4.82**
Education	0.55**	2.15	4.62**
# generations farm in family			
First	--		9.35***
Second	-2.50***	-2.72	
Third or more	-1.90***	-2.93	
N	353		141

Notes: Dependent variable is the probability that a respondent belongs to latent class 2. The Wald statistic tests for joint significance of the variable.