Disadoption of Agricultural Practices by Livestock Farmers

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Abstract

To be effective, policies that encourage farmers to use new technologies or practices need farmers both adopt and also keep using these technologies and practices. Adoption of new technologies has been widely analyzed in the literature. However, there is little known about the factors that cause farmers to keep using new technologies or quit using them. Using hazard function estimation, the current study investigates disadoption of Roundup Ready soybeans, injecting manure into the soil, and soil testing. The results of the current study show that over time farmers observe the true benefits and costs of these practices and they become more likely to disadopt these practices.

Introduction

Technology adoption has been extensively analyzed in the literature. There are well-established theoretical models that explain factors that impact adoption of new technologies by farmers (Sunding and Zilberman, 2001). A large number of empirical studies provide additional evidence regarding adoption decisions (An, 2008). The design of effective policies to promote use of new practices or technologies by farmers requires understanding the factors that affect whether farmers continue to use them.

The literature on disadoption of technologies has investigated similar variables to the adoption studies (Moser and Barrett, 2003). The recent study by An (2008) investigates the adoption and disadoption of recombinant bovine somatotropin (rBST), a growth hormone injected into cows to increase milk production, by U.S. dairy producers. However, the disadoption decision is negatively correlated with use of complementary technologies. Their results also show that farmer characteristics such as education and experience and farm characteristics such as herd size were not significant in the disadoption decision. The results of this study were similar to the results of the study by Barham, Smith and Moon (2002). The study by Moser and Barrett (2002) analyzes adoption and disadoption of a high-yielding, low-external input rice production method, which is called System of Rice Intensification (SRI), by farmers in Madagascar. Their results show that farmers with better education are less likely to disadopt SRI. However, farmers with off-farm work are more likely to disadopt SRI, which is due to higher opportunity cost of labor (Moser and Barrett, 2003). The study by Cornejo, Alexander and Goodhue (2002) shows that farmers do not disadopt herbicide-tolerant soybeans (Roundup Ready soybeans), even if the price of glyphosate, an herbicide to which the variety is tolerant, increased during the study period. This was explained by higher measured benefits of this crop compared to traditional soybeans. The study by Bravo-Ureta, Cocchi and Solis (2006) analyzes the determinants of adoption and disadoption of soil conservation technologies by farmers participating in the Environmental Program of El Salvador. Their results show that farmers with off-farm income, higher education and higher frequency of extension visits are less likely to disadopt conservation technologies. However, farmers with larger and more diversified farms are more likely to disadopt conservation practices. Overall, the studies reviewed show that farmers with higher education are less likely to disadopt the practices. However, the impact of farm size and off-farm income on the probability of disadopting a practice is not clear.

Previous studies incorporated the decision to disadopt a practice as a dummy variable in a probit or a multivariate logit regression, which does not include information on the time period between the adoption and disadoption of the practice (An, 2008; Barham, Smith and Moon, 2002; Bravo-Ureta, Cocchi and Solis, 2006). The contribution of the current study is to use hazard function estimation, which is also known as duration analysis, to examine disadoption of different practices. This study, to our knowledge, is the first one that uses hazard function estimation for disadopting a practice or technology. Unlike the previous studies, the current study will incorporate the time span between adoption and disadoption of the practices.

The three practices that are going to be analyzed in this study are; Roundup Ready soybeans, injecting manure into the soil, and soil testing.

Roundup Ready Soybeans

The Roundup Ready gene allows resistance to the herbicide Roundup (Couvillion *et al*., 2000). Hence, when Roundup is sprayed on Roundup Ready soybeans, weeds are killed without harming the soybean crop (Couvillion *et al*., 2000). According to Couvillion *et al*., (2000), Roundup Ready soybeans will allow farmers to decrease their chemical application costs and also the costs of trips to the field to apply herbicide. According to Monsanto (2006) conducted trials, Roundup Ready soybeans are expected to increase yields by 4.5 bu/acre over conventional herbicide systems. The study by Sydorovych and Marra (2008) shows that when farmers chose their herbicide, they consider both the application costs and the product costs. It is expected that Roundup Ready soybeans is primarily adopted to reduce costs and increase profitability.

Injecting Manure into the Soil

Injecting manure into the soil minimizes nitrogen losses and odor problems (Prairie Agricultural Machinery Institute, 1997). The nutrient loss can be minimized to as low as 1%, whereas with sprinkler irrigation, nutrient loss can range from 20 to 90% (Prairie Agricultural Machinery Institute, 1997). The disadvantage of manure injection systems is the cost of the required equipment. The main equipment types required for manure injecting systems are; an agitator that agitates the manure in the manure storage unit, the main line that transports the manure from storage to the field, a pump that is connected to the main line and the storage, the drag line that transports the manure from main line to the manure injector, an injector that injects the manure into the soil, and three tractors (Prairie Agricultural Machinery Institute, 1997). The tractors will be connected to the agitator, the drag line and to the injector. Depending on the size of the farm, the cost of purchasing equipment other than the three tractors can range from $60,000 to $120,000 (Prairie Agricultural Machinery Institute, 1997). Due to the costs associated with manure injecting systems, injecting manure is considered to be a capital intensive technology.

Soil Testing

Soil testing is done to measure the fertility of soil and to determine the amount of manure or fertilizer to be applied (U.S. Department of Agriculture, 1996). Since the soil sample will represent the whole field, taking the sample should be done very carefully. If the field has sections with different slope, drainage or soil, then the field should be divided into sections (U.S. Department of Agriculture, 1996). For each section of the field, 20 or more samples should be taken and then these samples should be mixed in a clean plastic pail for each section of the field and then sent for the laboratory analysis (U.S. Department of Agriculture, 1996). University extension services and fertilizer dealers have laboratories for soil testing (U.S. Department of Agriculture, 1996) and cost is $7 per sample (field or portion of a field). No large equipment is needed, only a soil sampler that costs less than $100. Also, since soil testing is typically done every three or four years it isn't particularly time intensive. Hence, soil testing is neither capital nor labor intensive. It is a profitable practice since it can save on fertilizer costs but soil testing also can have environmental benefits if it results in reduced run-off to streams and lakes.

Conceptual Framework

In general, the disadoption decision can be analyzed with a Bayesian framework for decision making under uncertainty. When farmers are introduced to the new technology, they have incomplete information about the benefits and costs of this technology. Based on their prior beliefs, which might be impacted from other farmers or extension staff, farmers make their decision to adopt a technology or not. In the case of this study farmers adopted the new technology. Over time, farmers observe the true benefits and costs of the technology and can make the decision to continue using the technology or disadopting the technology. Hence, over the time the rational decision for the farmers can be either continue using the technology or disadopting the technology.

One of the obstacles for the disadoption decision can be the irreversibility of the technology. If the new technology required high upfront investment, then over time even if the farmer observes that the technology is not profitable, the farmer may not be able to disadopt the technology. This would make smaller farmers less likely to disadopt and larger farms to more likely to disadopt if the technology turns out to be unprofitable.

It is expected that farmers with higher education can perceive the impacts of a practice faster than farmers with less education. This would lead farmers with higher education to be more likely to disadopt a technology that becomes unprofitable. Having off-farm income would mean higher opportunity cost of labor for a technology that turned out to require more labor. It is expected that farmers with off-farm income to be more likely to disadopt a technology that turns out to be more labor intensive than expected.

Specific Hypotheses

- For impact of learning about the technology; over time farmers will be either more likely or less likely to disadopt the practice.
- For the impact of farm size; farmers with smaller farms are less likely to disadopt a technology.
- For the impact of education; farmers with higher education are either more likely to disadopt a technology than farmers with lower education levels or there is no difference with respect to education levels.
- For the impact of off-farm income; farmers with off-farm income are either more likely to disadopt a technology or there is no difference with respect to off-farm income levels.

Empirical Model

For the empirical model, the disadoption decision that farmers make for the practices can be represented with a stochastic profit framework (Green). The profit gained from disadoption of a practice is compared to profit from continuing to use the practice. If the profit from disadopting the practice is bigger than the profit from continue to use the practice, then the farmer disadopts the practice. If the profit from disadopting the practice is less than or equal to the profit from continue to use the practice, then the farmer does not disadopt the practice.

The profit function $\Pi(.)$ is assumed to be a function of age (AGE), education (EDUC), off-farm income (OFI), farm sales (FS), farmer's plans to continue farming (CF) and expanding livestock numbers (EL), perceptions about the practice (PPP), influence of NRCS on farmer's decisions (NRCS), manure handling systems (MHS), and livestock specie (LS). It is also assumed that the profit has a random factor ε, which is assumed to have a normal distribution.

The profit function $\Pi(.)$ then can be represented as;

$$\pi(AGE, EDUC, OFI, FS, CF, EL, PPP, IGO, MHS, LS, \varepsilon)$$

If π_D represents the level of profit from disadopting a practice and π_{ND} represents the level of profit from not disadopting the practice, then the decision whether to disadopt a practice or not can be represented as;

$y_i = 1$ (farmer disadopts the practice) if $\pi_D > \pi_{ND}$

$y_i = 0$ (farmer does not disadopt the practice) if $\pi_D \leq \pi_{ND}$

For econometric analyses, the hazard function for the current study can be represented as (Wooldridge, 2001);

$$\lambda(t; \boldsymbol{x}) = \lim_{\Delta t \to 0} \frac{\Pr[t \leq T < t + \Delta t | T \geq t; \boldsymbol{x}]}{\Delta t}$$

which gives the probability that the length of time a farmer uses a practice *T* will be between *t* and $t + \Delta t$, given that it was bigger or equal to *t.* The explanatory variables such as characteristics of the farmer and the farm are included in the vector $\boldsymbol{x}$. The estimation is done using the maximum likelihood procedure.

Data

A mail survey of 3014 farmers, including both CAFOs and AFOs, was conducted in Iowa and Missouri in spring 2006. Farmers were stratified by farm sales and by type of livestock. Farmers with farm sales less than $10,000 were not sampled. This eliminates most retirement / lifestyle farmers (Hoppe, 2006). In designing the survey, the methodology discussed by Dillman (2000) was followed. The questions were designed to learn whether farmers have adopted the chosen conservation practices and how the farmer's and the farm's characteristics impacted the adoption decision. The effective response rate for the survey was 37.4 percent. For the regression analysis, the farmers who have adopted the practices at some point were included into the data set. CAFOs and farmers with no land were excluded from the data set. For Roundup Ready soybeans, farmers with no soybean production were also excluded from the data set.

The summary statistics are given in table 1. Farmers who have adopted the practice at some point in time and continue to use the practice are named as adopters. Farmers that adopted the practice at some point in time and then stopped using the practice are named as disadopters. For all the practices, having high school education has the highest percentage of adopters. However, for disadopters some college or vocational school education has the highest percentage for Roundup Ready soybeans and injecting manure. For being profitable, 82% of the adopters agree that Roundup Ready soybeans is a profitable practice, while only 50% of the disadopters agree with the statement. For injecting manure these numbers are 90% and 27% respectively. This would show more farmers observe that injecting manure was not profitable for them over time. For being time consuming, 33% of the adopters agree that injecting manure is time consuming, while this number is 64% percent for disadopters. This would mean that farmers also observe over the time that this practice is time consuming for them. With respect to total animal units, there is a big difference between adopters and disadopters for injecting manure than other practices. This would show evidence for the existence of economies of scale for injecting manure.

Regression Results

All three regressions are significant with p-values of 0.00. Age was insignificant for all three practices, which might show experience was not important for these practices. For injecting manure farmers with some college or vocational school and farmers with bachelor degrees are more likely to disadopt injecting manure than those with a high school education. This would show that farmers with higher education were better at observing the benefits and costs of the practice. For Roundup Ready soybeans, farmers with less than a high school degree are more likely to disadopt than farmers with high school degree. For soil testing education was not significant.

Farmers with no off-farm income were less likely to disadopt Roundup Ready soybeans and soil testing than farmers with off-farm income of $10,000-$24,499. For injecting manure, having off-farm income was not significant. For injecting manure, farmers with farm sales of $500,000 and over were less likely to disadopt than the farmers in the base category $100,000-$249,999. For soil testing, farmers in the lowest farm sales category, $10,000-$99,999, were more likely to disadopt than the farmers in the base category. Farm sales category was not significant for Roundup Ready soybeans.

For perceptions about the practices, farmers who agree that Roundup Ready soybeans, injecting manure and soil testing are profitable practices are less likely to disadopt these practices than farmers who disagree that these practices are profitable. Farmers who agree that Roundup Ready soybeans is a time consuming practice are more likely to disadopt than farmers who disagree. Farmers who agree that the practice is complicated are less likely to disadopt injecting manure but more likely to disadopt soil testing. Farmers whose agricultural production decisions are impacted by NRCS are less to disadopt soil testing, but this variable is not significant for Roundup Ready soybeans and injecting manure.

Type of manure handling system is not significant for any of the practices. Dairy, beef cattle and poultry operations are more likely to disadopt injecting manure than swine operations. This may be due to the odor reduction impact of this practice, which may be especially relevant for swine operations. Although beef cattle operations are less likely to disadopt soil testing, poultry operation are more likely to disadopt soil testing than swine operation. For Roundup Ready soybeans, the only significant category is beef cattle. Total animal units is significant for only soil testing. Farmers with more animal units are more likely to disadopt soil testing, perhaps because these farmers are more oriented to livestock production than crop production or because they need to buy less fertilizer.

An important feature of using hazard functions is to get information on how the probability of disadopting a technology changes with the length of time that farmers used the practices. This feature is called "time dependence". In the current analyses positive time dependence was found for all three practices, i.e., the probability of disadopting these practices increases as farmers use these practices for longer periods of time.

Conclusion

The results of the current study provided evidence for the impact of learning. Farmers are more likely to disadopt especially Roundup Ready soybeans and injecting manure the longer they use the practices. This shows evidence that farmers observe the true benefits and costs of these practices over the time. Profitability is the only perception that impacted disadoption of all the practices. Although injecting manure is beneficial for water and air quality, finding that farmers with higher education be more likely to disadopt this practice would mean that this practice is not profitable for all the farmers and disadoption of this practice would increase in the future.

Table 1. Summary Statistics

Variable	Roundup Ready Soybean		Injecting Manure		Soil Testing	
	Adopters Mean	Disadopters Mean	Adopters Mean	Disadopters Mean	Adopters Mean	Disadopters Mean
Age	51	47	48	52	50	49
Iowa	0.70	0.75	0.93	0.77	0.57	0.33
Missouri (Base Category)	0.30	0.25	0.07	0.23	0.43	0.67
Education						
Less than High School	0.05	0.25	0.01	0.00	0.09	0.16
High School (Base Category)	0.44	0.19	0.49	0.27	0.41	0.37
Some College or Vocational School	0.32	0.31	0.32	0.41	0.30	0.24
Bachelor Degree	0.18	0.25	0.17	0.27	0.19	0.22
Graduate Degree	0.01	0.00	0.00	0.05	0.01	0.02
Off-farm Income						
None	0.28	0.07	0.24	0.09	0.29	0.22
$0 - $9,999	0.14	0.07	0.15	0.09	0.13	0.08
$10,000-$24,999 (Base Category)	0.15	0.13	0.17	0.23	0.15	0.26
$25,000 - $49,999	0.27	0.67	0.27	0.41	0.26	0.24
$50,000 - $99,999	0.12	0.07	0.15	0.18	0.14	0.16
$100,000 +	0.03	0.00	0.03	0.00	0.03	0.04
Farm Sales						
$10,000 - $99,999	0.15	0.27	0.11	0.09	0.21	0.39
$100,000-$249,999 (Base Category)	0.37	0.40	0.27	0.27	0.36	0.43
$250,000 - $499,999	0.25	0.13	0.25	0.41	0.23	0.10
$500,000 +	0.22	0.13	0.36	0.23	0.18	0.06
Continue Farming						
Yes	0.91	0.69	0.92	0.95	0.90	0.88
No (Base Category)	0.02	0.13	0.03	0.00	0.03	0.02
Not Sure	0.07	0.19	0.05	0.05	0.05	0.08
Expand Livestock Numbers						
Yes	0.32	0.31	0.35	0.40	0.37	0.31
No (Base Category)	0.43	0.38	0.43	0.20	0.39	0.49
Not Sure	0.25	0.31	0.22	0.40	0.23	0.18
Perceptions about the Practices						
Profitable						
Disagree (Base Category)	0.06	0.31	0.03	0.41	0.06	0.10
Neutral	0.11	0.19	0.06	0.32	0.05	0.14
Agree	0.82	0.50	0.90	0.27	0.86	0.75
Improves Water Quality						
Disagree (Base Category)	0.07	0.25	0.02	0.09	0.06	0.04
Neutral	0.34	0.31	0.04	0.32	0.15	0.22
Agree	0.56	0.44	0.92	0.59	0.73	0.67
Time Consuming						
Disagree (Base Category)	0.83	0.69	0.48	0.18	0.35	0.18
Neutral	0.07	0.19	0.17	0.18	0.24	0.29
Agree	0.06	0.13	0.33	0.64	0.34	0.47
Complicated						
Disagree (Base Category)	0.85	0.81	0.69	0.50	0.58	0.37
Neutral	0.06	0.19	0.18	0.36	0.23	0.37
Agree	0.05	0.00	0.11	0.14	0.12	0.18
NRCS						
None (Base Category)	0.36	0.50	0.36	0.55	0.35	0.59
Some	0.37	0.31	0.35	0.23	0.38	0.29
Very Much	0.25	0.19	0.26	0.23	0.25	0.12

Table 1. Summary Statistics (Continued)

	Roundup Ready Soybeans		Injecting Manure		Soil Testing	
Variable	**Adopters Mean**	**Disadopters Mean**	**Adopters Mean**	**Disadopters Mean**	**Adopters Mean**	**Disadopters Mean**
EQIP (B.C. Do not Have a Contract)	0.20	0.19	0.16	0.27	0.23	0.14
Manure Handling						
Solid Handling	0.50	0.56	0.09	0.36	0.54	0.71
Liquid Handling (Base Category)	0.17	0.13	0.36	0.09	0.16	0.06
Solid and Liquid Handling	0.33	0.31	0.55	0.55	0.28	0.20
Total Animal Units	642	600	1099	671	668	424
Species						
Dairy	0.16	0.00	0.16	0.18	0.18	0.20
Beef Cow	0.28	0.25	0.09	0.41	0.23	0.08
Beef Cattle	0.13	0.13	0.02	0.09	0.12	0.14
Swine (Base Category)	0.36	0.44	0.69	0.23	0.29	0.18
Poultry	0.04	0.06	0.01	0.09	0.07	0.18
Turkey	0.03	0.06	0.02	0.00	0.10	0.14
Other	0.00	0.06	0.01	0.00	0.02	0.06

Table 2. Regression Results

Variable	Roundup Ready Soybeans		Injecting Manure		Soil Testing	
	Coeffient	p-Value	Coeffient	p-Value	Coeffient	p-Value
Age	0.01	0.89	0.23	0.23	-0.02	0.44
Iowa	1.97	0.36	-13.58	0.02	-1.21	0.01
Education						
Less than High School	17.61	0.03	6.42	1.00	0.17	0.79
Some College or Vocational School	2.62	0.34	7.51	0.01	-0.25	0.56
Bachelor Degree	4.26	0.13	7.64	0.05	-0.22	0.66
Graduate Degree	3.37	1.00	7.38	0.14	-13.22	0.99
Off-farm Income						
None	-10.13	0.06	-8.73	0.24	-1.27	0.02
$0 - $9,999	-2.23	0.44	-9.18	0.11	-1.46	0.03
$25,000 - $49,999	2.14	0.21	1.00	0.53	-0.59	0.24
$50,000 - $99,999	-1.14	0.65	-2.08	0.67	-0.17	0.76
$100,000 +	-17.50	1.00	-14.42	1.00	-0.22	0.83
Farm Sales						
$10,000 - $99,999	-2.54	0.31	-2.85	0.66	1.06	0.01
$250,000 - $499,999	-0.18	0.90	-5.34	0.17	-0.26	0.67
$500,000 +	-2.82	0.24	-12.11	0.02	-0.81	0.36
Continue Farming						
Yes	-6.52	0.10	29.36	0.99	0.55	0.50
Not Sure	-0.36	0.91	10.90	1.00	0.45	0.66
Expand Livestock Numbers						
Yes	1.58	0.22	2.60	0.29	-0.48	0.23
Not Sure	-0.66	0.71	6.04	0.04	-0.47	0.32
Perceptions about the Practices						
Profitable						
Neutral	-2.30	0.30	-7.20	0.02	-0.62	0.39
Agree	-6.38	0.04	-3.85	0.02	-2.00	0.00
Improves Water Quality						
Neutral	-2.37	0.26	0.34	0.97	-0.76	0.24
Agree	-1.66	0.49	-0.54	0.95	-0.65	0.27
Time Consuming						
Neutral	2.54	0.28	-3.25	0.53	0.84	0.10
Agree	5.35	0.01	10.62	0.12	0.65	0.19
Complicated						
Neutral	-5.75	0.10	0.76	0.82	0.60	0.17
Agree	-23.94	1.00	-6.70	0.05	0.97	0.07
NRCS						
Some	0.81	0.58	2.37	0.27	-0.92	0.03
Very Much	2.26	0.15	-5.99	0.11	-1.67	0.01
EQIP	0.37	0.78	2.62	0.35	-0.33	0.52
Manure Handling						
Solid Handling	3.22	0.18	4.74	0.53	0.80	0.24
Solid and Liquid Handling	3.35	0.11	7.47	0.35	0.93	0.19
Total Animal Units	0.00	0.16	0.00	0.82	0.00	0.03
Species						
Dairy	-19.13	0.99	15.92	0.02	-0.05	0.94
Beef Cow	-3.13	0.10	9.35	0.01	-2.01	0.01
Beef Cattle	0.51	0.74	9.91	0.11	-0.50	0.46
Poultry	-0.28	0.91	21.24	0.03	1.41	0.07
Turkey	-8.13	0.17	2.11	1.00	0.45	0.55
Other	-4.64	1.00	-3.61	1.00	1.42	0.10

Table 2. Regression Results (Continued)

	Roundup Ready Soybeans	Injecting Manure	Soil Testing
Number of Observation	383	178	494
Number of Disadopters	14	20	44
Time Dependence	2.27	2.84	1.05
Wald Chi-Square	83 (p-value = 0.00)	108 (p-value = 0.00)	105 (p-value = 0.00)

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