Count Data Analysis of the Adoption of Best Management Practices in Beef Cattle Production

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Abstract

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Soil and water conservation have been increasingly emphasized in the U.S. agricultural sector. Best Management Practices (BMPs) are a set of practices that producers may adopt on a voluntary basis to reduce nonpoint source pollution. Despite its relatively lower historical emphasis, nonpoint source pollution originating from crops and pasture-based livestock production has been identified as a major source of water quality problems, as indicated by the U.S. Environmental Protection Agency.

The technology adoption literature has relied primarily on binary logit and probit models to analyze adoption behaviors. More in-depth studies have included the investigation of joint adoption of technologies (e.g., Cardona, 1999; Rahelizatovo, 2002). However, largely missing has been investigation of the intensity of BMP adoption by farmers. Ramirez and Shultz (2000) explored the use of Poisson count data models on the adoption of Integrated Pest Management (IPM) in Central American countries. Rahelizatovo and Gillespie (2004) used count data models in their investigation of the adoption of dairy BMPs. The count data modeling approach helps one to understand the factors influencing farmers to intensively adopt, while others may not adopt any BMPs The primary motivation behind this study is to address these concerns with respect to the beef cattle industry, which has historically had a low level of adoption as well as relatively low level of targeting by regulatory agencies.

There are 16 BMPs recommended by the Louisiana State University Agricultural Center to beef cattle producers. The manual of Beef Production Best Management Practices includes the Natural Resources Conservation Services (NRCS) code number for each BMP. This study identified factors affecting the adoption of these BMPs. Knowledge of these factors will help policymakers to emphasize the most effective methods to reduce water pollution in affected watersheds.

Data

A state-wide survey of 1,700 beef cattle producers was conducted from May to September, 2004. For the pretest, 200 farms were used, and the remaining 1,500 farms were used in the main survey. The sample was drawn by the Louisiana Agricultural Statistics Service. It was stratified by the size of the beef cattle herd to reflect the population. The size categories were 1-19, 20-49, 50-99, and 100 or more head, constituting 26.7 percent, 23.3 percent 23.3 percent and 26.7 percent of the sample, respectively. The response rate was 41 percent after deducting 270 respondents who indicated they were out of the cattle business.

The survey collected information on 1) production characteristics, including measures such as size of operation, type of ownership, type of operation, and land characteristics; 2) the current adoption of BMPs; and 3) producer characteristics, including gender, age, education, income, income from cattle operation, debt load, off-farm job, farm succession, and number of contacts with regulatory and educational personnel. Table 1 presents a description of 16 beef cattle BMPs recommend by the Louisiana State University Agricultural Center.

Methods

If the events of adopting BMPs occur at a positive constant rate, over the exposure period within a beef cattle farm, the events can be considered as Poisson data. Then, the Poisson model is specified as equations (1) and (2) (Cameron and Trivedi, 1998).

$$(1)\quad f(y_i \mid x_i) = \frac{e^{-m_i} m_i^{yi}}{y_i!}, \qquad y_i = 0, 1, 2, \ldots,$$

where y_i is the number of BMPs adopted by a farmer and x_i are explanatory variables that affect BMP adoption. Here, the expected mean parameter, m_i, is

(2) $m_i = E[y_i \mid x_i] = \exp(x_i' b)$.

The estimation of this model involves maximization of the log-likelihood function, which is

(3) $\ln L(b) = [y_i (x_i' b) - \exp(x_i' b) - \ln(y_i!)]$.

The major weakness of the Poisson model is that it assumes the mean and variance of the dependent variable to be equal. In reality, count data often have greater variance than mean. Overdispersion arises when the variance is larger than the mean in a Poisson regression, resulting in underestimation of standard errors, overestimation of chi-square statistics, and inefficiency of estimates. Assume, then, that the variance (w) is a function of the mean, which can be written as in equation (4) (Cameron and Trivedi, 1998),

(4) $w_i = m_i + a m_i^p$,

where a is a scalar parameter and p is a specified constant. The commonly used negative binomial (NB2) model specifies p to be 2. Scalar a is the dispersion parameter to be estimated along with the coefficients of independent variables. Estimation of the NB2 model involves maximization of the following log-likelihood function, which is

(5) $\ln L(a, b) = \sum_{i=1}^{n} \left\{ \left(\sum_{j=0}^{y_i - 1} \ln(j + a^{-1}) \right) - \ln y_i! - (y_i + a^{-1}) \ln(1 + a \exp(x_i' b)) + y_i \ln a + y_i x_i' b \right\}$

Factors Influencing the Adoption of BMPs

A number of factors are hypothesized to influence the adoption of BMPs in cattle production, and are included in the count data models.

Farm size has been shown to have a significant effect on technology adoption behavior in the agricultural sector (Feder, 1980). Given the previous literature on technology and, specifically BMP, adoption (Rahelizatovo and Gillespie, 2004), it is expected that larger farms are more likely to adopt more BMPs. This is due to their greater propensity to adopt technologies of most types and the ability of the larger farmer to spread costs of adoption over more units of production, thereby reducing average total cost. Number of animals in the beef cattle herd (*Animals*) was used as a measure of farm size.

A purebred or seedstock production enterprise differs from a commercial cow-calf enterprise. While both typically produce calves, purebred operations generally result in higher returns, as breeding stock prices are generally higher than prices for animals produced for the sole purpose of eventual slaughter. Breeding stock is often purchased via private treaty on the farm. Thus, the appearance of a well-managed farm is considered to be of importance in the marketing of animals. Basarir (2002) found that purebred producers weighted the goal, "Maintain and Conserve Land," relatively higher than did commercial producers. For these reasons, it is expected that BMP adoption is higher for purebred producers than commercial operators. *Purebred* is a dummy variable representing the production of purebred animals.

Some BMPs may benefit not only beef cattle production but also other crops and/or livestock enterprises. For instance, a water trough or tank may also be useful for a pasture-based dairy operation. Thus, when a farm is engaged in more crops and/or livestock enterprises, it is expected that the farmer will more likely adopt more BMPs. Fernandez-Cornejo *et al.* (1994) used crop diversification as an explanatory variable in a study of vegetable growers' adoption of Integrated Pest Management (IPM). Results indicated a positively significant relationship between IPM adoption and crop diversification. Rahelizatovo and Gillespie (2004) included crop diversification as an explanatory variable in an analysis of the adoption of dairy BMPs. The variable was positive in the adoption of dairy BMPs, but not significant. Variable *Diversification,* representing the number of other crops and livestock enterprises included on the farm, is expected to positively influence the number of BMPs adopted.

Tenancy has been shown to influence technology adoption. Soule *et al.* (2000) showed the importance of land tenancy in the adoption of conservation practices. Their results indicated that share-renters were more likely to adopt conservation practices than cash-renters. Cardona (1999) showed that tenure was an influential factor in the adoption of BMPs, as sugarcane growers were less willing to implement BMPs on rented land. *Owned Land Ratio* represents the ratio of owned land to total land used in the beef cattle operation. This variable is hypothesized to positively influence the number of BMPs adopted, due to the ability of the landowner to realize the long-run benefits of BMP implementation.

Land characteristics are included in BMP adoption studies to account for their influence on adoption rate. Closer proximity to a stream may result in a higher delivery rate of sediment to the waterbody. Rahelizatovo (2002) found that having a stream or river running through a farm was significant in dairy farmers' adoption of BMPs. *Stream Through* represents having a stream or river running through the farm. It is hypothesized to increase the number of BMPs adopted.

One other land characteristic considered was hilly land. Hilly land would be more susceptible to weather hazards, thus resulting in greater erodibility compared with flat land. Variable *Hilly Land* is a dummy variable indicating hilly land is used for beef cattle grazing. It is expected to have a positive relationship with the number of BMPs adopted.

Exposure to information is expected to play a vital role in technology adoption (Feder *et al.*, 1985). A farmer must understand the benefits and costs of a technology in order to make an informed adoption decision. A role of the USDA Natural Resources Conservation Service (NRCS) is to assist farmers in conserving, maintaining, and improving natural resources and the environment. It promotes conservation via programs and one-on-one farm planning. Thus, greater contact with NRCS is expected to positively influence a farmer's BMP adoption decision. Variable *NRCS Contact* was included as a dummy variable indicating whether the farmer had contact with NRCS personnel at least once during 2002. These contacts were specified as through seminars or workshops, in-person, telephone, or e-mail.

Having a family member to take over the farm is expected to have a positive relationship with the number of BMPs adopted, effectively extending the farmer's planning horizon beyond the otherwise expected land sale date. Future returns of family members are expected to enter into the farmer's planning horizon and to be discounted at a relatively low rate if social capital with these family members is highly valued. Variable *Family Take Over* is included as a dummy variable.

A number of studies have found negative impacts of farmer *Age* on the adoption of technology in general and, more specifically, conservation practices (e.g., Soule *et al*., 2000). It is hypothesized that older producers are likely to adopt fewer BMPs, as they typically have shorter planning horizons and may not fully realize the long-term benefits of adoption.

An array of literature has assessed the effect of education on technology adoption. Rahm and Huffman (1984) reported that education enhances the adoption of reduced tillage. Wu and Babcock (1998) found college education to be significant in the adoption of conservation tillage, crop rotation and soil nitrogen testing. *College Education* is included as a dummy variable for holding a college bachelor's degree. More highly educated producers are generally able to make better-informed decisions, and are more likely to be aware of production alternatives. Thus, *College Education* is expected to positively influence the number of BMPs adopted.

Feder *et al.* (1985) discuss the significant impact of financial situation on technology adoption. A cattle producer's financial situation is, likewise, expected to play a role in BMP adoption decisions. Higher *Household Income* farmers are expected to adopt higher numbers of BMPs. A higher percentage of total household income from the beef cattle operation would indicate greater concern for economic efficiency. Thus, *Cattle Income Ratio* is expected to have a positive influence on the number of BMPs adopted.

Finally, credit constraints have been found to impede technology adoption (Feder *et al.*, 1985), especially for capital-intensive practices. On the other hand, a high debt load may have originated from investments the farmer recently made. Thus, some potential endogeneity issues are associated with using a debt load variable. *Debt-Asset Ratio* represents the producer's debt-asset ratio.

Results

Table 2 provides weighted estimated adoption rates of BMPs in Louisiana beef cattle production. The weighting adjusts according to differences in the numbers of operations in each size category of the stratified sample, as larger farms were over-sampled and smaller farms were under-sampled. The adoption rates ranged from 19 to 75 percent. Continuous Prescribed Grazing was the most widely adopted BMP, while regulating water in a drainage system was the least adopted BMP.

Figure 1 presents the percentage of farms adopting each BMP. Three percent of the farms had not adopted any BMPs, while two percent had adopted all 16. At the mode, 15 percent of the farms had adopted five BMPs. The average number of BMPs adopted was 6.7.

Descriptive statistics for dependent and independent variables are shown in Table 3. Sampled farms had an average of 130 beef animals, and 16 percent raised purebred animals. Thirty-eight percent of farms had NRCS contact at least once during 2002, and the average producer's age was 57 years. Twenty-six percent indicated they had a family member to take over the farm upon their retirement and 35 percent held a college Bachelor's degree. Forty-seven percent indicated the land they used for the cattle operation had a stream or a river running through it.

Table 4 presents the results of the Poisson and negative binomial models. Since the variance (15.21) of the dependent variable is greater than its mean (6.7), it is inappropriate to use the Poisson model. Results of marginal effects for the negative binomial regression are presented in Table 5. Having a greater number of animals was expected to result in a greater number BMPs adopted. However, *Animals,* was not a significant factor. This surprising result appears unique to cattle production. According to Basarir (2002), larger Louisiana beef cattle farms more heavily weighed profit maximization, while smaller farmers more heavily weighted maintaining and conserving land. Presence of purebred cattle in an operation was a positively significant factor in the Poisson regression, but not in the negative binomial regression.

As expected, diversified farms would adopt more BMPs, as variable *Diversification* had a positively significant sign. As beef cattle farms add one more crop or livestock enterprise to their operations, they would be expected to adopt 0.3 more BMPs, if other conditions remained constant. Having a stream or river running through cattle farm did not influence the number of

BMPs adopted. Some BMPs may be adopted because a farm has a stream or a river running through the farm (e.g. Streambank and Shoreline Protection), while other BMPs may not be adopted because they had a water source (e.g. Water Facility). As expected, operating a beef cattle farm based on hilly land would result in adopting a greater number of BMPs.

The role of NRCS turned out to be very important on the number of BMPs adopted. NRCS contact once a year resulted in the increased adoption of 1.2 more BMPs. *Family Take Over* and *Age* variables were not significant factors on the number of BMPs adopted. However, *College Education* was a significant factor. A college educated producer would adopt almost one more (marginal effect = 0.8) BMP.

Among the three financial indicators, *Household Income* and *Cattle Income Ratio* were significant factors on the number of BMP adoption. A 20 percent increase in the portion of income coming from the beef cattle operation would result in 0.8 more BMPs being adopted, while an increase in household income of $30,000 would lead to an increase of 0.3 more BMPs being adopted.

Conclusion and Discussion

Adoption rates of BMPs were generally lower for cattle producers than for some of the other enterprises examined in recent years, such as dairy (Rahelizatovo and Gillespie, 2004) and sugarcane (Cardona, 1999). This is likely due to the fact that many cattle producers are small, part-time farmers who do not depend upon the cattle operation for a large percentage of their incomes. As seen in the results, as the percentage of income from the beef operation increased, greater BMP adoption rates were seen. It was of interest to see that the modal producer utilized only five BMPs in the operation. It was surprising, however, that operation size did not affect intensity of adoption. This is consistent with probit results found in Kim (2004) for individual BMPs.

Results of the study suggest that greater educational efforts would increase BMP adoption rates, as both level of formal education and contact with NRCS were positively significant. This suggests that, if society wishes to increase BMP adoption, greater funding for programs that educate farmers about the benefits of BMP adoption would likely result in greater land conservation.

Also of interest is that farmers with greater financial resources to devote to the cattle operation were more likely to intensively adopt BMPs. From a policy perspective, this would suggest that increased funds made available to assist producers in BMP adoption would help to promote greater soil and water quality. Some such programs are already in place, such as the Environmental Quality Incentives Program, which provides cost-sharing to farmers in adopting BMPs. Such programs will not likely be very effective with many smaller, part-time cattle producers unless targeted educational efforts accompany them.

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Table 1. Description of Best Management Practices in Beef Cattle Production

Description of Best Management Practice
Cover and Green Manure Crop Crop of close-growing grasses, legumes or small grain grown for seasonal soil protection and improvement.
Critical Area Planting Planting trees, shrubs, vines, grasses or legumes, on highly erodible or critically eroding areas.
Field Borders and Filter Strips Strips of grasses or other close-growing vegetation planted around fields and along drainage ways, streams and other water bodies.
Grassed Waterways Natural or constructed channels that are shaped or graded to required dimensions and planted in suitable vegetation to carry water runoff.
Heavy Use Area Protection Establishment vegetative cover, installing suitable surface materials and constructing needed structures where animals congregate.
Livestock Exclusion Excluding animals from an area to protect, maintain or improve the quantity and quality of the natural resources.
Regulating Water in Drainage Controlling the removal of surface runoff, primarily through the operation of water control structures.
Riparian Forest Buffer An area of trees, shrubs and other vegetation located adjacent to and uphill from water bodies for creation of shade to lower temperature, and removal and reduction of nutrients, sediment, organic material and other pollutants before entry into water bodies.
Streambank and Shoreline Protection Use of vegetation or structures to stabilize and protect banks of streams, lakes, estuaries or excavated channels against erosion.
Fence Constructed barrier to prevent, restrict or control use by animals, vehicles or people. This may be applied on areas where livestock or wildlife control is needed such as along waterways, and for use in grazing system.
Water Facility Watering system installed to provide drinking water for livestock.
Continuous Prescribed Grazing Unrestricted grazing of one pasture by livestock throughout a certain season or during the entire year.
Rotational Grazing Grazing more than one paddock in sequence followed by a rest period for recovery and regrowth of the grazed forage.
Mortality Management Proper management of animal carcasses using cremation or deep burial to prevent, control and eradicate contagious or communicable diseases and viruses.
Nutrient Management A strategy for making use of plant nutrients to enhance profits while protecting water resources. Included practices are soil testing, basing fertilizer and lime applications on soil test results, using animal manures and organic materials, using legumes, controlling nutrient losses through erosion, and rotating crops.
Pesticide Management Pesticide management program consistent with crop production and environmental standards.

Table 2. Beef Cattle Producers' Weighted Adoption Rates of BMPs

Practices	Number of Farms Responding	Percentage Adopted
Cover and Green Manure Crop	484	23
Critical Area Planting	483	25
Field Borders and Filter Strips	476	28
Grassed Waterways	480	24
Heavy Use Area Protection	483	31
Livestock Exclusion	480	25
Regulating Water	482	19
Riparian Forest Buffer	483	21
Streambank and Shoreline Protection	487	24
Fence	487	65
Water Facility	487	75
Continuous Grazing	480	67
Rotational Grazing	480	57
Mortality Management	481	65
Nutrient Management	475	53
Pesticide Management	480	61

Table 3. Definitions, Means, and Standard Deviations of the Variables (n=339)

Variables	Definition	Mean	Std. Dev.	Min.	Max.
BMPall	Total number of BMP adopted.	6.735	3.609	0	16
Animals	Number of animals in beef cattle divided by 100.	1.297	2.261	0.01	21.5
Purebred	Dummy for purebred or seedstock cattle operation.	0.156	0.364	0	1
Diversification	Number of farming activities including crops and other livestock.	1.071	1.131	0	7
Owned Land Ratio	Ratio of owned land in beef cattle operation.	0.690	0.371	0	1
Stream Through	Dummy for a stream or river running through the farm.	0.469	0.499	0	1
Hilly Land	Dummy for hilly land used for beef cattle grazing.	0.407	0.492	0	1
NRCS Contact	Dummy for having contact with NRCS at least once in the year, 2002.	0.383	0.487	0	1
Family Take Over	Dummy for whether any family member plans to take over the farm.	0.260	0.439	0	1
Age	Age of the respondent divided by 10.	5.701	1.204	2.3	8.6
College Education	Dummy for holding a college bachelor's degree.	0.348	0.477	0	1
Household Income	Household net income coded 1,2,3,4,5 for increments of $30,000.	2.551	1.250	1	5
Cattle Income Ratio	Percentage of household net income coming from the beef cattle operation, coded 1,2,3,4,5 for increments of 20 percent.	1.322	0.791	1	5
Debt-Asset Ratio	Debt-Asset ratio, coded 1,2,3,4,5 for increments of 20 percent.	1.708	1.038	1	5

Table 4. Results of Poisson and Negative Binomial Regressions (n=339)

Variables	Poisson		Negative Binomial	
	Coefficient	Standard Error	Coefficient	Standard Error
Constant	1.222***	(0.144)	1.226***	(0.195)
Animals	-0.008	(0.013)	-0.003	(0.079)
Purebred	0.114**	(0.057)	0.120	(0.079)
Diversification	0.049**	(0.019)	0.046*	(0.027)
Owned Land Ratio	0.038	(0.063)	0.037	(0.086)
Stream Through	0.016	(0.044)	0.016	(0.059)
Hilly Land	0.115***	(0.043)	0.114*	(0.059)
NRCS Contact	0.174***	(0.046)	0.174***	(0.063)
Family Take Over	0.015	(0.050)	0.015	(0.068)
Age	0.021	(0.020)	0.020	(0.026)
College Education	0.131***	(0.048)	0.126*	(0.066)
Household Income	0.052***	(0.018)	0.052**	(0.026)
Cattle Income Ratio	0.119***	(0.030)	0.116***	(0.042)
Debt-Asset Ratio	0.017	(0.022)	0.018	(0.031)
Dispersion Parameter			0.105*	(0.022)
Log Likelihood	-908.260		-826.517	

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels, respectively. Weighting variable used to adjust over-sampling larger farms and under-sampling smaller farms.

Table 5. Marginal Effects of Negative Binomial Regression

Variables	Negative Binomial	
	Coefficient	Standard Error
Animals	-0.020	(0.114)
Purebred (D)	0.826	(0.564)
Diversification	0.306*	(0.175)
Owned Land Ratio	0.241	(0.569)
Stream Through (D)	0.104	(0.389)
Hilly Land (D)	0.762*	(0.400)
NRCS Contact (D)	1.178***	(0.443)
Family Take Over (D)	0.101	(0.451)
Age	0.129	(0.175)
College Education (D)	0.846*	(0.453)
Household Income	0.346**	(0.168)
Cattle Income Ratio	0.765***	(0.277)
Debt-Asset Ratio	0.122	(0.202)

Note: ***, ** and * indicate significance at 1%, 5 % and 10 % levels, respectively. (D) dy/dx is for discrete change of dummy variable from 0 to 1. Otherwise, marginal effects are computed at the means of the Xs. Weighting variable used to adjust over-sampling larger farms and under-sampling smaller farms.

Figure 1. Percentage of Farms Adopted BMPs (n=339)