Bulletin 725 June 1993

Adoption of Bovine Somatotropin by Kentucky Milk Producers: An Ex Ante Projection

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Introduction

Over the next few years, dairy farmers will be offered an extensive array of new biotechnologies. Timely adoption of these will likely affect the entire dairy industry. Historically, dairy farmers have relied on new technologies and improved management practices to remain efficient and competitive in producing milk.

Bovine Somatotropin (bST), a protein hormone, is currently receiving a great deal of attention as a stimulant to milk production. bST is a naturally-occurring protein hormone produced in the pituitary gland of cattle which regulates metabolism and therefore milk production (Baldwin and Middleton). When supplemental bST is administered to lactating cows, milk production increases (Asimov and Krouze). However, until the advent of recombinant DNA technology, there was no cost-effective method of producing sufficient supplies of bST. Now, bST can be produced economically on a large scale.

There are many questions regarding the impact of bST on the dairy industry. Ultimately, the impact at the farm level will depend on adoption rates. But, adoption of bST by all dairy farmers, even those with feasible opportunities, is highly unlikely. Although the dairy industry can claim one of the highest rates of productivity increases in U.S. agriculture, adoption of existing proven technologies has not been universal among dairy farmers. Ex ante analyses

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have resulted in a wide range of projected bST adoption rates (Carley *et al.*; Lesser *et al.*; OTA; Kinnucan *et al.*; Marion and Wills; and Fallert *et al.*).

In addition, the trend toward fewer total cows and larger herds in the U.S. is likely to continue irrespective of bST. However, bST alone is not likely to force the nonadopter out of existence while assuring the adopter of continued prosperity. There is evidence to suggest that the probability of survival for the adopter is only slightly higher than for the nonadopter (OTA).

A recent study (Gong) focuses on several aspects of the overall impact of bST on the dairy industry. One objective of that study was to estimate the rate of adoption by Kentucky milk producers. The approach involved an ex ante predicted rate of adoption. The following reports the findings of that study.

Research Procedures

Survey/Data

A survey designed to gather information regarding adoption plans of Kentucky farmers was completed in 1989. A 20% random sample of Kentucky dairy farmers was surveyed using a mail questionnaire. The sample included 204 manufacturing milk producers and 616 grade A milk producers. Usable questionnaires were received from 286 farmers for a 35% response (38% of the grade A sample and 26% of the manufacturing milk sample). The response represents 7% of total Kentucky milk producers (8% of grade A milk producers and 5% of manufacturing milk producers).

The survey focused on dairy farmers' plans for adopting bST. Three options were offered: adopt, not adopt, and uncertain. The "uncertain" choice provided an appropriate option for undecided dairy farmers to avoid biased responses.

The Binary Logit Forecast Model

In the analysis, dairy farmers who indicated plans to "adopt" were treated as potential users while those who responded "not adopt" were treated as definite nonusers. Dairy farmers responding "uncertain" were undecided at the time of the survey. The binary logit forecast model was then used to identify potential adopters within the uncertain category.

It is assumed that the adoption decision for each individual farmer is based on the profitability of adoption choices. Farmers choose the adoption choice which maximizes their expected profits. The expected profits associated with each adoption choice are affected by the socioeconomic characteristics of each individual farmer.

Dairy farmers who responded "uncertain" were unable to rank the adoption choice at the time of the survey. But those who have similar socioeconomic characteristics with adopters in the survey will probably adopt bST in the future. On the other hand, dairy farmers who were uncertain about adopting bST at the time will be forced to make a decision if, and when, bST is approved by FDA. Each must choose to adopt or not adopt bST. Being uncertain cannot be observed in practice. To remain uncertain is to be considered a nonuser. To forecast those in the uncertain category who will eventually adopt bST, given the socioeconomic characteristics, a binary probability model seemed most appropriate.

Let π_{ij} denote the expected profits of the jth adoption choice for the ith dairy farmer. The expected profits associated with jth adoption choice are affected by the individual farmer's socioeconomic characteristics and expressed as

(1) $\pi_{ij} = f_j(X_i) + \varepsilon_{ij} \qquad j=0,1.\ i=1,2,\ldots\ldots n.$

(2) $\pi_{i0} = \beta_{10}x_{i1} + \beta_{20}x_{i2} + \ldots\ldots + \beta_{k0}x_{ik} + \varepsilon_{i0}$
$= f_0(X_i) + \varepsilon_{io}$

(3) $\pi_{i1} = \beta_{11}x_{i1} + \beta_{21}x_{i2} + \ldots\ldots + \beta_{k1}x_{ik} + \varepsilon_{i1}$
$= f_1(X_i) + \varepsilon_{i1}$

where π_{i0} are the expected profits associated with not using bST for the ith producer, and π_{i1} are the expected profits associated with use of bST for the ith producer. $X_i = (x_{i1}\ x_{i2}\ \ldots\ldots\ x_{ik})$ is a vector of independent variables which are the ith farmer's socioeconomic characteristics. ε_{ij} are random errors of expected profits for ith farmer choosing the jth adoption choice (ε_{i0} is the random error for the ith farmer not using bST, and ε_{i1} is the random error for the ith farmer adopting bST).

Let Y_i=1 denote observed ith producer's response "adopt" and Y_i=0 "not adopt." If and only if $\pi_{i1} > \pi_{i0}$, the ith farmer chooses to use bST. The probability for the ith farmer to adopt bST can be written

$$\textbf{(4)}\quad P(Y_i=1) = P(\pi_{i1} > \pi_{i0})$$
$$= P\{f_1(X_i) + \varepsilon_{i1} > f_0(X_i) + \varepsilon_{i0}\}$$
$$= P\{\varepsilon_{i0} - \varepsilon_{i1} < f_1(X_i) - f_0(X_i)\}$$

Form of the probability function depends on the distribution form of the difference of the two random components, ε_{i1} and ε_{i0}. Let G denote the cumulative distribution function of the difference between the two random components. Domencich and McFadden show that

$$\textbf{(5)}\quad P(Y_i=1) = G\{f_1(X_i) - f_0(X_i)\}$$
$$= G\{(\beta_{11}-\beta_{10})x_{i1} + (\beta_{21}-\beta_{20})x_{i2} + \ldots\ldots + (\beta_{k1}-\beta_{k0})x_{ik}\}$$
$$= G\{f(X_i)\}$$

$$f(X_i)=(\beta_{11}-\beta_{10})x_{i1} + (\beta_{21}-\beta_{20})x_{i2} + \ldots\ldots + (\beta_{k1}-\beta_{k0})x_{ik}\}=X_i\beta$$

where b is a column vector, $b'=(b_{11}-b_{10}, b_{21}-b_{20}, \ldots\ldots b_{k1}-b_{k0})$. If the cumulative distribution function, G is linear over the range of $f(\cdot)$, equation (5) yields a regression equation

$$\textbf{(6)}\quad Y_i = f(X_i) + \mu_i$$
$$= P_i + \mu_i$$

$P_i=f(X_i)$, which is termed the linear probability function. The error terms, μ_i, are not normally distributed and take only two values: $1-f(X_i)$ for $Y_i=1$ and $-f(X_i)$ for $Y_i=0$. Because of the heteroscedasticity of the variances, parameters estimated by ordinary least squares procedures are not efficient. In addition, predicted probabilities from linear probability functions can be negative or greater than 1, even though actual observations must lie within the range (0, 1). Therefore, a linear probability function is not preferred in this study. In order to force the predicted probabilities to fall in the range (0, 1), we assume that $G\{f(X_i)\}$ has a logistic distribution. The binary probability function can be written

$$\textbf{(7)}\quad P_1=P(Y_i=1) = \frac{\exp\{f(X_i)\}}{1 + \exp\{f(X_i)\}} = \frac{\exp(X_i b)}{1 + \exp(X_i b)}$$

$$\textbf{(8)}\quad P_0=P(Y_i=0) = \frac{1}{1 + \exp\{f(X_i)\}} = \frac{1}{1 + \exp(X_i\beta)}$$

P_1 is the probability that ith producer chooses to adopt bST. P_0 is the probability that ith producer chooses not to adopt bST.

LIMDEP software was used and Maximum Likelihood Estimation (MLE) methods were applied to estimate the coefficients in the binary logit forecast model. Only binary response data (adopt or not adopt) collected in the survey based on a sustained-release administration method were fitted. Also, two sets of coefficients (grade A and manufacturing milk producer) were estimated to avoid any biases in estimation and forecasts.

Variables used in the model are defined in **Table 1**. Since adoption of bST is a farm level decision and depends on the expected profitability of the new technology, economic and productive conditions of individual dairy operations as well as social characteristics of individual operators are important factors affecting the expectations. The expectation of each individual dairy farmer regarding adoption of bST not only depends on the past information available to the farmer but is related also to the potential ability of the operator to access available information and how that information is used in assessing the technology.

The variables COW, PROD, DINC, NETW, and MP represent operational characteristics of dairy farms relative to size, productivity, specialization, financial situation, and the level of management. AGE and EDU reflect the social characteristics of operators. The former group of variables represents the on-farm information which can be used to estimate the expected profitability regarding adoption of bST. The latter indicates the potential ability of a dairy farmer to obtain additional information such as requirements for efficient use of bST and effectively evaluate the information. Actual performance of bST in milk production is subject to economic, technological, and biological constraints on each individual farm, while anticipated performance is determined by an individual operator based on all available information. Therefore, socioeconomic characteristics of an individual dairy operation affect both the expected profitability as well as the probability of adopting bST.

Table 1. Definition of Variables.

Variables		Definition
Dependent Variable		
Adoption Choices:		
		Not Adopt=0
		Adopt=1
Independent Variables		
COW	=	Herd size (number of milk cows, dry cows and freshened heifers)
PROD	=	Average milk production per cow in 1988 (pounds)
DINC	=	Percent of total farm gross sales derived from dairy products
NETW	=	Percent of sales price that would be retained after all debts paid if dairy farm and dairy herd were sold.
AGE	=	Age of principal operator
EDU	=	Education level of principal operator
MP	=	Number of the following dairy herd management practices currently being used (forage testing, balanced feed rations, computerized feeding, artificial insemination, group feeding, method of concentrate feeding)

Results

Impacts of Socioeconomic Factors

The estimated coefficients of the binary logit model are presented in **Tables 2 and 3**. COW, NETW, and EDU significantly affect the probability of adoption of bST by grade A milk producers. The results indicate that grade A milk producers with large herds and higher education will be more likely to use bST. Those who are in a better financial situation will be less likely to use bST. This may imply the risk attitude toward adoption of bST for this group of farmers. AGE, PROD, DINC, and MP do not significantly affect the probability of adoption. DINC, NETW, EDU, and MP significantly affect the probability of adoption of bST by manufacturing milk producers.

Dissimilar results associated with estimated coefficients of COW, PROD, and DINC for grade A and manufacturing milk producers were observed. While the research provided no logical explanation for such, the results do not appear to be inconsistent, given the different socioeconomic characteristics of each group.

Table 2. Estimated Coefficients of Binary Logit Model, Grade A Milk Producers.

Explanatory Variables	Coefficients	T-ratio
CONSTANT	-.696721	-.547
COW	.841966E-02*	1.584
PROD	.162971E-04	.208
DINC	.396610E-01	.332
NETW	-.182203*	-1.424
AGE	-.129321E-01	-.836
EDU	.408352****	2.532
MP	.279770E-01	.194

****=Significant at .01 level
*=Significant at .20 level

Table 3. Estimated Coefficients of Binary Logit Model, Manufacturing Milk Producers.

Explanatory Variables	Coefficients	T-ratio
CONSTANT	4.03377	.661
COW	-.761101E-01	-1.183
PROD	-.184575E-03	-.880
DINC	-.650180*	-1.342
NETW	-.700371*	-1.406
AGE	-.531262E-01	-.902
EDU	1.51239*	1.330
MP	1.05284*	1.547

*=Significant at .20 level.

The predictive capability of the model was tested by in-sample prediction. Predicted results for grade A dairy farmers are presented in **Table 4**. The model shows overall good predictive capability. The total number of adopters of bST is slightly underpredicted while the total number of nonadopters of BST is slightly overpredicted. Only 46 of 77 potential bST adopters and 57 of 81 nonadopters, however, are predicted correctly. The percentages of correct predictions are 60% for potential adopters and 70% for potential nonadopters.

The in-sample prediction results for manufacturing milk producers are listed in **Table 5**. The results indicate that the model underpredicted the total number of adopters and slightly overpredicted the total number of nonadopters. Although 32 of 33 nonadopters are correctly predicted, only 4 of 8 adopters are predicted correctly. Percentages of correct prediction for non-adopters and adopters are 97% and 50%, respectively.

Table 4. In-Sample Prediction of bST Adoption Using the Binary Logit Model, Grade A Milk Producers.

	Number Observed[1]	Number Predicted[2]		Percent Correctly Predicted
		Adopt	Not Adopt	
Adopt	77	46	31	60
Not Adopt	81	24	57	70
Total	158	70	88	—

[1]Survey response.
[2]The predicted outcome has maximum probability.

Table 5. In-Sample Prediction of bST Adoption Using the Binary Logit Model, Manufacturing Milk Producers.

	Number Observed[1]	Number Predicted[2]		Percent Correctly Predicted
		Adopt	Not Adopt	
Adopt	8	4	4	50
Not Adopt	33	1	32	97
Total	41	5	36	—

[1]Survey response.
[2]The predicted outcome has maximum probability.

Predicted Rates of Adoption

The forecast rates of adoption for those in the uncertain category are shown in **Table 6**. Only 23 grade A milk producers and 4 manufacturing milk producers were included in the forecast because of missing values in explanatory variables. Seven of the 23 grade A milk producers were forecast to be adopters of bST. All the manufacturing milk producers in the uncertain category were forecast to be non-adopters. Thus, 30% of the grade A milk producers who were uncertain in the survey will likely become adopters of bST.

The total number of potential adopters of bST was obtained by combining the number of dairy farmers in the "uncertain" category who were forecast to be adopters of bST with the observed responses from the survey. The forecast rate of adoption of bST in Kentucky is 39% of all producers (44% of grade A producers, and 16% of manufacturing milk producers). Grade A milk producers showed a higher level of interest in adopting bST than manufacturing milk producers. The adoption rate, however, is relatively low compared to forecast rates of adoption in some other states. For example, a Georgia study showed a predicted adoption rate of about 70% (Carley, *et al.*).

Table 6. Forecast Rates of bST Adoption.

	Grade A		Manufacturing		Total	
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Uncertain[1]						
Adopt	7	30	0	0	7	26
Not Adopt	16	70	4	100	20	74
Total	23	100	4	100	27	100
Observed[2]						
Adopt	89	45	8	18	97	40
Not Adopt	108	55	37	82	145	60
Total	197	100	45	100	242	100
Total[3]	220	100	49	100	269	100
Adopt	96	44	8	16	104	39
Not Adopt	124	56	41	84	165	61

[1]Forecast adoption rates of bST using the binary logit model for those in the uncertain categories, based on socioeconomic characteristics.
[2]Actual responses of dairy farmers.
[3]Uncertain plus observed.

Conclusions

COW, NETW, and EDU are factors significantly affecting the probability of adoption of bST by grade A milk producers. For manufacturing milk producers, DINC, NETW, EDU, and MP significantly affect the probability of adopting bST.

The total number of potential adopters of bST was obtained by combining the observed "adopt" responses from the survey with the forecast adopters within the "uncertain" category. Thus, the rate of adoption of bST in Kentucky was 39%. The forecast rate of adoption was much higher for grade A producers (44%) than for manufacturing milk producers (16%).

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