AN EX ANTE ADOPTION MODEL OF BOVINE SOMATOTROPIN BY CALIFORNIA MILK PRODUCERS

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Abstract: An Ex Ante Adoption Model of Bovine Somatotropin by California Milk Producers.

A multinomial logit model is estimated with survey data from California milk producers to test hypotheses of factors affecting adoption of bovine somatotropin. The model is used to forecast adoption rates and to derive implications of adoption patterns on the structure of the California dairy industry.

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Who gains and who loses from technological change has been a topic of research since Griliches' (1957) paper first quantified technology diffusion. Diffusion models estimated by Bass (1969), Jarvis (1981), and Byerlee and Hesse de Polanco (1986) explained past adoption processes. Predicting adoption rates before a new technology is available, or ex ante, permits identification of potential gainers and losers and anticipation of policy implications.

Bovine somatotropin (BST) offers a unique opportunity to explore technology adoption ex ante. Kronfeld (1988) reports BST increased milk production by 15 percent ($\pm$ 8.4 percent) over full lactation in 9 long term research experiments. The properties of this hormone have been known for decades, but recent developments in DNA technology have made commercial production of BST feasible.

Controversy exists about BST's effect on cows and humans (Lesser et al.). However, the Food and Drug Administration (FDA) is likely to approve BST for commercial use. Since commercial approval of BST takes many years and because it is controversial, information about BST is widely available and has been highly publicized. Therefore, many dairy farmers have developed perceptions as to the riskiness of BST, and whether they will be adopters.

The objectives of this paper are to identify likely adopters of BST ex ante and obtain insights on the factors influencing adoption. In the following sections an ex ante model of adoption is developed and estimated with survey data of California milk producers. The model is used to test hypotheses on factors influencing BST adoption, to compare probabilities of adoption for individuals, and to derive implications from the pattern of BST adoption on the structure of the California dairy industry.

THE MODEL

A general economic framework for analyzing technology adoption can be built on the work of McFadden (1974) and Domencich and McFadden (1975) who used Thurstone's (1927) random utility formulation. With respect to adoption of BST, assume an individual attempts to maximize the expected utility of the present value of profit by choosing among m discrete technologies. The expected utility of the present value of profit of the j^{th} technology for the i^{th} individual is denoted by

$$(1) \quad \pi_{ij} = f_j(X_i) + \epsilon_{ij}$$

The vector X_i reflects the i^{th} individual's personal and production endowments which can affect the desirability of a particular technology. Assume the ϵ's are random variables with a given subjective probability distribution. In this context the i^{th} individual chooses the j^{th} technology that maximize the expected utility of the present value of profit. Let $y_{ij} = 1$ if the i^{th} individual chooses the j^{th} technology, and $y_{ij} = 0$ otherwise. From (1), the probability the i^{th} individual chooses the j^{th} technology is

$$(2) \quad P_{ij} = P(y_{ij} = 1) = P[\pi_{ij} \geq \pi_{ik};\ k \neq j,\ k=1,2,\ldots,m]$$
$$= P[\epsilon_{ik} - \epsilon_{ij} \leq f_j(X_i) - f_k(X_i)]$$

If the ϵ_{ij} in (1) are independently and identically distributed with a Weibull density function, then McFadden (1974) has shown that

$$(3) \quad P_{ij} = P(y_{ij} = 1) = \frac{\exp f_j(X_i)}{\sum_{k=1}^{m} \exp f_k(X_i)}$$

Expression (3) can be rewritten as a multinomial logit model (Maddala)

$$(4a) \quad P_{ij} = \frac{\exp f_j(X_i)}{1 + \sum_{k=1}^{m-1} \exp f_k(X_i)} \qquad j=1,2,\ldots m-1$$

$$(4b) \quad P_{i0} = \frac{1}{1 + \sum_{k=1}^{m-1} \exp f_k(X_i)}$$

where the P's are conditional probabilities of adoption given the explanatory variables. This specification is appealing because it is consistent with the maximization hypothesis commonly used in economic theory and it is empirically tractable. The conditional probabilities can be estimated by maximum likelihood estimation (MLE). In the absence of a priori information on $f_j(X_k)$ we will adopt a linear form, $f_j(X_i) = X_i\beta_j$.

Allowing m to be greater than one, reflects the dynamics of decision making with respect to the adoption decision. That is, milk producers can be differentiated with respect to what they know about BST and how fast they plan to use it. The conditional probabilities for these different adoption schemes are P_o, P_1, P_2, ... as defined in (4a) and (4b).1/

Since the β's enter the probabilities P_{ij} nonlinearly, these coefficients cannot be interpreted directly. However, a convenient interpretation of the coefficients can be obtained by taking the logarithm of the ratio of P_{ij}/P_{i0}:

$$(5) \quad \mathrm{Ln}\,\frac{P_{ij}}{P_{io}} = X_i'\,\beta_j \qquad j = 1,2,3,\ldots$$

1/ Note that there is no β_o in these equations. So while the conditional probability can be estimated, these coefficients cannot.

Choice of attributes (the X's) associated with the adoption of BST is guided by human capital theory, sociological research and ex post adoption models. Nelson and Phelps (1966), Khaldi (1975) and Wozniak (1984) show education affects the adoption of new technology. Sociological research by Rogers (1962) and Rogers and Stanfield (1968) associated farm productivity and size, and farmer age, education, industry involvement, and other technology use with innovation. Feder and Slade (1984) find farm size is important to pesticide adoption by Indian rice farmers. Rahm and Huffman (1984) find farm size and education are significant in explaining the adoption of reduced tillage among Iowa corn farmers.

Farm size is associated with technology diffusion because returns to adoption are often greater in an absolute sense and the risk of adoption or experimentation is often less for a large farm. Productivity of a farm is associated with technology diffusion because early adoption of technology results in higher productivity. Education is a human capital measurement which reflects the ability to implement new technology. Industry involvement measures how receptive and well informed a manager is. Use of other new technologies indicates a receptiveness and ability to use new technology. Age is negatively associated with technology adoption; younger farmers have a longer planning horizon and may be less risk averse than older, established farmers.

Therefore, the hypotheses tested are: farm size and productivity influence knowledge and potential adoption of BST. Further hypotheses are: education, industry involvement, and use of other technologies by milk producers are positively associated with knowledge and receptiveness of BST, and age is inversely associated.

SURVEY DATA

Data were collected from 153 (7 percent) randomly selected California Grade A milk producers, who produce 97 percent of California's milk [CA Dept of Food & Ag]. California is a suitable setting for assessing the impact of BST because technology has played a strong role in making its dairy industry one of the most productive in the U.S.; it ranks number two in the U.S. in total milk production and in production per cow [GA Dept of Food & Ag]. Also, California has its own marketing order and sets its own price for milk, so it is somewhat self-contained.

The telephone survey was conducted between August 10 and October 23, 1987. Producers were asked structured questions about their proposed adoption plans, and characteristics of themselves and their farms. Five adoption schemes were investigated. Those who had not heard of bovine somatotropin or bovine growth hormone are labeled 'Haven't Heard'. The rest of the respondents had heard of BST. Those who would use BST as soon as it becomes available are 'Users'. Those that would wait before using it are 'Waiters'. Respondents who would not use BST are 'Non-users'. Undecided producers are referred to as 'Don't Know'.

ESTIMATION RESULTS

LIMDEP software is used to estimate the model using the survey data. LIMDEP estimates the coefficients by the MLE method and calculates t-statistics using the asymptotic variances of the information matrix.

The five categories of response are Haven't Heard, User, Non-user, Waiter, and Don't Know, P_o, P_1, P_2, P_3 and P_4, respectively. Potential adopters include Waiters and Users. The explanatory variables are: herd size (COWS), production per cow (PROD), age of respondent (AGE), education of respondent (EDUC), number of dairy industry organizations the respondent belongs to (COWCLUB), and use of a computer for record keeping (PC).2/

The predicted probabilities are listed in Table 1. The model over-predicts the Non-user and Waiter categories slightly, and under-predicts the Haven't Heard and User categories.

2/ Other variables of interest, such as membership in the Dairy Heard Improvement Association or three times a day milking, are highly correlated with production causing multicollinearity problems when incorporated in the model.

HYPOTHESIS TESTING

The coefficients in equation (5) represent a comparison between the j^{th} adoption category and the Haven't Heard category (j=0). Since there are five categories of response, taken in pairs, there are 10 comparisons to be examined. Coefficients and standard errors can be derived for all ten pairs to interpret the impact of characteristics on BST adoption and test hypotheses by noting that:

(6)[3/] $$\ln \frac{P_{im}}{P_{ik}} = X_i' \beta_m - X_i' \beta_k \qquad m = 2,3,4 \quad k = 1,2,3$$

$$= X_i' \beta_{mk} \qquad m>k$$

where

(7) $$\beta_{mk} = \beta_m - \beta_k$$

(8) $$\text{var } \beta_{mk} = \text{var } (\beta_m - \beta_k) = \text{var } \beta_m + \text{var } \beta_k - 2 \text{ cov } (\beta_m \beta_k)$$

Table 2 presents estimates of β_{mk}. The lower left triangle of estimates is omitted to avoid duplication. Positive coefficients imply that the probability of being in a category of BST adoption listed across the top of Table 2 increases relative to a category listed along the side, as the explanatory variable increases.

The probability of not having heard of BST increases with age and decreases with industry involvement and education. Relative to the probability of being a User, the probability of not having heard of BST increases with production and decreases with herd size. There is no significant difference in production or herd size from other groups.

3/ Note that equation (5) is a special case of (6) where k=0 and β_k=0.

The probability of early adoption of BST (User) increases with herd size and decreases with age. It decreases with production per cow relative to the probability of being a Don't Know, Waiter, or Haven't Heard. User probability increases significantly with membership in industry organizations relative to the Haven't Heard and Non-user respondents.

The probability of non-use relative to use of BST decreases with herd size, but does not differ with respect to other groups. The probability of non-use decreases with age relative to the Haven't Heard group and increases with age relative to the User, Waiter, and Don't Know categories. Computer use decreases the probability of non-use relative to use or waiting.

The probability of waiting to use BST (Waiter) relative to immediate use decreases with herd size and increases with production per cow. There is no significant difference in herd size or production level from the other respondents. Age decreases the probability of waiting relative to not having heard of BST and non-use, and increases the probability of waiting relative to Users or undecided respondents. Computer use significantly increases the probability of waiting relative to the Haven't Heard, Non-user, and Don't Know categories.

FORECASTING

Table 3 contains predicted probabilities of adoption derived from equations (4a) and (4b) for different levels of explanatory variables. Only one variable is changed at a time. For comparison, the unconditional probability of each adoption category derived from survey data is listed in the first line of Table 3, the predicted conditional probability, given mean values for the explanatory variables, is listed in line two. The mean values of the explanatory variables are: 46 years old (AGE), High School education (EDUC), two dairy industry organizations (COWCLUB), 17 percent probability of personal computers use (PC), herd size is 508 cows (COWS), and rolling herd average is 17,900 pounds of milk per year (PROD).

Herd size does not affect the probability of being in the Don't Know or Haven't Heard category much. The probability of being a Waiter or Non-user decreases slightly between a herd of 100 to one of 1000 cows. However, the probability of being an immediate adopter increases by more than 20 times between a herd of 100 and 1000 milking cows.

The probabilities of adoption change little between 15,000 and 20,000 pounds milk per cow per year. The probabilities of being a User or a Non-user fall, and that of being in the Waiter, Don't Know, or Haven't Heard category rise between 15,000 and 20,000 pounds average production.

Age has an impact on the probability of BST adoption. A 30 year old dairy farmer is seven times more likely to adopt BST right away than a 65 year old. A 65 year old is one and a half times more likely to not use BST than a 30 year old. Thirty year old dairy operators are less decisive, but better informed about BST than 65 year old operators; a 30 year old producer is five times more likely to be undecided about BST and four times more likely to have heard of BST than a 65 year old farmer.

Education is a factor in the adoption of BST. College graduates are twice as likely as junior high graduates to adopt BST immediately. Junior high graduates are twice as likely as college graduates to not have heard of BST.

Industry involvement is another important explanatory variable. A producer belonging to three industry organizations is eight times more likely to be a user than a farmer who belongs to none. The member of three organizations is over two and a half times more likely to use BST sometime after it is released than a farmer belonging to no organizations. Operators belonging to three clubs are 12 times more likely to have heard of BST than operators belonging to none.

A producer with a personal computer for record keeping is more than twice as likely to use BST right away, or to wait before using it, as one who does not have a computer.

IMPLICATIONS

Factors which contribute significantly to early adoption of BST are: large herd size, below average production, college education, industry involvement, computer use, and below average age of the dairy operator. Factors correlated with adoption of BST can be generalized to other regions of the U.S. Except for production level, these are consistent with past research.

It is speculated that the hypothesis that production level is associated with anticipated BST use is rejected for three reasons. First, this is an ex ante study and herds with lower production may be looking for technologies to increase production. Secondly, herd size of early adopters is almost twice as large as other groups, and they may be able to spread the risk of trying a new technology over their larger herd. Finally, productivity is not the best measurement of management skill, profitability is. Unfortunately, few respondents were able or willing to provide data on cost of production.

Factors that significantly increase the probability of a cautious, but receptive attitude towards BST, the Waiter category, are similar to those of the Users. However, age and production per cow increase the probability of being a Waiter rather than a User, while herd size decreases the probability. These characteristics are consistent with greater risk aversion by late adopters.

The probability of not using BST (Non-users) increases with age and decreases with industry involvement and computer use. These characteristics indicate greater risk aversion, less exchange of knowledge and less interest in new technology, which is consistent with lack of receptiveness to BST.

Characteristics affecting the probability of being an undecided producer are close to those who have not heard of BST. However, youth and industry involvement increase the probability of being undecided relative to the Haven't Heard group.

Since early adopters gain most from new technologies, if BST is profitable, it will improve the profitability of large, young adopters. Small dairies run by older farmers would lose the most, given that they are more cautious or reluctant to adopt. If adopters do not reduce their herd size, their share of production will increase with BST use. If regulation allows a decrease in milk prices to accompany this rise in production, the absolute income and profitability of small farms would fall.

These changes in the profitability of small versus large farms will accelerate the structural trends in the dairy industry towards larger and fewer dairies. Other implications of this work for the structure of the dairy industry are the increased occurrence of younger, more educated farmers who participate more in the dairy industry, and use compuers for recordkeeping. Finally, the association between below average production per cow and early adoption of BST indicates a structural change away from production oriented milk producers. It may indicate a structural change towards dairy farmers who are more profit oriented.

Table 1. Predicted Versus Actual Probabilities

of BST Adoption (Percentage)

	Predicted Conditional Probabilities*	Unconditional Probabilities from Survey
Haven't Heard	13	21
User	4	8
Non-user	35	29
Waiter	40	34
Don't Know	9	8
Total	100	100

Log Likelihood = -153
Restricted Log Likelihood = -187
Chi-squared = 68 with 20 degrees of freedom.
Cragg and Uhler's Pseudo R^2 = 0.48**

* Evaluated at the sample mean of the independent variables.
** Values between 0.2 and 0.4 are considered extremely good fits (Hensher and Johnson).

Table 2. β_{mk} Coefficients, Equation (6):

Characteristics Affecting BST Adoption

		Users, k=1	Non-users, k=2	Waiters, k=3	Don't Know, k=4
Haven't Heard, m = 0	COWS	.0033****	-.0004	-.0003	-.00004
	PROD	-.0002*	-.00004	-.00001	.00006
	AGE	-.0963*****	-.0276*	-.0506***	-.0877*****
	EDUC	.2215*	.1489**	.1155*	.0637
	COWCLUB	1.5073*****	.8266***	1.1672*****	.9869***
	PC	2.1142*	-.1384	2.0049**	.3325
User m = 1	COWS		-.0037*****	-.0036*****	-.0033***
	PROD		.0002	.0002*	.0003**
	AGE		.0687***	.0456*	.0085
	EDUC		-.0726	-.106	-.1578
	COWCLUB		-.6807**	-.3400	-.5204
	PC		-2.2526***	-.1093	-1.7816*
Non-user m = 2	COWS			.0001	.0004
	PROD			.00003	.0001
	AGE			-.0230*	-.0601***
	EDUC			-.0333	-.0852
	COWCLUB			.3407*	.1603
	PC			2.1432****	.4709
Waiter m = 3	COWS				.0002
	PROD				.00007
	AGE				-.0371*
	EDUC				-.0519
	COWCLUB				-.1803
	PC				-1.6723*

* Significant at .1 level
** Significant at .05 level
*** Significant at 0.25 level
**** Significant at .01 level
***** Significant at .005 level

Table 3. Probability of Being in Each Adoption Category Given Different Levels of Explanatory Variables*

	User	Non-user	Waiter	Don't Know	Haven't Heard
Unconditional Survey Values:	.08	.29	.34	.08	.21
Conditional:					
Mean values	.04	.35	.395	.085	.13
100 Cows	.01	.38	.41	.08	.12
300 Cows	.023	.362	.404	.084	.127
600 Cows	.06	.33	.39	.09	.13
1000 Cows	.22	.26	.32	.08	.12
15,000 lbs.	.07	.36	.38	.07	.12
20,000 lbs.	.03	.33	.40	.10	.14
30 yrs old	.092	.254	.424	.17	.06
65 yrs old	.013	.403	.301	.033	.25
Jr. High	.03	.31	.387	.097	.176
College	.06	.40	.39	.07	.08
No Clubs	.01	.286	.176	.053	.475
3 Clubs	.08	.29	.50	.09	.04
No PC	.03	.41	.32	.09	.15
PC	.08	.109	.726	.039	.046

*Unless otherwise indicated, the probabilities are evaluated at sample mean values.

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