The Impact of recombinant bovine Somatotropin on Dairy Farm Profits: A Switching Regression Analysis

Loren W. Tauer

Professor, Applied Economics and Management, Cornell University

Abstract

Production and profit impacts from the use of recombinant Bovine Somatotropin (rbST) on dairy farms were estimated using switching regression, with separate regressions for rbST-using farms and non-rbST-using farms. To correct for potential self-selection bias, a probit adoption function was estimated and used to correct the error term in each regression equation. Farmers who use rbST were found to have more formal education and have larger dairy herds, but age was not a significant determining factor in adoption. RbST was estimated to increase milk production per cow even when correcting for the fact that rbST users would have higher milk production per cow without the use of rbST. However, that greater production per cow from rbST use did not translate into an estimated impact on profits per cow.

Introduction

Bovine Somatotropin is a hormone produced by the dairy cow that regulates milk production. The genetic material for this compound has been isolated by genetic engineering and is produced by recombinant biotechnology. This recombinant-produced bovine Somatotropin (rbST) can be injected into the dairy cow to augment her naturally produced levels of this hormone, enhancing milk production, but requiring additional feed and other inputs to achieve increased milk production. It has been commercially available to U.S. dairy producers from the Monsanto Company since February of 1994 under the registered tradename POSILAC.

RbST was subject to years of investigation and testing before approval for commercial sale in the United States. Given the large production response per cow that most of these tests reported, rbST was generally projected to be profitable for dairy farmers, with estimates often exceeding $100 per year per cow (Butler), although some projected little or no profit (Marion and Wills, 1990). Although POSILAC has been available to U.S. dairy farmers for over 5 years and a number of studies have estimated the determinants of rbST adoption, few studies have assessed actual profitability on dairy farms.

Tauer and Knoblauch (1997) used data from the same 259 New York producers in 1993 and 1994 to estimate the impact of rbST on milk production per cow and return above variable cost per cow. RbST was not available in 1993, but one-third of these farmers used rbST in 1994. The use of rbST had a positive and statistically significant impact on the change in average production per cow between the two years, but the profit change affect, although positive and large, was not statistically different from zero. Stefanides and Tauer (1999) also analyzed the production and profit effects using the same data source, but included data from 1995,

resulting in a panel data set of 211 farms. They likewise found a statistically significant positive effect on milk production per cow from the use of rbST, and found the impact of rbST on profits was statistically zero. They suggested that farmers may still be learning how to profitably use rbST, or that such a large number of farmers are using rbST, including those getting a low return, that the average farm is not making a profit from its use. Tauer (2001) used this same data source but included data from 1996 and 1997. Positive profit rbST treatment coefficients were generally estimated, but the standard errors were so large that statistically he concluded the profit impact was zero.

Foltz and Chang (2002) sampled all Connecticut dairy farms for the 1998 production year and likewise found that rbST had a positive and statistically significant effect on milk production, but the impact on profits was statistically zero (although numerically negative). They found that supporting technologies significantly interacted with rbST productivity (output per cow) on these farms. A limitation of these studies was that the intensity of rbST use on these farms was not accurately measured. Farmers were only asked whether or not they used rbST, or were asked to reply to broad ranges of herd usage.

Ott and Rendleman (2000) used actual milk production experienced on U.S. rbST adopting farms, but since they did not have actual cost changes, they imputed costs and returns in a partial budget framework. They concluded that rbST would increase profits by $126 per cow, similar to previous ex ante impact studies. In their analysis they did not correct for the potential self-selection bias that might occur with rbST using farmers. If better managed, those adopting farms might have experienced a greater production increase per cow even without the use of rbST.

Estimates of actual rbST adoption by dairy farms include Barnham (1996) and Barham, et al. (2000). Results generally show that larger farms and farms that use other new technologies are more apt to have adopted rbST. Younger and more formally educated farmers have also adopted rbST to a greater extent.

This paper revisits the New York dairy farms for the production years 1998 and 1999. These years have not been previously analyzed. More importantly, farm expenditure on rbST was first collected in 1998, permitting an examination of the production and profit response per cow based upon a measure of the intensity of rbST use on the farm. To accomplish this, a switching regression technique is used.

Methods

The technique used is endogenous switching regression, sometimes referred to as the Mover/Stayer model since it has been used to measure the earnings of individuals moving or staying in a region or industry. Obviously, it can be applied to any situation where it is possible for the decision-maker to choose one of two (or more) regimes, in this case either using or not using rbST. Distinct regressions are estimated for rbST using farms and non-rbST using farms, with rbST expenditure per cow as an explanatory variable for farms using rbST. To correct for potential self-selection bias, a probit adoption function is estimated and used to correct the error term in each regression equation. These equations are estimated jointly using Maximum Likelihood. A discussion of this and alternative modeling approaches, including instrumental variables, is available in Vella and Verbeek (1999).

The first step is to estimate rbST adoption by a probit function with the specification:

$$A^* = \alpha'Z + \mu \tag{1}$$

where

$$A = 1 \text{ if } A^* > 0,$$

$$A = 0 \text{ if } A^* \leq 0,$$

$$\mu \sim N(0,1).$$

A^* is an underlying index reflecting the likelihood of choosing to use rbST, given the farmer's assessment, such that when A^* exceeds the threshold value (here 0) we observe the farmer using rbST and $A=1$. Matrix Z consists of exogenous variables which explain adoption, α is a vector of estimated parameters, and μ is an error term with mean zero and variance σ^2. The adoption equation is a reduced form equation since the structural equation determining adoption invariably includes the profit from adoption, which is not observed, but is being estimated.

Production or profit per cow is estimated by the following regression equations with regime 1 representing rbST use, and regime 0 representing non-rbST use:

$$y_1 = \beta_1'x_1 + (\rho_1\sigma_1\sigma_u)\{\phi(\alpha'Z)/\Phi(\alpha'Z)\} + \varepsilon_1 \tag{2}$$

$$y_0 = \beta_0'x_0 + (\rho_0\sigma_0\sigma_u)\{-\phi(\alpha'Z)/1-\Phi(\alpha'Z)\} + \varepsilon_0 \tag{3}$$

where y is production or profit per cow. The vector x_1 represents the explanatory variables for rbST users, and x_0 represents the explanatory variables for non-rbST users, with β representing the corresponding estimated parameter vectors. The remaining terms represent the error structure of each equation, correcting for self-selection bias since rbST using (or non-using) farms may have greater (or lower) production and profit per cow even without the use of rbST. The terms ε_1 and ε_0 are

standard normally distributed errors with means of zero. The terms ϕ and Φ are the

probability density and cumulative distribution function of the standard normal

distribution, respectively. The ratio of ϕ and Φ evaluated at $\alpha'Z$ is the inverse Mills

ratio, which reflects the truncation of a normal distribution at $\alpha'Z$ (Greene).

The multiplicable terms $(\rho_1\sigma_1\sigma_u)$ and $(\rho_0\sigma_0\sigma_u)$ represent the covariance of the

adoption equation [1] and rbST impact equation [2], and the adoption equation [1] and

the non-rbST impact equation [3], respectively. These covariances can be broken

down into the standard deviations of the appropriate equations (σ_u, σ_1, σ_0) and the

correlations ρ_1 and ρ_0. However, given the structure of the model and the nature of

the derived data, σ_u cannot be estimated so it is normalized to 1.0 (Greene).

Since estimates of ρ_1 and ρ_0 show the correlation of the "unobservables" of the

adoption equation with the "unobservables" of the rbST use and non-use regression

equations respectively, a test of whether ρ_1 and ρ_0 are statistically different from zero

measures the endogeneity of the rbST adoption decision. If ρ_1 and ρ_0 are zero, then

rbST adoption is exogenous and it would not be necessary to model and include an

adoption equation in estimating the treatment impact of rbST on profits or output.

Equations [1], [2] and [3] are estimated using the software LIMDEP. The

probit function [1] is first estimated by maximum likelihood using OLS estimated

starting values. The predicted values from the probit function are then used to

calculate the inverse Mill's ratio, which is subsequently included as an explanatory

variable when estimating equations [2] and [3] by OLS. Given the linear structure of

these equations, a single parameter is estimated for $\rho_1\sigma_1$ and for $\rho_0\sigma_0$. Finally,

equations [1], [2] and [3] are estimated jointly by maximum likelihood using previous

estimates of β_1, β_0, and α for starting values. Given the structure of the MLE

equation, separate estimates for ρ_1 and σ_1, and then ρ_0 and σ_0 are possible.

The average production or profit impact of rbST for a farm with characteristics

x is then computed as:

$$\delta = (\beta_1' - \beta_0')x \qquad\qquad (4)$$

This is typically referred to in the literature as the "average treatment effect", which is

the average treatment effect of a farm using rbST "randomly" assigned to the

treatment. Although treatment was not randomly assigned, this terminology expresses

the idea that the unobservables capturing the treatment decision that are correlated

with the rbST response have been controlled for (Vella and Verbeek).

Data

The data are from the New York Dairy Farm Business Summary Program

(Knoblauch and Putnam). This is a record collection and analysis project primarily

meant to assist dairy farmers in managing their operations. Farmers receive a

business analysis of their farm and benchmark performance measures from combined

participants. This is not a random sample. It represents a population of farmers that

actively participate in agricultural extension and research programs. The farms in this

sample are larger on average than New York dairy farms and they experience higher

levels of production per cow. To be included in this data set, milk receipts must

constitute at least 90 percent of total farm receipts.

Variable specification is consistent with the annual Dairy Farm Business

Summary Report (DFBS) and is shown in Table 1. A limited number of exogenous

variables are collected but these include age, education, and in the short-run, the

number of cows and milking system. Performance variables used are herd production

per cow and net farm income per cow. Technology adoption is typically assessed by farmers based upon the impact it has on net farm income. Although not reported in this article, the total cost of production per hundred weight of milk produced was also used as a performance variable with results similar to the reported net farm income per cow results.

The DFBS surveys for each year asked farmers to indicate their use of rbST in one of five categories as follows: (0) not used at all; (1) stopped using it during the year; (2) used on less than 25 percent of the herd; (3) used on 25-75 percent of the herd; or (4) used on more than 75 percent of the herd. Most responses were in categories 0 and 3. Very few farms indicated they used it on more than 75 percent of the herd. Likewise, few farms used it on less than 25 percent of the herd. These groups pertain to the percentage of cows that were treated during lactation. The usage categories are not concisely defined, so farms were simply sorted as rbST users if they checked categories 2, 3, or 4 and non-users if they checked categories 0 or 1. For farms that have adopted it, intensity of rbST use for adopting farms is measured by the expenditure on POSILAC during the year divided by the average number of cows during the year.

Results

Adoption results

The probit adoption functions for 1998 and 1999, estimated by maximum likelihood, are shown in Table 2. The education of the farmer and the size of the farm appear to be the determining factors influencing adoption. Farmers who have more years of formal education and those who have larger farms are more apt to adopt rbST. Age appears not to be a determining factor. Whether the farm milks with a

parlor was a determinant in 1998 (the correlation between the number of cows and milking in a parlor is only 0.45), but not in 1999. The price of milk was not a determinant for adoption, although variation of price was spatial and not temporal in these data. These results carry through when the adoption function is later estimated jointly with the production per cow or profit per cow equations. The accuracy of the adoption function estimates is illustrated in Table 3. Of the 171 farms actually using rbST in 1999, 130 farms, or 76 percent are predicted to be users by the model.

Impact of rbST on production per cow

The impact of rbST on estimated herd production per cow is shown in Table 4. This is herd average production and includes both cows treated and not treated with rbST during the calendar years. The same variables as used in the adoption equation were used in both the rbST and non-rbST production per cow equations. Since these variables were transformed in the probit adoption equation, singularity was not a problem. Also included in the rbST equation are the expenditure of rbST per cow and rbST per cow expenditure squared. These are herd average expenditures and not expenditures per treated cow.

Coefficients on the linear and quadratic rbST expenditure variables were not statistically significantly different from zero in 1998 and only the linear rbST expenditure was statistically significant in 1999. Lack of statistical significance could occur if all farms used identical amounts of rbST, implying little variability in usage, but there is large variability in rbST use per cow, with an average expenditure of $61.24 and a standard deviation of $30.70 in 1999.[1]

---

[1] Monsanto sold POSILAC during these years at $5.80 per 14-day dose, with discounts as a higher percentage of a farmer's herd is treated. Cows are not treated in early lactation or during dry periods, but ignoring that, the most a farmer could pay would be $150.80 a year per cow.

It is interesting that in the non-rbST equation, education and the number of cows were both highly statistically significant in both years and use of a parlor for milking was mildly statistically significant in 1998, but none of these were important in the rbST equation. More cows and greater education leads to greater output per cow for farms not using rbST. Since the no rbST farmers generally operated smaller farms, moving from the smallest farms to slightly larger farms shows increases in production per cow, but that relationship was not displayed in the rbST using farms, which generally were larger in size.

Production per cow increases rapidly initially and then becomes flat as farm size increases (Knoblauch and Putnam). Limited overlap of observations by farm size and other variables makes using the difference in estimated coefficients to estimate the impacts of rbST problematic as specified in equation [4], since these coefficients are only relevant over the range of data from which they are estimated. The only statistically significant variables in the rbST use equations were age and the milk price in 1999, and both had negative impacts on output per cow.

The correlation between the adoption equation error and rbST production regression equation error is −0.81 for 1998 and −0.79 for 1999, both statistically significantly different from zero. The corresponding correlation between the adoption equation error and non-rbST production regression error is 0.03 for 1998 and −0.80 for 1999, neither statistically significantly different from zero. Thus, contrary to expectation, this shows rbST users having lower production per cow regardless of rbST use. However, virtually none of the variables in the rbST equation were statistically significant so the residuals from this equation might be suspect. In fact, when these equations were estimated with only intercepts and rbST expenditure variables in the rbST use equation, the rbST correlation between the adoption error

and rbST regression error was 0.73 in 1998 and 0.71 in 1999, both statistically significant.

A Wald test of whether the estimated coefficients as a group (excluding intercept and rbST quantity use variables) are different between the rbST use and rbST non-use equations produced a Chi-Square value of 8.46 in 1998 (alpha =0.13), and a Chi-Square value of 18.11 in 1999 (alpha=0.003). Thus, statistically the coefficients as a group are different. Yet, the predicted output response for rbST was negative for both years using equation [4]. The predicted herd response per cow from rbST in 1998, given the characteristics of those rbST-using farms, was a negative 1,975 pounds of milk per cow. This may appear to be an error, but the reason that the estimate is negative is due to the large estimated output response per cow to education and log(cows) of the non-rbST farms compared with the rbST using farms. These impacts more than offset the higher intercept of the rbST farms. The computed rbST impact for 1999 was also negative, although only at a negative 242 pounds for average farm characteristics.

Given these results, and given that previous studies have found rbST to be output increasing, the production per cow equations were re-estimated using only intercepts for the rbST using and rbST non-using farms. Modeling two equations, rather than one equation with a dummy rbST use variable, allows the error terms on the two equations to differ. Results are show in Table 5. A Wald test of the equality of the intercepts of the rbST equation and the non-rbST equation produced chi-Squared values of 104.10 for 1998 and 104.08 for 1999, both highly statistically significant. On average, rbST does increase output per cow. The estimated increase is rather large, however, at over 6,000 pounds per cow. The rbST correlation between the adoption equation error and rbST production regression equation error is 0.74 for

1998 and 0.71 for 1999, both statistically significantly different from zero. The corresponding correlation between the adoption equation error and non-rbST production regression error is –0.61 for 1998 and –0.59 for 1999, both also statistically significantly different from zero. These results support the belief that rbST users would have higher production per cow regardless the level of rbST use than would none rbST users.

Impact of rbST on net farm income per cow

The impact of rbST on net farm income per cow using the full model specification is shown in Table 6. Although the rbST expenditure per cow coefficient estimates of the rbST equation are of the expected signs for both years, such that there is a concave relationship between net income per cow and rbST expenditure, those coefficients are not statistically different from zero, indicating no relationship between rbST expenditure and net income per cow.

Age has a negative and statistically significant impact on net farm income per cow for rbST users in both 1998 and 1999, and although age also had a negative impact on net farm income per cow for rbST non-users, that impact was not statistically significant. The existence of a parlor for milking also negatively impacted income for rbST users in 1999. As expected, in all years and impact equations a higher milk price has a positive and statistically significant impact on net farm income per cow.

In the non-rbST equation, besides the price of milk, the number of cows in both 1998 and 1999, and education in 1999 had statistically significant impacts on net farm income per cow. A greater number of cows lead to greater net farm income per cow, and more education increased net farm income.

The correlation between the adoption equation error and rbST profit regression equation error is –0.71 for 1998 and –0.82 for 1999, both statistically different from zero, and the corresponding correlation between the adoption equation error and non-rbST profit regression error is –0.12 for 1998 and –0.01 for 1999, neither statistically different from zero. These signs and statistical significance were similar to the previous results using the full model on production per cow and imply contrary to most expectations, that rbST users have lower profits per cow regardless of rbST use.

A Wald test of whether the estimated coefficients as a group are different between the rbST use and rbST non-use equations, except for the intercept and rbST quantity use variables, produced a Chi-Square value of 2.00 (alpha =0.84) for 1998, and a Chi-Square value of 11.19 (alpha=0.05) for 1999, concluding that statistically the coefficients are not different for 1998, but may be different for 1999. However, the predicted rbST profit was a negative $166 for 1998 and a negative $251 for 1999 using characteristics of all farms.

Net farm income per cow equations were re-estimated modeling only intercepts for the rbST using and rbST non-using farms, consistent with the previous second approach used with production per cow. Results are shown in Table 7. The probit selection (adoption) equation results are similar to previous models. The estimated net farm income per cow return to rbST is statistically zero (and numerically negative) as summarized in Table 8. In fact, the rbST non-users have higher numerical income per cow of about $20 and $30 per cow in the two years.

The correlation between the adoption equation error and the rbST net income equation error is still negative in both years as estimated in the full model, but the magnitude is less negative, and only weakly statistically different from zero for 1998. The corresponding correlation between the adoption equation error and the non-rbST

net income regression error is statistically zero in both years. These results imply that although rbST adopting and non-adopting farms may have different characteristics, neither may be inherently more or less profitable before adoption, and it appears that rbST does not make the adopting farms as a group more profitable.

If a profit impact is not measured it may be because Monsanto is fully capturing the net return from the use of rbST by charging a high price for POSILAC. Adding individual farm expenditures on rbST back into net farm income, and re-estimating the equations without the rbST expenditure explanatory variables tests that hypothesis. Results are summarized in Table 8. The farms using rbST in 1998 earned $699 per cow if they did not have to pay for POSILAC, which is $63 more than the return when they paid for POSILAC. The farms not using POSILAC in 1998 earned $659 per cow. A Wald test of these values did not allow rejection of the null hypothesis that these means are equal. Farms using POSILAC in 1999 earned $585 if they did not have to pay for POSILAC, which is $68 more than when they paid for POSILAC. The farms not using POSILAC in 1999 earned $533 per cow. A Wald test of these values produces a chi-square value of 0.55, which does not allow rejection of equal means. It appears that a rbST profit per cow is not statistically measured even if Monsanto provided rbST free to the using farmers.

Conclusions

Dairy farm record data for 1998 and 1999 from New York were used to estimate the production and profit response from the use of rbST. The compound rbST has been commercially available in the U.S. since 1994, so farmers have had four years of observation and experience. An endogenous switching regression model

was estimated with self-selection of whether to use rbST or not corrected by a probit adoption function. Slightly over half of the farmers used rbST.

Farmers who used rbST were found to be more apt to have formal education beyond high school and have larger dairy herds. Age was not a significant determining factor in adoption. In a reduced model, rbST was estimated to increase milk production per cow even when correcting for the fact that rbST users would have higher milk production per cow without the use of rbST. However, that greater production per cow from rbST did not translate into an estimated impact on net income per cow. There was no statistical difference in net income per cow between rbST using and non-using farms.

Why do these dairy farmers use rbST when it does not appear to generate a profit? The foregoing results cannot give a clear answer, but the estimates do represent an average group response. Within that group there may be farmers that are experiencing a positive profit response. The implicit assumption then is that other farmers may be experiencing a negative profit response. It is also notoriously difficult to quantify and estimate the determining factors of farm level profitability.

Table 1. Definition of Variables

Variable	Definition	*1999 Average Value (Standard Deviation)*
Education	Years of formal education	13.56 (1.80)
Age	Years	47.65 (9.47)
Log Cows	Natural log of number of average cows in herd.	4.96 (0.90)
Milking System	1 If parlor 0 Otherwise	0.61
rbST Use	1 If used on farm 0 Otherwise	0.53
Profit per Cow	Net farm income per cow	472 (418)
Production per Cow	Milk sold divided by reported average number of cows (lbs.)	19,502 (3,728)
Milk Price	Milk price per hundredweight of milk sold	14.85 (0.85)
rbST per Cow in 1999	Expenditure on POSILAC per cow for 171 using farms in 1999	61.24 (30.70)
rbST per Cow in 1998	Expenditure on POSILAC per cow for 169 using farms in 1998	55.12 (30.93)

Table 2. RbST Adoption Function Estimates for 1998 and 1999 from Probit Maximum Likelihood Estimation (Test statistics in parentheses)

	1998	*1999*
Intercept	-5.25 (-3.06)***	-3.99 (-2.41)**
Education	0.111 (2.46)***	0.135 (2.85)***
Age	0.003 (0.36)	-0.004 (-0.48)
Log Cows	0.763 (5.48)***	0.925 (6.21)* **
Parlor	0.399 (1.94)**	0.327 (1.51)
Milk Price	-0.017 (-0.19)	-0.154 (-1.50)
Log Likelihood Value	-171	-157
Number of Observations	324	324
	(249 farms overlap)	

*Statistically significant at $\rho = 0.10$.
**Statistically significant at $\rho = 0.05$.
***Statistically significant at $\rho = 0.01$.

Table 3. Frequencies of Actual and Predicted Outcomes for rbST Adoption in 1999 (Adoption = 1)

	Predicted		
Actual	*0*	*1*	*Total*
0	120	33	153
1	41	130	171
Total	161	163	324

Table 4. Impact of rbST on Herd Production per Cow for 1998 and 1999, Estimated by Maximum Likelihood Switching Regression (Test statistics in parentheses)

	1998	1999
- - - - - - - - - *Probit Selection Equation* - - - - - - - - -		
Intercept	-5.16 (-2.76)***	-4.71 (-2.31)**
Education	0.113 (2.42)**	0.147 (2.91)***
Age	0.004 (0.479)	-0.004 (-0.40)
Log Cows	0.746 (5.24)***	0.958 (6.33)***
Parlor	0.407 (1.97)**	0.271 (1.25)
Milk Price	-0.023 (-0.24)	-0.127 (-0.97)
-------- *rbST Regression Equation* --------		
Intercept	19,834 (1.83)*	25,738 (3.50)***
Education	-24.58 (-0.12)	134.92 (0.75)
Age	-20.58 (-1.02)	-33.82 (-1.67)*
Log Cows	874 (0.81)	990 (1.09)
Parlor	733 (0.68)	-319 (-0.39)
Milk Price	-309 (-1.59)	-730 (-2.76)***
RbST Expenditure	15.44 (0.76)	36.01 (1.72)*

RbST Expenditure Squared	0.228	-0.167
	(1.18)	(-0.84)

---------- No rbST Regression Equation ----------

Intercept	4,419	-4,401
	(0.76)	(-0.90)
Education	668	539
	(3.70)***	(2.85)***
Age	-6.75	-38.33
	(-0.22)	(-1.17)
Log Cows	3121	3332
	(4.02)***	(5.16)***
Parlor	920	26.23
	(1.18)	(0.03)
Milk Price	-511	215
	(-1.93)*	(0.71)

---------- Variance Estimates ----------

σ_{rbST}	3,899	3,647
	(8.80)***	(9.04)***
r_{rbST}	-0.81	-0.79
	(-6.00)***	(5.54)***
$\sigma_{no\ rbST}$	2,193	2,307
	(16.82)***	(15.04)***
$r_{no\ rbST}$	0.03	-0.80
	(0.03)	(-0.09)
Log Likelihood Value	-3,179	-3,165
Number of Observations	324	324

(249 overlap)

*Statistically significant at $\rho = 0.10$.
**Statistically significant at $\rho = 0.05$.
***Statistically significant at $\rho = 0.01$.

Table 5. Impact of rbST on Herd Production per Cow for 1998 and 1999, Reduced Model, Estimated by Maximum Likelihood Switching Regression (Test statistics in parentheses)

	1998	1999
- - - - - - - - - Probit Selection Equation - - - - - - - - -		
Intercept	-4.49	-4.24
	(-3.16)***	(-2.71)***
Education	0.137	0.150
	(3.48)***	(3.45)***
Age	0.0009	-0.010
	(0.141)	(-1.27)
Log Cows	0.782	0.968
	(5.73)***	(6.86)***
Parlor	0.368	0.186
	(2.06)**	(0.97)
Milk Price	-0.087	-0.14
	(-1.13)	(-1.38)
-------- rbST Regression Equation --------		
Intercept	21,708	22,440
	(57.70)***	(64.70)***
---------- No rbST Regression Equation ----------		
Intercept	15,382	15,776
	(32.68)***	(37.87)***
---------- Variance Estimates ----------		
σ_{rbST}	3,900	3,599
	(11.78)***	(14.19)***
r_{rbST}	0.74	0.67
	(6.07)***	(5.09)***
$\sigma_{no\ rbST}$	2,910	2,756
	(13.59)***	(15.88)***
$r_{no\ rbST}$	-0.61	-0.59
	(-5.22)***	(-4.67)***

Log Likelihood Value	-3,211	-3,187
Number of Observations	324 (249 overlap)	324

*Statistically significant at $\rho = 0.10$.
**Statistically significant at $\rho = 0.05$.
***Statistically significant at $\rho = 0.01$.

Table 6. Impact of rbST on Net Farm Income per Cow in 1998 and 1999, Estimated by Maximum Likelihood Switching Regression (Test statistics in parentheses)

	1998	1999
- - - - - - - - - *Probit Selection Equation* - - - - - - - - -		
Intercept	-5.06 (-2.79)***	-3.75 (-1.81)*
Education	0.108 (2.30)**	0.139 (2.76)***
Age	0.003 (0.32)	-0.004 (-0.38)
Log Cows	0.778 (5.53)***	0.916 (5.97)***
Parlor	0.407 (1.96)*	0.351 (1.60)
Milk Price	-0.030 (-0.31)	-0.175 -1.36
-------- *rbST Regression Equation* --------		
Intercept	-207 (-0.12)	-388 (-0.47)
Education	-14.27 (-0.46)	0.332 (0.02)
Age	-5.26 (-1.76)*	-5.72 (-2.10)**
Log Cows	-10.70 (-0.06)	48.51 (0.44)
Parlor	-127 (-0.65)	-237 (-1.64)*
Milk Price	91 (2.27)**	77 (1.88)*
rbST Expenditure	1.20 (0.36)	1.50 (0.50)

rbST Expenditure Squared	0.0036	-0.0224
	(0.111	(-0.82)

-------- *No rbST Regression Equation* --------

Intercept	-2,093	-2,977
	(-3.07)***	(-4.64)***
Education	28.36	56.86
	(1.29)	(2.51)***
Age	-2.08	-0.236
	(-0.53)	(-0.06)
Log Cows	153	278
	(1.81)*	(3.36)***
Parlor	8.81	-119
	(0.08)	(-1.15)
Milk Price	121	117
	(4.40)***	(3.00)***

--------- *Variance Estimates* --------

σ_{bST}	469	464
	(10.32)***	(10.70)***
r_{rbST}	-0.71	-0.83
	(-4.75)***	(-8.48)***
$\sigma_{no\ rbST}$	353	298
	(11.55)***	(18.41)***
$r_{no\ rbST}$	-0.12	-0.01
	(-0.09)	(-0.01)
Log Likelihood Value	-2550	-2496
Number of Observations	324	324
	(249 overlap)	

*Statistically significant at $\rho = 0.10$.
**Statistically significant at $\rho = 0.05$.
***Statistically significant at $\rho = 0.01$.

Table 7. Impact of rbST on Net Farm Income per Cow in 1998 and 1999, Reduced Model, Estimated by Maximum Likelihood Switching Regression (Test statistics in parentheses)

	1998	1999
- - - - - - - - - Probit Selection Equation - - - - - - - - -		
Intercept	-3.98	-2.79
	(-2.30)**	(-1.58)
Education	0.103	0.123
	(2.37)**	(2.61)***
Age	0.004	-0.003
	(0.52)	(-0.39)
Log Cows	0.728	0.873
	(5.28)***	(5.72)***
Parlor	0.442	0.431
	(2.19)**	(1.95)**
Milk Price	-0.087	-0.214
	(-0.93)	(-1.86)*
-------- rbST Regression Equation --------		
Intercept	636	517
	(10.94)***	(11.94)***
-------- No rbST Regression Equation --------		
Intercept	667	536
	(11.11)***	(9.95)***
--------- Variance Estimates --------		
σ_{bST}	437	421
	(19.91)***	(20.08)***
r_{rbST}	-0.35	-0.26
	(-1.85)*	(-1.23)
$\sigma_{no\ rbST}$	367	319
	(21.42)***	(18.79)***
$r_{no\ rbST}$	0.16	0.18
	(0.79)	(0.91)

Log Likelihood Value	-2566	-2524
Number of Observations	324 (249 overlap)	324

*Statistically significant at $\rho = 0.10$.
**Statistically significant at $\rho = 0.05$.
***Statistically significant at $\rho = 0.01$.

Table 8. Impact of rbST on Net Farm Income per Cow in 1998 and 1999 without rbST Expenditure Explanatory Variables, Estimated by Maximum Likelihood Switching Regression

	1998	*1999*
-------- rbST Regression without Expenditure Coefficients Estimated ------		
rbST (Intercept)	$636	$517
No rbST (Intercept)	$667	$536
Wald Test (Chi-Squared Value)	0.14	0.07
--------- rbST Regression Equation with Cost of rbST Removed from NFI ----------		
rbST (Intercept)	$699	$585
No rbST (Intercept)#	$659	$533
Wald Test (Chi-Squared Value)	0.23	0.55

Estimates change slightly because of estimation of equations as a system.
*Statistically significant at $\rho = 0.10$.
**Statistically significant at $\rho = 0.05$.
***Statistically significant at $\rho = 0.01$.

References

Barham, B.L. 1996. Adoption of a politicized technology: bST and Wisconsin dairy farms, *American Journal of Agricultural Economics*, 78, 1056-1063.

Barham, B.L., Jackson-Smith, D. and Moon, S. 2000. The adoption of rbST on Wisconsin dairy farms, *AgBioForum,* 3, 181-187.

Butler, L.J. 1992. Economic evaluation of bST for onfarm use, in *Bovine Somatotropin and Emerging Issues: An Assessment* (Ed.) M.C. Hallberg, Westview Press: Boulder, CO, pp. 145-171.

Folz, J. and Chang, H.H. 2002. The adoption and profitability of rbST on Connecticut dairy farms, *American Journal of Agricultural Economics*, 84, 1021-1032.

Greene, W. 1997. *Econometric Analysis*, Prentice Hall: Englewood Cliffs, NJ.

Knoblauch, W.A. and Putnam, L.D. 1998. *Dairy farm management business summary, New York State, 1997*, R.B. 98-06, Department of Agricultural, Managerial, and Resource Economics, Cornell University, Ithaca, NY.

LIMDEP, Version 7.0 1998. *Econometric Software*, 15 Gloria Place, Plainview, NY.

Marion, B.W. and Wills, R.L. 1990. A prospective assessment of the impacts of bovine somatotropin: a case study of Wisconsin, *American Journal of Agricultural Economics*, 72, 326-336.

Ott, S. L. and Rendleman, C.M. 2000. Economic impacts associated with bovine Somatotropin (BST) use based on survey of US dairy herds, *AgBioForum,* 3, 173-180.

Stefanides, Z. and Tauer, L.W. 1999. The empirical impact of bovine somatotropin on a group of New York dairy farms, *American Journal of Agricultural Economics*, 81, 95-102.

Tauer, L. 2001. The estimated profit impact of recombinant bovine somatotropin on New York dairy farms for the years 1994 through 1997, *AgBioForum,* 4, 115-123.

Tauer, L. and Stefanides, Z. 1998. Success in maximizing profits and reasons for profit deviation on dairy farms, *Applied Economics,* 30, 151-156.

Tauer, L.W. and Knoblauch, W.A. 1997. The empirical impact of bST on New York dairy farms, *Journal of Dairy Science,* 80, 1092-1097.

Vella, F. and M. Verbeek 1999. Estimating and interpreting models with endogenous treatment effects, *Journal of Business and Economic Statistics,* 17, 473-478.