**Production and Financial Impacts of the Adoption of
Bovine Somatotropin on U.S. Dairy Farms**

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Abstract

Production and financial impacts of recombinant bovine somatotropin (rbST) adoption are assessed using a survey of U.S. dairy operations and a model that corrects for self-selection bias. A substantial increase in milk production per cow is associated with rbST adoption, but large estimated financial impacts are not statistically significant. Substantial variation in the net returns of rbST adopters may be related to the management-intensive nature of rbST.

Introduction

Recombinant bovine somatotropin (rbST), a synthetic version of a naturally occurring bovine hormone, is one of the first commercial agricultural technologies from recombinant DNA technology research. Prior to commercial release in 1994, numerous experimental trials suggested that rbST could increase milk production by up to 30 percent with profit opportunities as high as $250 per cow. However, since its introduction little has been discussed about how widely rbST has been adopted and what the production and financial impacts have been for U.S. dairy farms. The objective of this study is to examine the adoption of rbST by U.S. dairy farms and to evaluate the impacts that rbST adoption has had on milk production and on farm financial performance.

The profitability of an innovation compared to traditional methods is regarded as a primary reason why producers adopt new technologies. This view of the adoption process suggests that the adoption of rbST will occur if it is perceived to be more profitable than traditional methods. Several studies evaluated the potential adoption and profitability of rbST prior to its commercial release (see Caswell, Fuglie, and Klotz for a review of these studies). However, few studies have used actual farm results in an *ex post* evaluation of the profitability of rbST. Research evaluating the impacts of rbST adoption on a group of New York dairy farms during the period of 1994-97 showed that rbST adoption increased milk production per cow, but did not show that rbST use had an impact on farm profitability (Tauer and Knoblauch; Stefanides and Tauer; Tauer).

This study expands on previous studies by conducting an *ex post* analysis of rbST adoption using data from a national survey of U.S. dairy producers. The research questions addressed in this

study are: 1) What factors have influenced the rbST adoption decision?, and 2) How has rbST adoption impacted milk production and profitability? Results of this analysis can serve as a means of evaluating the results of *ex ante* and other *ex post* studies of rbST adoption, and may provide insights into the future adoption of rbST.

The Theoretical Economics of rbST

The economics of rbST are based on the premise that its use increases milk production. However, rbST is profitable only if the costs of the increase in milk production are less than the revenue generated by the added milk. An approximation of the added profit from rbST is simply an estimate of the additional revenues realized from rbST use minus the additional costs of supplementing cows with rbST.

The following example, adapted from Butler (1999), illustrates the profitability that producers may expect. If rbST increases milk production by 8 pounds per cow per day and the average price of milk is $12.00 per hundredweight, the additional revenue from using rbST is $0.96 per cow per day. Supplementing with rbST for the recommended 245 days would generate additional revenue of $235.20 per cow per lactation.

rbST costs about $5.50 per 14-day treatment, or about $0.40 per cow per day. Also, extra feed costs of about $0.05 per pound of milk are incurred to achieve the increase in production. For 8 pounds of additional milk per cow per day, the extra feed cost will be $0.40 per cow per day. Therefore, total added costs associated with using rbST are $0.80 per cow per day, or $196.00 per cow per lactation.

Subtracting costs from additional revenues in this example, profits increase by $0.16 per cow per day or $39.20 per cow per lactation. Assuming that producers not using rbST are earning $300 profit per cow per year from milk sales ($1.50 net return per hundredweight on 20,000 pounds of milk per cow), then rbST can be expected to increase returns from $300 to $339.20 per cow, an increase of about 13 percent. Butler (1999) notes that this example does not account for other potential extra costs, such as labor, record keeping, increased days open, mastitis, lameness, and heat stress, that may or may not be significant. He also does not account for any increase in feed efficiency that may occur and admits to using conservative response and price parameters. Regardless, this example suggests that many producers would expect rbST to be a good investment.

The example also illustrates management requirements associated with rbST. Producers need to have the time, the skill, and the technologies to monitor individual cow milk production and feed intake to determine the profits from rbST use. The response to rbST varies among cows in a herd and it would be difficult to determine the response of each cow without daily monitoring. This means that even though rbST is a relatively inexpensive technology for producers to adopt and does not require an investment in capital assets, it is a relatively management-intensive activity to determine the profitable use of rbST. A significant investment in human capital and possibly other information technologies may be needed to profitability use rbST.

Background

Most published studies on rbST adoption and impacts have been *ex ante* in nature. These studies

often used a producer survey asking dairy farmers whether or not and to what extent they

planned to adopt rbST (Lesser, Magrath, and Kalter; Zepeda; Kinnucan et al.; Saha, Love, and

Schwart; Klotz, Saha, and Butler). The objectives of these studies were, among other things, to

determine the socio-economic characteristics of producers and to relate these characteristics to

their intention to adopt. The data were then used to predict aggregate adoption rates and in many

cases to assess potential social and economic impacts of rbST.

Predicted rbST adoption rates from *ex ante* studies range from 8 to 41 percent for early-

adopters, and from 33 to 92 percent for eventual-adopters. Such a wide range in predicted

adoption rates could be the result of regional differences among the studies, or could arise from

survey bias and changing opinions about rbST (Caswell, Fuglie, and Klotz). Most studies

identified producers who were younger, better-educated, and more skilled managers, and

operations that were larger and more productive as those more likely to adopt rbST. These

studies also identified a significant proportion of dairy producers who were committed non-

adopters because of the socio-economic issues surrounding rbST. Predicted profitability from *ex

ante* studies of rbST use range from negative values on poorly managed dairy farms with low

herd productivity, to $250 per cow on the most productive operations with elevated response

rates (Fallert et al.; Schmidt; Butler 1992; Marion and Wills; Jarvis).

Actual adoption of rbST has been difficult to determine. Monsanto, the only company currently

selling rbST (sold as Posilac) reports that approximately one-third of U.S. dairy cows are in

herds supplemented with rbST, and that the average dairy producer treats more than 50 percent

of the herd (Monsanto). Few *ex post* studies of rbST adoption have been conducted. Data from

a panel of New York dairies suggest that adoption rates had reached about 37 percent by the end

of 1996 (Lesser, Bernard, and Billah). Only about 15 percent of surveyed dairy farms in

Wisconsin were using rbST in 1999 (Barham, Jackson-Smith, and Moon). Data from a survey of

California diary producers in 1998 indicated that 25 percent of producers were using rbST, but

only 30 percent of the cows in these herds were treated (Butler 1999).

The profitability of rbST has been evaluated *ex post* using data from New York dairy farms

(Tauer and Knoblauch; Stefanides and Tauer; Tauer). Stefanides and Tauer estimated that farms

using rbST on a portion of the herd had production increase by about 1,000 pounds per cow a

year on average compared to farms where rbST was not used. Tauer estimated a production

response to rbST ranging from 2,700 to nearly 3,500 pounds per cow per year between 1994 and

1997. However, none of these studies found the adoption of rbST to have a statistically

significant impact on farm profits. Ott and Rendleman used 1996 U.S. Department of Agriculture

dairy data and measured a herd milk response of nearly 3,000 pounds per cow and an optimal

rbST use rate of 73 percent of the herd. These data did not include cost information, but

combining cost budgets with the data it was estimated that rbST use would increase profits by

$126 per cow.

Empirical Procedure

The empirical approach used in this study follows that used by Stefanides and Tauer. The rbST

impact is estimated by regressing several explanatory variables on milk production and

profitability. Among the explanatory variables is a binary variable indicating whether or not

rbST was used on the operation. The potential endogeneity of the rbST variable is

acknowledged and corrected using the instrumental variable procedure.

To illustrate the empirical approach consider the following regression equation:

(1) $$Y = X\beta + R\gamma + \varepsilon$$

where Y indicates milk production or profitability, X is a matrix of explanatory variables, R is a

binary variable for rbST use (=1 if rbST is used, 0 otherwise), and ε is a random disturbance

assumed to be normally distributed. If γ is to measure the impact of rbST adoption, farmers

should be randomly assigned among the adopters and non-adopters of rbST. However, since

farmers themselves decide whether to adopt rbST the assignment is by self-selection. The

literature suggests that dairy producers who adopt rbST may be better managers and thus more

productive and more profitable than non-adopters even without the use of rbST (Barnham,

Jackson-Smith, and Moon; Fetrow). Because the differences between rbST adopters and non-

adopters are likely to be systematic, treating R as an exogenous variable and applying ordinary

least squares to (1) would result in inconsistent parameter estimates.

There are several remedies to the self-selection bias issue. Most involve the estimation of a

separate equation explaining the selection decision and then using the prediction from that

equation to correct for the bias. In this study the selection decision is modeled with an adoption-

decision equation relating the decision to use rbST to characteristics of the farm operator and the

farm operation. Predictions from the adoption decision equation serve as an instrumental

variable for rbST use, R, in the adoption-impact equation shown in (1).

The adoption-decision equation is specified with a binary probit model that can be represented by:

(2) $$R^* = Z\delta + \mu$$

where R^* is unobservable, Z is a matrix of explanatory variables, and μ is the error term that is assumed to be normally distributed with a zero mean and a variance of one. R^* is related to the observed decision to adopt R, where R=1 if $R^*>0$ and R=0 if $R^*\leq0$. The probability of adoption is $prob(R=1) = prob(R^*>0) = prob(Z\delta + \mu >0) = prob(\mu < Z\delta) = \Phi(Z\delta)$, where Φ is the cumulative distribution function of the standard normal distribution. The binary probit model is estimated by the method of maximum likelihood (Greene). The predicted probabilities of rbST adoption, $\Phi(Z\delta)$, are used as the instrumental variable for R in equation (1).

Data

Data for the analysis comes from a detailed survey of U.S. dairy operations conducted in 2000 as part of USDA's annual Agricultural Resource Management Survey (ARMS). Each farm in the ARMS sample represents a known number of farms with similar attributes so that weighting the data for each farm by the number of farms it represents provides a basis for calculating estimates for the target population. The target population in the dairy survey was operations milking 10 or more cows at any time during 2000. Information about dairy production practices and performance, farm financial status, and operator human capital and demographic characteristics was collected in the survey. The survey also collected specific data about rbST use on the dairy operation. The data includes information from 872 dairy operations in 22 states. All operations are used to examine adoption rates, but only dairy operations that reported being in business

during all of 2000 are used in the empirical analysis. Also, 13 observations are deleted because of missing data. This left data from 820 dairy operations available for the empirical analysis.

An estimated 17 percent of U.S. dairy operations used rbST in 2000 (table 1). Operations treating with rbST are obviously larger than other operations as these 17 percent of farms included about 32 percent of U.S. dairy cows. Producers treating with rbST treated an average of 47 percent of their herd and report an average increase in production of 11 percent, very similar to the figures reported by Monsanto. Barham, Jackson-Smith, and Moon report that at the recommended use of rbST, a farm would be near full-adoption if approximately 66 percent of the herd is under treatment at any given time. This means that the 47 percent estimated from the survey translates to just over 70 percent of what may be considered as full-adoption.

Regional adoption estimates show that the highest rbST adoption rate was in the Southeast (30 percent of farms) while the lowest was in the Appalachian region (8 percent of farms). The farm adoption estimate for the Upper Midwest, at 17 percent, is in line with the 15 percent reported for Wisconsin in 1999 (Barham, Jackson-Smith, and Moon). Farm adoption estimates in the Northeast and Pacific regions, however, are lower than those reported in New York (Lesser, Bernard, and Billah) and California (Butler 1999). Also, rbST adoption was more common on larger farms in all regions, particularly in the Upper Midwest and Southwest. Adoption rates by size of operation illustrate the size-bias of rbST adoption (table 1). Adoption rates increase across all of the size groups, ranging from only 11 percent of operations with fewer than 50 cows to 65 percent of operations with 1,000 or more cows. The size-bias is significant despite the assertion that rbST is by nature a scale-neutral technology.

Farm and operator characteristics and the production practices used by adopters and non-adopters are shown in table 2. rbST adopters tend to be younger and better educated than non-adopters, and also have a longer planning horizon for the dairy operation. The difference in education may reflect differences in management strategies and a familiarity with and preference for more recent technological options. Dairy producers with a longer planning horizon may be more willing to invest in the human capital and other technologies that support the efficient use of rbST. Adopters are also more specialized in dairy production and more likely to be organized as a corporation than are non-adopters.

The dairy operations of rbST adopters are, on average, significantly larger than the dairy operations of non-adopters (220 versus 95 cows). Average milk production on adopting farms is nearly 2,300 pounds per cow higher, but this difference is not statistically significant. The reason these means are not significantly different is the substantial variation on the production estimate of adopters compared to that for non-adopters[2]. The average net return per hundredweight of milk is lower on adopting farms. Much of this difference can be attributed to the greater hired labor costs incurred by the larger adopting farms whereas the smaller non-adopting farms use more unpaid labor. rbST adopters earn significantly more per hour of unpaid labor than non-adopters ($32 versus $14 per hour). However, like the variation in milk

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[2] The coefficient of variation (i.e. standard error relative to the mean) on the estimate of production per cow for rbST adopters is nearly 10 percent, compared to only about 2 percent for non-adopters. A 95-percent confidence interval around the mean production among rbST adopters ranges from about 14,300 to 22,000 pounds per cow.

production, variation in the net returns of rbST adopters is substantially higher than variation in the net returns of non-adopters[3].

The adoption of rbST was also associated with the use of other productivity-oriented dairy practices (table 2). A higher percentage of adopters use a parlor milking system, a computerized milking system, and milked cows more than two times per day. Adopters are also more likely to be participants in the Dairy Herd Improvement Association (DHIA), and in genetic and breeding programs. Feeding practices used by rbST adopters more often include a computerized system, a nutritional consultant, and the monitoring of forage quality. Adopters are less likely to be using a rotational grazing system, which is expected since this is a low-input strategy to minimize feed costs that might not be compatible with rbST use. The strong correlation between these practices and rbST use suggests that management and production systems oriented with these technologies are critical in shaping rbST adoption decisions.

Model Specification and Estimation

The impact of rbST adoption on milk production and farm financial performance is assessed by statistically controlling for several other factors that may also affect these variables. That is, the effect of economic and environmental conditions, management practices, and operator characteristics are accounted for in order to isolate the effect of rbST adoption. To control for factors other than rbST adoption, multiple-regression is used in a two-stage econometric model of adoption and the adoption impact. The first stage of the model consists of an adoption-decision model that describes factors that influence the likelihood of adopting rbST. Predictions

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[3] Coefficients of variation on the estimates of net returns for rbST adopters are twice those on the estimates for non-adopters.

from the adoption-decision model are included as an explanatory variable in regressions relating farm and operator characteristics to measures of milk production and financial performance. This specification is used as a means of correcting for potential self-selection bias.

The adoption-decision model was estimated by a probit analysis of rbST adoption. The model is specified using several variables that have shown to be related to technology choice (Feder, Just, and Zilberman; Feder and Umali). Adopters are those who reported rbST use on any portion of the herd during 2000. Farm operator variables regressed against the decision to adopt include age (*AGE*), experience (*EXPERIENCE*), education (*EDUCATION*), and planning-horizon (*PHORIZON*)[4]. Farm operation variables are herd size (*COWS*) and size squared (*COWSSQ*), specialization in milk production (*SPECIALIZE*), business organization (*BUSORG*), and geographic location. Whether the farm operator had a long planning-horizon is indicated if the operator expected to be in the dairy business for more than 10 years. Business organization is specified by an indicator that the operation was organized as a corporation. Variables indicating the use of a computerized feeding system (*COMPFSYS*) and computerized milking system (*COMPMSYS*) are added because these technologies would be useful for maintaining individual cow records for evaluating the efficiency of using rbST, and also indicate comfort with using new technologies. The use of rotational grazing (*ROTGRAZE*) is added as an indicator of a low-input system that would discourage the use of rbST. Variables for geographic location are also included in the model to account for the impact that differences in other production practices, climate, and cultural perceptions of rbST would have on adoption[5].

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[4] Operator experience is the number of years that the operation had been in business. A preferred measure of experience is the number of years that rbST had been used, but this is not available from the data.

[5] For example, Wisconsin enacted into law during April of 1994 a voluntary labeling measure allowing processors to package milk products as free of rbST as long as the label included a disclaimer that no health differences have been

The adoption-impact model was then estimated for milk production and alternative measures of financial performance. Milk production is measured as the average pounds of milk produced per cow, including milk from both treated and untreated cows. The farm's operating margin, defined as gross income less variable input costs including rbST, is used as the measure of financial performance[6]. The operating margin is examined because rbST adoption mainly impacts variable input costs, including feed and other livestock expenses. The operating margin is measured per hundredweight of milk production and per hour of unpaid labor used on the operation. Dairy operations use a significant amount of labor in milk production, including a mix of both hired and unpaid labor that varies mainly by size of the dairy operation. Hired labor is charged as a variable cost, whereas the net returns are a residual payment to the unpaid labor.

Regressors in the adoption-impact models include operator and farm characteristics, and production practices likely to impact milk production and net returns. Operator experience and education, but not age, are included in the adoption-impact models. Production practices include participation in the DHIA (*DHIA*), use of genetic selection and breeding programs (*GENSELECT*), monitoring of forage quality (*MFORQ*), use of a parlor milking system (*PARLOR*), and an indicator if the cows were milked more than two times per day (*TIMES*). Milk price (*MPRICE*), calculated implicitly for each farm as milk receipts divided by pounds of milk sold, is also included in financial impact models. All adoption-impact models include

shown between milk from treated and untreated cows. This effectively constrained rbST adoption in Wisconsin (Barham).

[6] Gross income is comprised of commodity sales, government payments, and other farm-related income. Variable input costs include costs for feed, other livestock related costs (e.g. veterinary and medicine), seed, fertilizers and chemicals, hired labor, fuels and oils, repairs and maintenance, custom work, and utilities. The operating margin is expressed on an accrual basis by adding the annual change in accounts receivable, and annual inventory changes in farm commodities and production inputs (Farm Financial Standards Council).

variables to account for herd size and geographic differences among farms. Heckman's two-step

procedure is used to estimate the model, along with weighted-regression procedures and a

jackknife variance estimator designed to be used with the ARMS data (Dubman).

Results

Probit parameter estimates for the rbST adoption-decision model are presented in table 3. A

McFadden R-squared of 0.15 and an 82 percent correct prediction percentage suggests that the

model performed reasonably well in describing rbST adoption behavior. Also, several variables

were statistically significant in the model with signs that are consistent with prior expectations.

The results indicate that rbST adoption is more likely by younger, more highly educated milk

producers (table 3). Experience with the dairy operation also has a positive impact on the

adoption decision. As expected, larger producers (number of cows) are more likely to adopt

rbST and the negative sign on the quadratic term indicates that the size impact on adoption

increases at a decreasing rate[7]. Once the operator and size effects are accounted for, the use of

technologies complementary with rbST (i.e. computerized feed and milking systems) and

contrasting with rbST (i.e. rotational grazing) do not have a statistically significant impact on

adoption behavior. Estimated coefficients on the geographic variables indicate that location in

the Appalachian region is associated with a lower adoption probability than in the Upper

Midwest, consistent with the mean adoption rates found in these regions. However, once the

difference between the size of dairy operations in the Upper Midwest and western regions (i.e.

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[7] The size effect on adoption does not reach a maximum until a size of nearly 1,500 cows. Few operations in the sample are at or above this size.

Southwest and Pacific) is statistically controlled, the probability of adopting rbST is estimated to be higher among Upper Midwest producers.

Results of the adoption-impact models are shown in table 4. The estimated model for milk production per cow indicates that more educated dairy producers and more specialized operations have a higher output per cow. Estimated coefficients on the size of operation and location variables are not statistically significant in the production-impact model. Productivity oriented practices, including participation in the DHIA program, use of genetic selection and breeding programs, and milking more than two times per day have a strong and positive correlation with production per cow. Accounting for these impacts, treatment of some portion of the herd with rbST has a statistically significant impact that adds about 3,000 pounds of annual milk production per cow. This is about the same impact estimated by Ott and Rendleman, and within the 2,700-3,500 pounds per cow range reported by Tauer.

The estimated models for the rbST impact on operating margin per hundredweight of milk and per hour of unpaid labor are also shown in table 4. Coefficients on education and specialization indicate an unexpected negative relationship between these variables and the operating margin per hundredweight. Geographic variables are also significant in this equation showing higher returns for producers in the Upper Midwest compared to producers in the Appalachian and Southeast regions. Size of operation has a positive impact on the operating margin per unpaid labor hour mainly because larger operations hire more labor for production activities and spread their unpaid managerial labor over more units of production. Milk price has a strong positive

and statistically significant impact on both measures of financial performance. None of the production practice variables specified in these models are significant.

The coefficient on rbST use is positive and substantial in both financial performance models, but not statistically significant at the conventional significance levels (table 4). Since rbST use increases milk production, this means that the costs of additional inputs used to generate the production response offset the additional milk revenue. However, the magnitude of the estimated profit response ($3.62 per hundredweight and $10.46 per hour) suggests that rbST generates a substantial increase in net returns on some operations. The lack of statistical significance implies that the variation in net returns among operations using rbST is also substantial. These results coincide with other *ex post* studies of rbST adoption impacts that also show positive production impacts but a profit response that is not statistically significant (Stefanides and Tauer; Tauer; Tauer and Knoblauch).

Table 5 includes a summary of the adoption impacts measured by the difference in adopter and non-adopter sample means, and regression results with and without the sample selection correction. The results show that a comparison of means does not yield a statistically significant production response to rbST, but by statistically controlling for other factors in the regression analysis the response is significant. Another point illustrated in table 5 is that the regression results corrected for selection bias are greater in magnitude than the uncorrected results in both models of rbST profitability. This implies that, contrary to a priori expectations, there may be a negative self-selection bias associated with the profitability of rbST adoption. If some rbST

users are inherently less profitable than non-users before adoption, we might expected there be a wide variation in the net returns among the users of rbST.

Summary and Conclusions

Data from a sample of dairy producers in 22 states were used to estimate an *ex post* adoption function for rbST and to measure the impact of adoption on milk production and measures of farm financial performance. Factors found to influence the adoption of rbST include many of the same factors shown to influence the adoption of other agricultural technologies. Younger, more educated, and more experienced dairy producers are more likely to use rbST. Despite the inherent scale-neutral nature of rbST, adoption is much greater on larger farms. rbST is a management-intensive technology that is associated with the use of other productivity-oriented technologies and management practices, such as computerized feeding and milking systems, genetic and breeding programs, and frequent milkings, that have been adopted more often on larger farms. Thus, rbST use is more common on larger farms probably because of the overall management approach taken by these farms.

The use of rbST was found to significantly increase milk production per cow, an average of about 3,000 pounds, after statistically controlling for other factors that would affect milk production and the potential self-selection bias from survey data. The impact on financial performance, however, was not statistically significant. Estimated coefficients measuring the financial impact are substantial, at $3.62 per hundredweight of milk and $10.46 per hour of unpaid labor, but large standard errors prevent the estimates from being statistically significant. These results suggest that there are probably farm operations where rbST use is substantially

improving the financial performance, and that there are also probably situations where rbST is unprofitable. Wide variation in the financial performance of operations using rbST means that statistical tests about the average impacts are not conclusive.

Why is there such a wide variation in financial performance among U.S. dairy operations using rbST? rbST is a management-intensive technology that requires producers to not only treat cows about twice monthly, but to also adjust feed intake to take advantage of the greater production potential. Experience with rbST has also indicated that there can be considerable variation among cows in response to rbST treatments (Butler, 1998). Most producers do not have the time or the technologies to monitor individual cow feed intake and production and, therefore are not able to calculate the profits from using rbST. Also, rbST has been on the market since 1994 and there may be a significant learning process associated with using the technology profitably. Early adopters may be earning significant profits from rbST, whereas later adopters may still be learning how to use the technology profitably. The close tie between the level of management and the production and profits obtained from rbST is probably a major reason why rbST is associated with such a substantial variation in farm performance.

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Table 1. Estimated adoption rates of rbST on U.S. dairy operations in 2000

Group	Farms adopting	Cows on adopting farms	Cows treated on adopting farms	Increase in production from treatment
		percent		
U.S.	17	32	47	11
Region[1]:				
Northeast	20	34	55	12
Upper Midwest	17	35	37	9
Corn Belt	14	20	66	11
Appalachian	8	12	42	10
Southeast	30	44	52	11
Southwest	20	42	47	21
Pacific	19	32	44	12
Size of operation:				
Fewer than 50 cows	11	13	64	12
50-99 cows	16	17	53	10
100-499 cows	25	27	52	11
500-999 cows	40	41	55	11
1,000 or more cows	65	64	34	15

Notes: Farms adopting are those treating any cows with rbST. Cows on adopting farms are the entire herd on farms treating with rbST, including treated and untreated cows. Cows treated on adopting farms is the proportion of the herd treated on adopting farms. The increase in production from treatment is that reported by the survey respondents.
[1]The regions are defined as: Northeast-VT, NY, and PA; Upper Midwest-MN, WI, and MI; Corn Belt-IA, IL, MO, IN, and OH; Appalachian-KY, TN, and VA; Southeast-GA and FL; Southwest-TX, NM, and AZ; Pacific-CA, WA, and ID.

Table 2. Characteristics and production practices of rbST adopters and non-adopters, 2000

Item	Adopters	Non-adopters	All farms
Farm operator:			
Age (years)	45**	50	49
Experience (years operating)	20	22	21
Education:			
Formal school (years)	12.7**	12.1	12.2
Completing college (percent)	17**	8	10
Planning horizon (percent):			
Out of business by 2005	15**	32	29
In business in 2010 and beyond	61**	43	46
Farm business:			
Milk cows (head)	220**	95	116
Milk production (pounds per cow)	18,179	15,909	16,640
Dairy specialization (percent of value)	88*	84	86
Business organization (percent):			
Individual	73*	81	80
Partnership	16	14	14
Corporation	11*	5	6
Operating margin (dollars per unit)[1]:			
Per hundredweight of milk	4.84	5.58	5.29
Per hour of unpaid labor	32.67**	14.06	17.09
Dairy production practices (percent)[2]:			
Parlor milking system	49**	37	39
Computerized milking system	15**	5	6
Milking more than 2X per day	14**	1	4
DHIA program	78**	39	45
Genetic and breeding program	83**	61	65
Computerized feeding system	17**	7	9
Consulting nutritionist	96**	61	67
Monitoring forage quality	80**	51	56
Rotational grazing system	14*	24	22

Notes: Single and double asterisks (*) denote estimate is significantly different from the estimate for non-adopters at the 10% and 5% levels.

[1]Operating margin is defined as the gross cash income (commodity sales, government payments, and other farm-related income) less variable input costs. Variable input costs include costs for feed, other livestock related costs (e.g. veterinary and medicine), seed, fertilizers and chemicals, hired labor, fuels and oils, repairs and maintenance, custom work, and utilities. The operating margin is expressed on an accrual basis by adjusting for the annual change in accounts receivable, and changes in commodity and production input inventories.

[2]DHIA indicates participation in the dairy herd improvement association. Genetic selection and breeding programs include such practices as embryo transplants and artificial insemination to improve herd quality.

Table 3. Probit estimates of the rbST adoption-decision model, 2000

Variable	Coefficient	Std. error
INTERCEPT	-0.8249	0.6445
AGE	-0.0307**	0.0077
EXPERIENCE	0.0112*	0.0059
EDUCATION	0.0555*	0.0291
PHORIZON	0.1194	0.1238
SPECIALIZE	0.0009	0.0068
BUSORG	0.1677	0.3353
COWS[1]	0.3248**	0.1077
COWSSQ	-0.0111*	0.0054
COMPFSYS	0.2971	0.2572
COMPMSYS	0.2950	0.2833
ROTGRAZE	-0.2841	0.2589
NORTHEAST	0.1895	0.2777
CORNBELT	-0.1764	0.1688
APPALACHIAN	-0.5081**	0.2349
SOUTHEAST	-0.3762	0.3510
SOUTHWEST	-0.9216**	0.3357
PACIFIC	-1.0079**	0.3227
Log-liklihood	-26,119	
McFadden's R^2	0.15	
Percent correct prediction	82	
Sample size	820	

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels. Critical t-values are 2.145 at the 5% level and 1.761 and the 10% level using the jackknife variance estimator with 15 replicates. Coefficients on location variables are interpreted relative to the deleted group, Upper Midwest. The regions are defined as: Northeast-VT, NY, and PA; Upper Midwest-MN, WI, and MI; Corn Belt-IA, IL, MO, IN, and OH; Appalachian-KY, TN, and VA; Southeast-GA and FL; Southwest-TX, NM, and AZ; Pacific-CA, WA, and ID.
[1]Measured as 100's of cows.

Table 4. Regression estimates of the rbST adoption-impact models, 2000

Variable	Milk production per cow (lbs.)		Operating margin per hundredweight ($)		Operating margin per unpaid hour ($)	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
INTERCEPT	5819.34*	2923.83	16.196**	5.014	-6.997	37.512
EXPERIENCE	2.20	21.17	0.017	0.018	0.292	0.191
EDUCATION	204.93**	90.88	-0.246**	0.092	-1.613	1.433
SPECIALIZE	58.04**	23.68	-0.190**	0.041	-0.305	0.196
COWS[1]	-189.16	328.90	-0.437	0.319	13.222*	6.752
COWSSQ	1.87	9.78	0.013	0.012	0.023	0.330
MPRICE[2]	-	-	0.810**	0.120	4.294**	1.751
DHIA	2223.70**	495.92	0.089	0.518	-1.131	3.478
GENSELECT	698.92*	387.87	0.085	0.623	-1.010	3.394
MFORQ	978.07	603.84	0.142	0.771	4.376	3.192
PARLOR	-267.68	928.12	-0.416	0.616	5.489	6.902
TIMES	2522.52**	1149.49	-0.739	0.704	11.890	14.547
NORTHEAST	-57.20	914.37	-2.295**	0.662	-11.923**	3.365
CORNBELT	-261.22	854.87	-1.566	0.899	-8.065	5.563
APPALACHIAN	-201.15	941.49	-1.914**	0.804	-8.395	10.587
SOUTHEAST	-923.01	1857.40	-2.974**	1.021	24.931	25.066
SOUTHWEST	-383.05	1412.54	-1.656	1.401	7.713	20.580
PACIFIC	1355.44	1455.95	-0.538	0.802	18.234	16.929
PrbST[3]	3033.45*	1641.43	3.616	2.454	10.459	37.560
R^2	0.22		0.29		0.34	
Sample size	820		820		820	

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels. Critical t-values are 2.145 at the 5% level and 1.761 and the 10% level using the jackknife variance estimator with 15 replicates. Coefficients on location variables are interpreted relative to the deleted group, Upper Midwest. The regions are defined as: Northeast-VT, NY, and PA; Upper Midwest-MN, WI, and MI; Corn Belt-IA, IL, MO, IN, and OH; Appalachian-KY, TN, and VA; Southeast-GA and FL; Southwest-TX, NM, and AZ; Pacific-CA, WA, and ID.
[1]Measured as 100's of cows.
[2]Milk price was not included in the production model.
[3]The predicted probability of adopting rbST estimated from the adoption-decision model.

Table 5. Comparison of the rbST adoption impact using different measurement methods, 2000

Measurement method	Impact of Adoption on:		
	Milk production per cow (lbs.)	Operating margin per hundredweight ($)	Operating margin per unpaid hour ($)
Difference in adopter and non-adopter means	2,270	-0.74	18.61**
Regression without sample selection correction[1]	3,124**	-0.79	6.52
Regression with sample selection correction[2]	3,033*	3.62	10.46

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels.
[1]Estimated impact by using a binary (0,1) variable for rbST adoption.
[2]Estimated impact by using the predicted probability of adopting rbST estimated from the adoption-decision model.