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ABSTRACT

Data from the same 138 New York dairy farms for the years 1994 through 1997 were used to estimate whether Bovine Somatotropin (bST) generated profits for adopters. Data from these same farms from 1993 were used to sort farms into groups by production per cow, profit per cow, and farm size, in order to test bST response by these delineators. Statistically, farms that used bST on average experienced an output response per cow, but did not profit from using bST. The exception are farms with cows producing between 8159 to 9157 kilograms per cow, who appear to be making money from bST. Lower production per cow farms are getting a bST output response, but are not making money from that response; higher production per cow farms are not even getting a statistically significant output response.

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INTRODUCTION

The compound bovine Somatotropin (bST) has been commercially available to U.S. dairy producers since February of 1994. Before approved for sale, bST was subject to years of investigation and testing. Given the large production response per cow that most of these tests reported, bST was generally projected to be profitable for dairy farmers, with estimates often exceeding $100 per year per cow (Butler, 1992), although some projected little or no profit (Marion and Wills, 1990). Now that bST has been used by U.S. farmers for a number of years, it is possible to estimate their actual production and profit responses.

Bovine Somatotropin is a hormone produced by the dairy cow that regulates milk production. The genetic material for this compound has been isolated and is produced by recombinant biotechnology. This recombinant-produced bovine Somatotropin can then 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 increase milk production. Monsanto (1999) is currently the only U.S. supplier of recombinant bST under the registered tradename POSILAC. As of May 11, 1999, Monsanto states that 13,000 dairy producers were using bST, and of the nearly 9 million dairy cows in the United States, approximately 30 percent of the cows are in herds that are supplemented with POSILAC.

Tauer and Knoblauch (1997) used data from the same 259 New York producers in 1993 and 1994 to estimate the impact of bST on milk production per cow and return above variable cost per cow. BST was not available in 1993, but one-third of these farmers used bST in 1994. The use of bST had a positive and statistically significant impact on average production per cow ($\propto = .005$), but the profit effect, although positive and large, was not statistically different from zero ($\propto = .014$).

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 corrected for self-selection bias by using the two-step Heckman approach, and estimated a probit adoption function for each year (Greene, 1997). They likewise found a statistically significant and positive effect on milk production per cow from the use of bST, but found that the impact of bST on profits was zero. They suggest that farmers may still be learning how to profitably use bST, or that such a large number of farmers are using bST, including those getting a low return, that the average farm is not making a profit from its use.

Nonetheless, there may still be a subset of farmers earning a positive return from the use of bST. These farmers may either have been the most effective learners or have a unique position or characteristic to profit from bST. This paper implements that concept using four years of bST-use data and measures the impact by different types of farmers. Observations from 138 New York dairy farms are available. Since farmers displayed various historical use patterns over the four years of bST availability, those patterns are used to accommodate any self-selection bias. Likewise, since data were available from 1993 before bST was available, farms are sorted based upon managerial abilities displayed that year, and the impact of bST in later years is estimated by management level.

METHODS AND MODEL

The data comprise a group of farms some of which use or have used bST. The intent is to determine whether the use of bST increases profits. A profit function was estimated where profit is a function of output and input prices, other exogenous determining variables, and the use or non-use of bST. The data available are from an ongoing farm business analysis program, and actual or expected prices were not collected, except for an implicit milk price computed by dividing milk revenue by milk sold. Published price data are available for only a few inputs, and those that exist are collected and reported at the state level, resulting in no variability across farm observations. Four years of data also provides little temporal price variability. Because of these data limitations, prices are not included in the profit function except for the price of milk.

Included in the profit function was a dummy variable representing the use or non-use of bST. However, the potential exists for self-selection bias since the farmers themselves determined their use or non-use of bST. Farmers that use bST may be more or less profitable as a group even without the use of bST. The result is that the error term on the profit function may be correlated with this treatment effect. There are a number of remedies to this data limitation, most of which involve the estimation of a separate equation explaining the selection decision, and using the prediction from that equation as an instrumental variable (Davidson and MacKinnon, 1993). Stefanides and Tauer (1999) used Heckman's two-step estimation procedure and found insignificant evidence of bST selection bias in an earlier use of this data source. This result may be due to the fact that all the farms in the data set are relatively well managed. Hence, the selection of bST may not be related to a management performance variable such as profit, but due to farm characteristics.

Measuring the impact of an event on welfare is pervasive in economic research. Examples include estimating the returns to education or to membership in labor unions. If data are available for a number of years, and individuals have histories of membership and non-membership in an event, then these historical patterns can be used to estimate the returns to individuals exclusive of membership in the event, resulting in a better estimate of the return to the event (Card, 1996). The dairy data used here include farmers that ceased using bST after initially using bST, and farmers who delayed their adoption of bST. Modeling the error structure as dependent on these various bST use histories alleviates the correlation between the error term and the use of bST. That approach was used in the empirical results reported below.

The profit w_{it} of farm i in period t is specified as:

$$(1) \quad w_{it} = a_t + b_t x_{it} + d\, u_{it} + v_{it}$$

where u_{it} denotes the use of bST of farm i in period t and d is the impact of bST use on profit, x_{it} represents observed exogenous variables for farm i and time t and β_t is the impact of those variables on profit at time t, a_t is the intercept for time t, and v_{it} is a residual component of profit. This residual profit can be separated into a permanent farm η_i component and a transitory (error) component as:

$$(2) \quad v_{it} = h_i + e_{it}.$$

It is assumed that bST will only affect the permanent component so that $E(u_{it} e_{it}) = 0$.

Following Card (1996), the permanent component of profit for farm i is specified as a function of a bST use history dummy variable m_{ih}, where h defines some historical bST use pattern, and a vector of exogenous variables x, as:

$$(3) \quad h_i = \sum_{h=1}^{H} u_{ih} f_h + l x_{it} + x_i$$

where x_i is an independent error term. The variable μ_{ih} models various patterns of bST use and non-use over time for the specific farm i, ϕ_h is the impact of that specific bST use history on farm profit, and λ is the impact of the exogenous variables on farm profit.

The data consists of four separate years of bST use or no bST use so 16 possible combinations of annual use and non-use are possible. Many of these combinations are null or sparse. Many farms either have used bST for the entire four years or have not used bST in any of the four years. BST use is coded and is translated into a usage history as $h = kl$; $k = 0,1$; $l = 0,1$; where 0 is non-usage and 1 is bST usage during the first two years k, or during the last two years l. BST usage history is then coded as the four-member set h={00, 01, 10, 11} with membership of {50, 11, 15, 62}.

The profit equation (1) can also be modified to use this bST use history as:

$$(4) \quad w_{it} = a_t + b_t x_{it} + d\, u_{ikl} + v_{it}$$

where δ=0 by definition if bST is not used in period t. Then inserting equation (3) into (2) into (4), produces a system of four equations, one equation for each year:

$$w_{i1} = a_1 + (b_1 + l)x_{i1} + (d + f_{10})u_{i10} + f_{01}u_{i01} + (d + f_{11})u_{i11} + x_i + e_{il}$$
$$w_{i2} = a_2 + (b_2 + l)x_{i2} + (d + f_{10})u_{i10} + f_{01}u_{i01} + (d + f_{11})u_{i11} + x_i + e_{i2}$$
$$w_{i3} = a_3 + (b_3 + l)x_{i3} + f_{10}u_{i10} + (d + f_{01})u_{i01} + (d + f_{11})u_{i11} + x_i + e_{i3}$$
$$w_{i4} = a_4 + (b_4 + l)x_{i4} + f_{10}u_{i10} + (d + f_{01})u_{i01} + (d + f_{11})u_{i11} + x_i + e_{i4}$$

With this specification, l represents the impact of general skill on profits, d measures the impact of bST on profits when bST is used, while ϕ_{kl} represents the impact of the various use histories on the profit for any period t. If bST users would have larger profits even if bST is not used, then the impact of that is estimated separately as ϕ_{11} rather than from using bST. The parameter ϕ_{01} represents the impact on profits for later users of bST even if they are not using bST during years 1 or 2, and conversely ϕ_{10} represents the base profits of later bST users even if bST is not used.

This model specifies that the impact of bST on profits as measured by δ is not influenced by bST use history. Thus, the profit from bST for those farms that tried but discontinued the use of bST is the same as those farms that continuously used bST, and those farms that waited to use bST. Readers may find this tenuous. Many would believe that farms may have ceased using bST because those farms found bST unprofitable, while farmers who found bST profitable would have continued to use bST. However, modeling separate bST effects (separate δ's) for three bST use patterns, and including the bST history variables, would lead to a singular equation system without the ability to estimate separately modeled δ's. As a remedy, the bST parameter δ, and use history parameter φ's can be combined to measure bST profitability, with the understanding that any inherent greater profitability of continuous bST farms that would have occurred even without the use of bST might be erroneously included as the return to bST. The estimate of δ might be interpreted as a lower bound on bST return from the modeled equation, and the estimate ($\delta+\phi_{11}$) might be considered as an upper bound.

This system of four equations was jointly estimated with cross-equation restrictions imposed. The error structure consists of a term specified by farm across years, $\xi_{i,}$ as well as an error unique to each period, $\varepsilon_{it.}$. These errors were estimated by seemingly unrelated regression which allows for this contemporaneous correlation.

This system approach was also used to model and estimate the change in milk production per cow from the use of bST. The dependent variables w_{it}'s were replaced with milk production changes per cow.

Initial model estimates using the Wald test determined that unique a or $b + l$ vectors by year did not exist. As such, a common intercept and beta ($b + l$) vector coefficients were estimated across equations.

Previous studies using earlier years of this data source concluded that bST has no impact on profits (Tauer and Knoblauch, 1997; Stefanides and Tauer, 1999). It is difficult to imagine that farmers would continue to use bST if it failed to generate a profit, although as Stefanides and Tauer (1999) suggest, the impact on milk output is unmistakable, possibly making it difficult for farmers to ascertain the true profitability of bST. Yet, it might be possible that a subset of bST users may be finding that product profitable. Various authors have conjectured that bST may only be profitable for the better managed farms (Marion and Wills, 1990). This was tested by dividing the sample into groups, based upon individual farm performance in 1993 before bST was available.

DATA

The data were from the New York Dairy Farm Business Summary Program (Knoblauch and Putnam, 1998). 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. Farm analysis is done temporally if farmers participate annually. For the five-year period of 1993 through 1997, a total of 138 farms participated every year. This provides the data set for the empirical analysis with data from 1993 used to sort farms, and bST impacts measured with data from 1994 through 1997.

This is not a random sample. It represents a population of farmers that actively participate in agricultural extension and research programs. It would be tenuous to make inferences to the general population of dairy farms. The farms in this sample are larger on average than New York dairy farms and they experience higher levels of production per cow. Yet, there is a significant amount of hetereogeneity in the data. The smallest farm has only 29 cows, while the largest has over 2000 cows. The average number of cows is 165 (standard deviation of 236).

Variable specification is consistent with the annual Dairy Farm Business Summary Report (Knoblauch and Putnam, 1998). Production per cow is the total milk sold for the year divided by the reported average number of dairy cows. Short-run profit is measured as milk receipts minus the operating costs of producing milk. Operating cost includes variable costs, and excludes fixed cost items such as depreciation. If bST does increase farm revenue, farmers may use that additional revenue to purchase additional equipment not necessary for bST use, which would mute the measured impact of bST on profits. To be included in this published data set, milk receipts must constitute at least 90 percent of total farm receipts, yet some culled cows, calves, and excess feed were sold each year. Those receipt items were subtracted from total operating costs to estimate the operating costs of producing milk. This calculation assumes that the cost of producing products other than milk was equal to the value of those products. Although not necessarily true, detailed cost accounts were not collected by enterprise or receipt source.

Many of these farms are multiple owned operations, mostly parent-child. This was coded as 1 if multiple owned, 0 otherwise. Since there are multiple operators, age and education of the first manager were used. Education was coded as 1 if more than a high school education, 0 otherwise. Age was measured in years. Milking system was coded as a 1 if parlor, 0 if stanchion. Milk price was computed as gross milk receipts divided by the quantity of milk sold during the year. Finally, cows are the average number of cows the farm reported for the year. The average and standard deviation of these data are reported in Table 1.

Table 1. Definition of variables

Variables	*Definition*	*Mean 1993*	*S.D. 1993*
SRPCOW	Short-run profit per cow	$603	$325
MILKCOW	Milk production per cow (kilograms)	8577	1180
COWS	Average number of cows	165	236
MILKPR	Milk price per cwt.	$13.20	$0.52
AGE	Age of principal owner in years	46	10
BUS_ORG	Business organization, 1 if multiple owner	0.41	0.04
EDUC	Education, 1 if more than high school	0.54	0.04
MILK_SYS	Milking system, 1 if parlor	0.53	0.04

N = 138 observations

As stated in the model section, farmers were coded as either using bST or not using bST during the first two years and then the last two years of bST availability. The DFBS surveys for each of the four years asked farmers to indicate their use of bST in one of five categories as (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, (4) used on more than 75 percent of the herd. Most responses over the period were in categories 0 and 3. Very few farms indicated they used it on more than 75 percent of the herd, and if they did one of the years, the other years they typically dropped back to using it on 25-75 percent of the herd. Likewise, few farms used it on less than 25 percent of the herd, and if they did any year, other years their use was usually 25-75 percent of the herd.

This bST use coding has limited informational content. Although most of these farms are DHIA (Dairy Herd Improvement Association) members, that organization does not code bST use on individual cow records, so neither age nor production level of individually treated cows was known. This lack of detailed bST management information precludes analysis on bST use tactics, which may be complex and unique by farm. Farmers using bST must believe that it is profitable on their farms. As such, farms were simply sorted into bST users and non-users.

EMPIRICAL RESULTS

The system regression of return over operating costs per cow for all four years that bST was available, using the entire sample of 138 farms, shows that the impact of bST on profits was statistically not different from zero (Table 2). The profit estimate from bST use was $15.88 per year per cow, but the t-value testing whether this estimated coefficient is statistically different from zero is only 0.32. Farmers that used bST continuously for each of the four years experienced an overall numerical increase in profits per cow of $44.92 compared with farmers who did not use bST during any of the four-year period. This $44.92 represents a bST use impact of $15.88 and a base profit impact of $29.04. As discussed earlier, the value of $44.92 might be viewed as an upper bound to the return from continuous bST use while the value of $15.88 can be viewed as the lower bound estimate. However, a Wald test that the sum of δ and ϕ_{11} ($44.92) is different from zero, produced a Chi-square value of only .69, failing to reject the null hypothesis, and accepting the alternative hypothesis that continuous bST users are not making money from using bST. Likewise, although the estimate of the combined bST and base return to those who stopped using bST was a negative $28, and the estimate of the combined bST and base return to the wait/use sequence was a positive $4, neither of these estimates was statistically different from zero by Wald tests.

Table 2. Impact of bST on milk production per cow (kilograms) and short-run profit per cow ($US); full sample

Independent variables (Standard error of each estimate is in parentheses below each coefficient estimate)	*Dependent variable* Δ *(MILKCOW)*	*SRPCOW*
BST Use (d)	297 (101)	15.88 (50)
Continuous BST(f_{11})	393 (164)	29.04 (74)
BST Use/Drop(f_{10})	191 (193)	-43.77 (80)
BST Wait/Use(f_{01})	184 (211)	-11.99 (92)
AGE	9 (36)	10.88 (17)
AGE^2	-0.10 (0.39)	-0.131 (0.18)
EDUC	55 (95)	38.79 (42)
BUS_ORG	167 (96)	133.96 (43)
MILK_SYS	-28 (100)	-188.46 (44)
MILKPR	-88 (22)	70.88 (12)
Constant	819 (964)	-613.87 (438)
Wald Tests		
Ho: $\delta + f_{11} = 0$ Chi-square (Prob)	28.46 (0.00)	0.69 (0.41)
Ho: $\delta + f_{10} = 0$ Chi-square (Prob)	7.02 (0.01)	0.13 (0.72)
Ho: $\delta + f_{01} = 0$ Chi-square (Prob)	4.77 (0.03)	0.00 (0.96)

Although bST does not appear to be profitable on average for the types of farmers this sample represents, bST does increase milk output per cow. Knoblauch and Putnam (1998) report that DFBS farms using bST increased milk sold per cow from 9187 kg in 1993, before bST was available, to 10,469 kg in 1997. In contrast, farms not using bST sold 7905 kg per cow in 1993 and 7778 kg in 1997. This pattern suggests that the difference in milk sales each year from the base year of 1993 rather than level values of milk sold per cow should be defined as the regressand. The difference in milk produced per cow from the base year of 1993 was regressed on the same independent variables used in the profit equation. The bST impact was estimated to be 296 kg per year, and with a t-value of 2.93 statistically different from zero. This is the increase in the herd average and includes cows that may not have been treated with bST at all during the period. Farmers that used bST continuously for each of the four years experienced an increase in milk production per cow of 689 kg per year compared with farmers who did not use bST during any of the four-year period (Table 2). This 689 kg per year represents a bST impact of 296 kg per year and a base impact of 393 kg per year. Farms that used bST during the early part of the four-year period, but discontinued during the last part of the four-year period, experienced an overall response of 486 kg per year, while farmers that waited to use bST for the second half of the four-year period experienced an overall response of 480 kg per year.

These results support the earlier estimates of Tauer and Knoblauch (1997), and Stefanides and Tauer (1999) that bST has a measurable and significant impact on output per cow, but has no statistical significant impact on profits per cow. With more experience, bST may spawn a larger milk output response, supporting the assertion that learning has occurred, but that learning only vaguely appears to translate into greater profits, since the bST use coefficients on the profit equation have high relative standard errors. Yet, some individual producers might be making money from using bST. To identify these farmers, the next section divides the sample into sub-samples based upon various metrics used to measure management and performance among dairy farmers, to determine if better managers are making money from the use of bST.

EMPIRICAL RESULTS OF SUB-SAMPLES

One measure of managerial performance is profit. Return above operating costs is the statistic used to measure the impact of bST on profits per cow, and is used to sort farms into one of three managerial levels. Return above operating cost from 1993, the year before bST was available, is used to sort the 138 farms into three groups of 46 farms from lowest to the highest return.

Since profit per cow is transient by year, with few benchmarks for comparisons, two other proxies for management were used to sort the farms. One measure is milk sold per cow. It is generally acknowledged that better managed farms have higher output per cow. It is also a variable that is easily measured and commonly collected. It does have limitations. Production per cow may be low not only because of poor feeding and managing of the cow, but also because of low genetic potential of the herd. Although the selection and use of inferior genetics might be viewed as the consequence of poor management, the herd might be optimally managed subject to that genetic resource. This has implications for measuring the impact of bST, since test results have shown that even cows with mediocre genetics can respond to the use of bST if they are fed and managed optimally (Patton and Heald, 1992). Since bST is known to increase output per cow, the 138 farms were sorted into three groups based upon milk per cow from the year 1993 when bST was not yet available. The group ranges were 5463 to 8153 kg per cow for the low group, 8159 to 9157 kg for the middle group, and 9161 to 11,088 kg for the high group.

Although not a direct measure of management, many believe that larger farms on average are better managed, or at least have the opportunity to benefit the most from the use of bST. Although small farms may be able to provide more individual attention to cows, correct feeding is important to effectively use bST, and larger farms are more apt to have state-of-the-art feeding facilities. This has policy implications since if larger farms benefit more from bST, in a competitive environment there will be additional pressure on the ability of the small dairy farm to survive. Size as measured by the number of dairy cows is also an easily measured and reported statistic. Here the farms were again separated into three equal size groups of 46 farms based upon the average number of dairy cows during the year 1993. The group's ranges were 29 to 71 cows for the small farm, 71 to 139 cows for the medium farm, and 139 to over 2000 cows for the large farm size, although most of the large farms in the sample have fewer than 250 cows.

The regression results, reported in Table 3 by sorting by profitability in 1993, show that the use of bST has no statistical impact on profits per cow regardless of the previous (inherent) profitability of the farm. Although the low profit per cow farms experienced a positive numerical return to bST ($49.47), and the use of bST on higher profit per cow farms generated negative profits, the standard errors on these estimates are so large that statistically one might conclude that the effect is zero profit response across all profit levels. Combining the bST impact coefficient with the various bST use history coefficients produces combined coefficients which are also not statistically different from zero, as determined by the individual Wald tests in Table 3.

The regression results from the sort based on milk production per cow in 1993 exhibits an interesting pattern (Table 4). On the low production per cow farms, bST use increases milk production per cow by 419 kg per year, statistically different from zero. On the middle production per cow farms, bST use increases milk production per cow by 575 kg per year, again statistically different from zero. But on the high production farms, bST use has no statistical impact on production per cow. These results support previous experimental results that low producing cows respond to bST (Patton and Heald, 1992). If base production effects are folded into the bST impact coefficients, then Wald tests show that all continuous bST users experience positive output effects from bST use, even on high production farms. On low production farms, that is 1165 kg per year; on middle production farms, that is 449 kg per year; and on high production farms, that is 1070 kg per year. Interesting, only on the low production farms are the combined bST and history use coefficients statistically different from zero for farms that discontinued bST use or waited to start the use of bST. On middle and high production farms, these combined coefficients were not statistically different from zero.

Table 3. Impact of bST on short-run profit per cow ($US); sample sorted by profitability

Independent variables (Standard error of each estimate is in parentheses below each coefficient estimate)	*Profit per cow* *Low*	*Middle*	*High*
BST Use(d)	49.47 (84)	-27.13 (73)	-11.68 (97)
Continuous BST(f_{11})	-67.04 (114)	-8.56 (86)	135.43 (137)
BST Use/Drop(f_{10})	-17.49 (97)	-114.71 (83)	24.21 (151)
BST Wait/Use(f_{01})	50.31 (123)	-48.78 (71)	27.77 (231)
AGE	16.17 (21)	-7.47 (25)	-41.35 (32)
AGE^2	-0.21 (0.22)	0.05 (0.26)	0.41 (0.32)
EDUC	84.17 (59)	73.6 (38)	40.58 (76)
BUS_ORG	43.47 (58)	38.61 (47)	59.33 (77)
MILK_SYS	21.21 (68)	-12.91 (45)	-252.23 (76)
MILKPR	102.23 (21)	37.01 (15)	42.29 (21)
Constant	-1349. (594)	192. (619)	1193. (785)
Wald Tests			
Ho: $\delta + f_{11} = 0$ Chi-square (Prob)	0.06 (0.81)	0.58 (0.44)	1.67 (0.20)
Ho: $\delta + f_{10} = 0$ Chi-square (Prob)	0.12 (0.73)	3.55 (0.06)	0.01 (0.93)
Ho: $\delta + f_{01} = 0$ Chi-square (Prob)	0.64 (0.42)	0.95 (0.33)	0.01 (0.94)

Table 4. Impact of bST on production change per cow (kilograms); sample sorted by production per cow

Independent variables (Standard error of each estimate is in parentheses below each coefficient estimate)	*Production per cow*		
	Low	*Middle*	*High*
BST Use(d)	419 (129)	575 (162)	-179 (236)
Continuous BST(f_{11})	745 (236)	-126 (242)	1249 (356)
BST Use/Drop(f_{10})	1061 (195)	-913 (305)	111 (411)
BST Wait/Use(f_{01})	470 (232)	-224 (303)	119 (496)
AGE	-172 (56)	13 (59)	53 (64)
AGE^2	1.6 (0.55)	-0.1 (0.48)	-0.6 (0.72)
EDUC	-33 (127)	160 (133)	157 (185)
BUS_ORG	196 (138)	65 (133)	140 (177)
MILK_SYS	-233 (147)	72 (136)	-8 (200)
MILKPR	-119 (32)	-77 (34)	-51 (44)
Constant	5922 (145)	600 (1429)	-1153 (1647)
- -			
Wald Tests			
Ho: $\delta + f_{11} = 0$ Chi-square (Prob)	34.28 (0.00)	7.10 (0.01)	15.91 (0.00)
Ho: $\delta + f_{10} = 0$ Chi-square (Prob)	56.38 (0.00)	1.67 (0.20)	0.03 (0.86)
Ho: $\delta + f_{01} = 0$ Chi-square (Prob)	14.84 (0.00)	1.05 (0.30)	0.01 (0.90)

Regressions of returns over operating costs per cow for the three (1993) production levels show a statistically zero profit bST response for both the low production farms and high production farms, but a $176.10 profit effect on the middle production farms (Table 5). So although it appears that low production farms generated an output response from bST use, that did not translate into profits. That was not the case on the middle production farms that turned their positive bST output response into profits. High output production farms experienced neither an output nor a profit response from using bST. Wald tests show zero effects on all combined coefficients, including for the middle output producers.

The results from sorting by farm size are reported in Table 6. The profit response from the use of bST is statistically zero for all farm size groups. However, when the bST coefficient is added to the various use history coefficients, one combined effect is statistically different from zero with a Wald test value of 5.59. The largest farms that continuously used bST earned $229 more per cow than the largest farms that did not use bST. Although detailed cow management practices are not collected on farms, larger farms may have management practices or facilities where they can profitably benefit from using bST. This might include more effective cow monitoring and feeding programs.

Table 5. Impact of bST on short-run profit per cow ($US); sample sorted by production per cow

Independent variables (Standard error of each estimate is in parentheses below each coefficient estimate)	*Production per cow*		
	Low	*Middle*	*High*
BST Use(d)	-91.05 (67)	176.10 (77)	-17.78 (118)
Continuous BST(f_{11})	-38.35 (128)	-261.93 (110)	24.64 (164)
BST Use/Drop(f_{10})	-33.05 (103)	-115.86 (121)	-132.54 (172)
BST Wait/Use(f_{01})	-35.12 (130)	-154.39 (144)	-182.12 (194)
AGE	14.48 (30)	-46.17 (27)	10.20 (28)
AGE^2	-0.19 (0.29)	0.416 (0.28)	-0.083 (0.30)
EDUC	23.77 (66)	-35.16 (69)	157.10 (75)
BUS_ORG	146.98 (72)	25.93 (67)	261.25 (72)
MILK_SYS	-136.21 (79)	-86.22 (62)	-345.35 (70)
MILKPR	80.90 (17)	59.15 (19)	66.52 (23)
Constant	-836.0 (760)	1047.0 (680)	-519.0 (741)
Wald Tests			
Ho: $\delta + f_{11} = 0$ Chi-square (Prob)	1.45 (0.23)	0.23 (0.63)	1.01 (0.31)
Ho: $\delta + f_{10} = 0$ Chi-square (Prob)	1.25 (0.26)	1.35 (0.25)	0.01 (0.95)
Ho: $\delta + f_{01} = 0$ Chi-square (Prob)	1.07 (0.31)	0.02 (0.88)	0.91 (0.34)

Table 6. Impact of bST on short-run profit per cow ($US); sample sorted by farm size (number of cows)

Independent variables (Standard error of each estimate is in parentheses below each coefficient estimate)	*Farm size*		
	Small	*Medium*	*Large*
BST Use(d)	-4.88 (98)	55.59 (65)	-77.64 (118)
Continuous BST(f_{11})	77.93 (150)	-43.83 (115)	306.59 (152)
BST Use/Drop(f_{10})	5.87 (147)	-101.21 (110)	387.29 (230)
BST Wait/Use(f_{01})	61.82 (182)	-130.06 (143)	169.25 (150)
AGE	3.09 (39)	-24.03 (30)	20.98 (26)
AGE^2	-0.09 (0.38)	0.22 (0.30)	-0.20 (0.27)
EDUC	14.99 (83)	59.34 (71)	-3.24 (65)
BUS_ORG	179.83 (89)	90.40 (73)	154.83 (60)
MILK_SYS	-223.66 (116)	-181.48 (70)	-23.50 (107)
MILKPR	97.60 (21)	67.66 (20)	37.82 (20)
Constant	-711.0 (936)	279.0 (820)	-746.0 (678)
Wald Tests			
Ho: $\delta + f_{11} = 0$ Chi-square (Prob)	0.00 (0.99)	0.02 (0.90)	5.59 (0.02)
Ho: $\delta + f_{10} = 0$ Chi-square (Prob)	0.41 (0.52)	0.02 (0.90)	2.00 (0.16)
Ho: $\delta + f_{01} = 0$ Chi-square (Prob)	0.11 (0.74)	0.27 (0.60)	0.30 (0.58)

CONCLUSIONS

Data from the same 138 dairy farms for the years 1994 through 1997 were used to determine if bST generates profits for adopters. BST has been commercially available since 1994 and slightly over half of these farms used bST during that time, with a number of them stopping or starting bST use during the four-year period. Data from these same farms from 1993 were used to sort farms into groups by production per cow, profit per cow, and farm size.

On average, farms that are using bST are experiencing an output response per cow, but are not profiting from using bST. The exception is farms with cows producing between 8159 to 9157 kg per cow, who appear to be making money from bST. Lower production per cow farms are getting a bST response, but are not making money from that response; higher production per cow farms are not even getting a statistically significant output response.

It appears that many farms using bST are experiencing an output response from bST, but are not generating profit from its use. Lack of detailed information on how bST is used on the sample farms precludes any analysis on how bST can be profitably used.

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