Economic Analysis of the Impacts of Bovine Somatotropin on the Profitability of Representative Dairy Farms in the Northeast

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This study evaluated the impacts of bST on the profitability of representative Pennsylvania dairy farms using a stochastic simulation model under two initial milk yield-per-cow levels, three levels of milk response to bST, and three milk price forecast scenarios. Results showed that farm profitability was improved with bST, but the magnitude of the benefits from bST depended on the farm's initial milk output per cow and the level of milk response to bST, both of which are related to quality of management. However, modest price declines due to bST-induced increases in the milk supply would have an offsetting effect on farm profitability.

Bovine somatotropin, or bST, is a naturally-occurring hormone that improves the productive efficiency (units of milk per unit of feed) of dairy cows by reducing the proportion of nutrients used for maintenance relative to the nutrients used for milk production (Bauman). Since 1982 when the first experiment on recombinant methionyl bovine somatotropin was reported (Bauman et al.), extensive research on this hormone has shown that supplemental bST improves milk yield between 4 to 24 pounds per day (Bauman; Chilliard; McBride et al.; Peel and Bauman; Thomas et al.). However, the magnitude of response to bST depends on many factors such as the dosage, the quality of management practices, and the prevailing environmental conditions (Bauman et al.). With respect to breed, experiments on Holstein and Jersey cows showed that the milk response to bST was of similar magnitude in relation to each breed's average milk yield (West et al.).

Bovine somatotropin is only the latest in a long line of technologies introduced in the dairy industry to improve productive efficiency. Other efficiency-enhancing technologies include genetic selection, artificial insemination, embryo transfer, and dietary and feed management (Bauman). The use of these technologies have sustained an average annual increase in milk yield per cow of 2.7% since 1955 (Fallert and Liebrand). However, bST technology is the first product of genetic engineering used in livestock production to be approved for commercial use by the U.S. Food and Drug Administration (FDA). The unprecedented research on and attention given to bST is the result of the high potential of this technology to enhance milk production efficiency. As a result, the implications on the profitability of dairy farms as well as market equilibrium and prices are key concerns.

The first published economic analysis of the potential impact of bST was made by Kalter et al. Using an LP model incorporating several crop mixes, the authors concluded that representative New York dairy farms would find bST economically profitable, assuming the experimental level of milk response to bST. With stable milk prices, farm returns over variable costs increased from 5 to 26% depending on farm characteristics and level of milk response to bST. Fallert and Liebrand combined a national dairy sector model with a set of linked spreadsheets to analyze the effects of bST on farm returns, income, and milk prices. Assuming a milk response to bST of 8.4 lbs of milk per day (25% less than the experimental responses), and that farmers adjust feeding to meet bST-supplemented cow needs, the authors concluded that milk production costs will be lower; however, the resulting increase in aggregate milk supplies

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would drive milk prices down, thus offsetting the net economic gain received by early adopters.

Marsh et al. used a simulation model to analyze the productivity of nine farms representing a cross section of Pennsylvania dairy farms by size and milk yield per cow. By comparing cash income and variable costs, the authors concluded that bST would be profitable for the good dairy manager if bST was priced favorably. By comparison, poorly managed farms (i.e. underfeeding, high mastitis incidence, and animal stress) would be hurt by bST technology (Bauman; Fallert and Liebrand). However, Marion and Wills analysis on the impacts of bST showed that the overall bST effects on milk yield per cow and milk prices will be much more modest than most earlier studies assumed.

Most of the reported studies on the farm-level economics of bST have used either an LP or a deterministic simulation approach, and therefore have not accounted for price and yield variability and risk. Profitability measures most often used were limited to partial budgeting and gross return analyses, and did not measure the overall farm-level profitability of bST technology. Moreover, past studies have focused on the profitability of dairy farms with Holstein breeds only. This paper addresses some of these limitations. The purpose of this analysis is to evaluate the economic impacts of bST technology on representative Pennsylvania Holstein and Jersey dairy farms using a stochastic simulation model that incorporates risk. Because results are sensitive to management factors, the level of milk response to bST, and milk prices, this analysis included two initial milk yield per cow levels, three levels of milk response to bST, and three milk price forecast scenarios.

Materials and Methods

A Monte-Carlo dynamic simulation model that incorporates risk was used in this study to evaluate the economic effects of bST on representative Jersey and Holstein Pennsylvania dairy farms. To account for farm management differences, the effects of bST were evaluated for two initial milk yield-per-cow levels: AVERAGE farms (with milk yield per cow of 15,800 lbs for Holsteins and 11,000 lbs for Jerseys, representing 1992 Pennsylvania state averages) and TOP farms (with milk yield-per-cow of 18,800 lbs for Holsteins and 12,500 lbs for Jerseys, representing 1992 Pennsylvania DHIA averages) (Pennsylvania Agricultural Statistics Services; Pennsylvania Dairy Herd Improvement Association). Because of the variability in the level of milk response to bST, three levels of milk response to bST were used. These response rates reflect the expected average response from commercially administered bST (9 pounds per day for large breeds such as Holstein and, assuming proportional response to milk yield per cow, 6 pounds per day for small breeds, such as Jerseys) (Monsanto). In this study, a no bST scenario was compared to the following three levels of milk response to bST: LOW (5 lbs of milk/day for Holsteins and 3 lbs of milk/day for Jerseys), MEDIUM (9 lbs of milk/day for Holsteins and 6 lbs of milk/day for Jerseys), and HIGH (15 lbs of milk/day for Holsteins and 10 lbs of milk/day for Jerseys). The effect of a bST-induced milk price decline was evaluated by comparing three milk price forecast scenarios: the BASELINE scenario based on 1993 baseline forecasts by the Food and Agricultural Policy Research Institute (FAPRI), and the MODIFIED scenario which takes the baseline prices per hundredweight of milk and subtracts $0.10 per year throughout the simulation period (e.g., $0.10 lower in year 1, $0.20 lower in year 2, $0.30 lower in year 3, etc.), and the BASELINE-plus-premium scenario which takes the baseline prices per hundredweight of milk and add $0.10 per year throughout the simulation period. Two preliminary studies on bST impacts on milk prices formed the basis of our assumption of taking $1.0 lower milk price per hundredweight cumulative over a ten-year period under the MODIFIED scenario. In an ex ante economic analysis by Fallert et al., the authors estimated that under the scenario where price support is allowed to fall to balance production and use, the all-milk price with bST will be $1.06 lower than without from 1986 to 1996. In addition, a second peer-reviewed study was released by the National Milk Producers Federation in which the authors concluded that ". . . All-milk prices are projected to average between 10 cents to 50 cents per hundredweight lower during the first half of the 1990's due specifically to the introduction of BST for commercial use . . .". The inclusion of the BASELINE-plus-premium price scenario was made to account for an alternative option taken by some farms which market their milk as bST-untreated and receive a premium price.

Milk prices for both breeds were based on the component milk pricing system which is used by 60% of milk producers in Pennsylvania (Federal Orders 4 and 36). The component milk pricing system pays milk producers on the basis of the amount of components produced. The 1992 Pennsylvania DHIA data show that milk from Jersey herds averages 4.73% fat and 3.76% protein compared to 3.64% and 3.20%, respectively, for milk from Holstein herds (Pennsylvania Dairy Herd Improvement Association). First-year prices per hundredweight of milk were $15.96 and $13.55 for Jersey and Holstein breeds, respectively, under the BASELINE milk price option. Milk prices for successive years of the simulation period were based on the projected annual U.S. all-milk prices adjusted for Pennsylvania average prices. It was assumed that bST use didn't change the proportion of fat and protein content for either breed.

The Model

The Farm Level Income and Policy Simulator (FLIPSIM) is a stochastic simulation model that simulates the economic activities of a typical dairy farm recursively using the ending financial position for one year as the beginning financial position for the next year (Richardson and Nixon). The model allows a multi-year planning horizon. A representative farm's financial position is a function of crop production, crops fed and sold, feed purchases, variable costs, fixed costs, debt payment, machinery replacement and depreciation, cash receipts, income and self-employment taxes, and cash withdrawal for family living expenses. A livestock farm's herd replacement strategy is also simulated recursively by tracking dairy livestock categories (cows, bulls, replacement heifers, and calves) and updating the livestock inventory at the beginning of each new simulation year following sales and culling and death losses. Input data required by FLIPSIM includes cropping enterprises (costs of crop production, acreage, average yield, and crop prices), livestock enterprises (replacement schedule, calving rates, and livestock prices), farm machinery and equipment, labor, off-farm income, and farm family living.

The simulation period used for this analysis was 10 years (1993–2002), with each year replicated 300 times (iterations). At each iteration, the model randomly draws different milk, livestock, and feed prices, milk output per cow, and crop yields from a multivariate empirical probability distribution using specified future annual average prices and yields. The choice of an empirical probability distribution was justified by the fact that historical yields do not follow normal distributions since they take either positive or null values but not negative ones, while the shape of the future price variations and trends is not exactly known. The multivariate empirical probability distribution was generated using exogenously supplied historical farm-level data (1982–91) for milk, crop and feed prices, milk output per cow, and crop yields (Pennsylvania Dairy Herd Improvement Association; Pennsylvania Agricultural Statistics Services; United States Department of Agriculture). The stochastic matrix generated by the model requires that correlations between yields and prices be inputed. For example, in a dry year with low yields, prices tend to rise above average. For historical data on crop yields, a 10 years data series (1980–1989) was used (Hoffman). The projected mean annual price and yield data for the planning horizon were taken from the FAPRI baseline forecasts adjusted for Pennsylvania averages (Pennsylvania Department of Agricultural Statistics Services).

The impacts of bST on farm financial performance were evaluated using the following output variables: (a) total cash receipts (from crops, livestock, and other farm related activities), (b) total cash expenses (for crop and livestock production, including interest costs and fixed cash costs but excluding depreciation), (c) cost per hundredweight of milk (total cash expenses divided by the 10-year mean of the annual average milk sold per farm), (d) net cash farm income (total cash receipts minus total cash expenses, excluding family living expenses, principal payments, and costs to replace capital assets), (e) after-tax present value of ending net worth (PVENW) (discounted value of farm net work in the last year simulated using 3% discount rate), (f) net present value (NPV) (difference between discounted benefits and discounted costs), (g) internal rate of return (IRR), and (i) probability of economic success (PES) (chance that the farm will experience an increase in net worth after adjusting for inflation). The selection of 3% discount rate was based on the average 1993 interest rate subtracted by 30% for after tax-discount rate. This choice may not reflect the fluctuations in the current interest rates; however the emphasis of the study is to compare the relative performance of different farm scenarios under similar conditions and not the change in farm financial performance under fluctuating interest rates conditions.

Description of Simulated Farms

In this study, the simulated Jersey and Holstein farms are representative of dairy farms with similar structure and type and which are common in Pennsylvania and the Northeast. The simulated dairy farms were developed using farm-level data from the Pennsylvania Dairy Farm Business Analysis (Ford), and Pennsylvania herd performance data (Pennsylvania Dairy Herd Improvement Association). The major characteristics of the Jersey and Holstein farms simulated in this study are summarized in Table 1. For all farms, the dairy herd consists of 50 lactating cows (at any one time during the year), 10 dry cows, 22 calves (0–12

Table 1. Major Characteristics of Simulated Pennsylvania Jersey and Holstein Farms

Farm Characteristics:	Jersey	Holstein
Physical Characteristics:		
Livestock		
Milking cows	50.0	50.0
Dry cows	10.0	10.0
Calves	20.0	20.0
Yearlings	22.0	22.0
Heifers (24 months and older)	5.0	5.0
Farm acreage, Ac		
Corn silage	28	50
Alfalfa hay and haylage	51	64
Grass hay	19	21
Total tillable acreage	98	135
Farmstead	5	7
Total farm acreage	103	142
	----- (×$1000) -----	
Financial Characteristics:		
Farm Assets		
Land and buildings	156.0	212.3
Machinery and equipment	127.3	127.3
Livestock	56.4	87.0
Cash reserve	5.3	6.0
Total assets	345.0	432.6
Farm Liabilities:	104.7	131.5
Beginning Net Worth	240.2	301.1
Equity to Assets Ratio (%)	0.69	0.69
Debt to Asset Ratio (%)	0.30	0.30

months) and 25 replacement heifers (12 months of age or older). For this analysis, it was assumed that the average calving interval for the herd is 13 months, the average age at first calving is 27 months, the cow culling rate is 31%, and 60% of all calves are sold at birth. These assumptions held regardless of bST use.

Total herd feed requirements in year one (1993) were determined using a least-cost total mixed ration program which account for milk yield per cow level as well as breed type. The farms were specified with sufficient acreage to provide all their forage needs, including alfalfa, orchard grass hay, and corn silage. The Holstein farms maintain 142 acres and the Jerseys 103 acres in order to supply forage needs for the herd. Corn grain and other supplemental feedstuffs (soybean meal, vitamins, and minerals) are purchased. Since 10-years regression of central Pennsylvania forage yields against time showed slightly negative yet nonsignificant coefficients, yields were not increased over the simulation period. At the end of each simulation year, 10 percent of the average annual production for each forage crop is stored for the following year and the excess forage is sold. For all the farm scenarios analyzed, it was assumed that annual milk output per cow increased by 2% (close to the 1993–2002 average milk yield increase from FAPRI baseline projections), and annual feed requirements for milking cows of each breed were adjusted accordingly.

It was assumed that bST is used bi-weekly starting the 9th week of lactation and continued through the end of the lactation period (335 days with a 13 month calving interval). Costs associated with bST use include $6.50 per injection of bST/cow, $0.02/cow/day for labor to administer bST, and $10.00/cow/year for added veterinary and medical costs associated with the higher milk production from bST use (Monsanto; Ford). Added feed costs due to bST were determined with the least-cost total ration based on bST-supplemented milk yield levels.

Crop production costs were specified using 1992 Pennsylvania enterprise budgets (Greaser). Total annual labor availability was assumed to be two worker equivalents, of which a half-time equivalent was hired as part-time labor and the remainder was provided by the farm family. The machinery and equipment complement used for all simulated farms was developed in 1992 with the assistance of Pennsylvania cooperative extension agents. The model assumes that all machinery and equipment is owned and that each machinery item is traded-in at the end of its economic useful life with farmers paying a minimum of 10% as a down payment for new machinery purchases.

Projected interest rates for new machinery loans, mortgages, operating capital, annual inflation rates for input costs, machinery, and labor during the planning horizon were based on 1993 FAPRI baseline forecasts (see selected data in Table 2). All simulated farms are assumed to have an initial debt-to-asset ratio of .30 with the loan length of outstanding debt fixed at 20 years for long-term debt and 7 years for intermediate term debt. It is also assumed that the farm operator will use any excess cash income to retire debt early. The crop mix did not change during the simulation period, and the farm was not permitted to grow by increasing acreage. However, the operator could sell cropland if necessary to remain solvent. Finally, it is assumed that the farm is no longer solvent when the equity-to-asset ratios falls below .10.

Results and Discussion

The effects of bST on simulated representative Jersey and Holstein farms are analyzed in three parts. First, the impacts of bST on the farm financial performance are discussed under the assumption of a MEDIUM milk response to bST. The second part

Table 2. Selected Data from 1993 Food and Agricultural Policy Research Institute Baseline Forecasts used in the Model

Variable	1993	1994	1995	1996	1997
Yields and Prices:					
Milk yield (Pound/cow)	15,601	15,920	16,142	16,484	16,779
All milk price ($/cwt)	12.43	13.04	12.76	13.06	12.67
Corn Yield (Bushel/acre)	121.8	123.6	125.1	126.2	126.3
Corn Price ($/Bushel)	2.09	2.11	2.26	2.36	2.22
Annual Interest Rates:					
Long term (%)	8.20	8.17	8.35	8.66	9.04
Intermediate term (%)	6.25	6.40	7.46	8.54	9.14
Operating loans (%)	2.25	2.40	3.46	4.54	5.14
Annual Rate of Inflation for Input Costs:					
Farmland Values (%)	4.00	3.30	2.00	1.06	0.53
Farm machinery (%)	2.65	1.25	2.66	2.96	2.93
Fuel & lube costs (%)	2.97	3.01	5.47	6.28	2.13
Input for Livestock (%)	2.40	2.77	5.21	3.33	4.93
Consumer Price Index:	140.40	144.93	150.19	156.17	162.49

Variable	1998	1999	2000	2001	2002
Yields and Prices:					
Milk yield (Pound/cow)	17,095	17,390	17,655	17,966	—
All milk price ($/cwt)	12.81	13.09	12.75	13.14	—
Corn Yield (Bushel/acre)	127.8	129.0	130.2	131.2	—
Corn Price ($/Bushel)	2.17	2.18	2.29	2.42	—
Annual Interest Rates:					
Long term (%)	9.36	9.65	9.64	9.53	9.40
Intermediate term (%)	9.21	9.24	9.20	9.16	9.16
Operating loans (%)	5.21	5.24	5.20	5.16	5.16
Annual Rate of Inflation for Input Costs:					
Farmland Values (%)	−0.1	−0.4	−0.7	−0.7	−0.7
Farm machinery (%)	2.82	3.13	3.25	3.24	3.23
Fuel & lube costs (%)	0.87	1.80	1.44	3.62	6.04
Input for Livestock (%)	4.84	4.82	5.33	5.35	5.30
Consumer Price Index:	168.72	175.16	181.95	189.05	196.47

compares the economic performance under a range of milk response levels to bST. The last part discusses the probabilities of economic success for all the simulated Jersey and Holstein farms with and without bST. All the simulation scenarios quantify Jersey and Holstein farms' economic and financial performance for the 10-year planning horizon. All the results represent 10-year and 300 iteration means.

Effects of bST on Profitability Under MEDIUM Milk Response Level

Data showing the effects of bST under the MEDIUM milk response level (6 lbs/d for Jerseys and 9 lbs/d for Holsteins) are summarized in Table 3a for AVERAGE milk yields and Table 3b for TOP milk yields. The effects of bST use on net cash farm income for the AVERAGE Jersey farm with a 60 cow herd was $4000 ($14,800 to $18,800) or a 27.0% increase under the BASELINE price option and $3200 (32.9% increase) under the MODIFIED price option. For the AVERAGE Holstein farm, the use of bST increased net cash farm income by $8400 or 38.0% under the BASELINE price option and $7400 or 50.3% under the MODIFIED price option. Compared to the AVERAGE farm, the use of bST by the TOP Jersey and Holstein farms increased net cash farm income by slightly smaller amounts in absolute values, but substantially lower in relative terms under the BASELINE price option. Similar results were observed under the MODIFIED price option. Beside higher net cash farm income with the use of bST, the fluctuation around income means was lower (smaller coefficient of variation) compared to no bST scenarios.

To evaluate the economic impacts on the dairy farms not using bST, net cash farm income was compared between the MODIFIED, BASELINE, and BASELINE-plus-premium price options. For the Jersey farm not using bST under the MODIFIED option, the annual net cash farm income was reduced by $5100 ($14,800 to $9700) or 34.4% for the AVERAGE farm and by $5700 (17.3%) for the TOP farm compared to similar farm under the

BASELINE option. In addition, the AVERAGE Jersey farm not using bST but receiving higher milk prices under the BASELINE-plus-premium option, generated a net cash farm income 26% higher than the same arm under the BASELINE option ($20,000 vs $14,800), and 6% higher than similar farm with bST ($20,000 vs. $18,000). Similar comparisons were observed for the TOP Jersey farm.

For the Holstein farm not using bST under the MODIFIED option, the annual net cash farm income was reduced by $7400 ($22,100 to $14,700) or 33.5% for the AVERAGE farm and $8200 (16.3%) for the TOP farm compared to similar farm under the BASELINE option. Compared to the BASELINE option, net cash farm income for Holstein farm under the BASELINE-plus-premium option was 33.5% higher than similar farm without bST for the AVERAGE farm and 15.7% higher for the TOP farm. However, for both the AVERAGE and TOP Holstein farms, net cash farm income for no bST under BASELINE-plus-premium option and for bST under BASELINE option scenarios was similar.

To analyze the observed effects of bST on net cash farm income, total cash receipts, total expenses, and cost per hundredweight of milk were examined. For the AVERAGE Jersey farm, bST use resulted in higher total cash expenses by $11,500 ($136,600 − $125,100) or 9.2% and higher total net returns by +$15,500 (or +11.1%) resulting in lower cost per hundredweight of milk by $0.70 under either milk price option. For the TOP farms, higher feed cost (due to higher milk yield) was offset by lower interest on loans (from higher income and faster debt retirement) resulting in total expenses little higher than those for the AVERAGE farm. Consequently, the increase in cost per hundredweight of milk due to bST use was lower with the TOP farms ($0.30 under either milk price option). For the AVERAGE Holstein farm with a 60 cow herd, the use of bST resulted in greater increase in total revenues (+$19,600 or +11.3%) than total expenses (+$11,100 or +7.3%), lowering the cost per hundredweight of milk by $0.89 under BASELINE price option. Similar results were observed with MODIFIED price option. For the TOP Holstein farm, the reduction in the cost per hundredweight of milk with bST use was $0.41 and $.43 under BASELINE and MODIFIED price options, respectively.

In addition to net cash farm income, long term farm profitability can be measured by the present value of ending net worth (PVENW), net present value (NPV), and internal rate of return (IRR). The NPV and IRR values were consistent across scenarios with NPV taking on positive values at or above 11% IRR. For the AVERAGE Jersey farm not using bST and compared to the initial farm net worth of $240,256, the PVENW dropped by 34.7% and 52.1%, respectively, under the BASELINE and the MODIFIED price options. With bST use, the decline of PVENW was lower but still substantial (−24.9% and −42.4% under the BASELINE and the MODIFIED price options, respectively). For this farm the cash flow was too low to observe a positive impact on PVENW by the use of bST. The low performance of the AVERAGE Jersey is also shown by the negative NPV and the relatively low IRR values (below 10%). For these farms long-term survival is uncertain and the use of bST with MEDIUM milk response level has little impact on the farm's economic viability. For the TOP Jersey farm however, the use of bST resulted in small increases in PVENW under both the BASELINE price option to 118.4% (from 112.6%) and MODIFIED price option to 103.1% (from 98%). Overall data on PVENW, NPV, and IRR suggest that the TOP Jersey farm showed a slight improvement in profitability with the use of bST under MEDIUM milk response level.

For the AVERAGE Holstein farm, the use of bST was not sufficient to turn around the decline of the PVENW which averaged −18.9% without bST and −2.6% with bST under the BASELINE option compared to the initial farm net worth ($301,113). However, the positive NPV value and a relatively high IRR (over 12%) under the BASELINE option shows that the use of bST technology does improve the overall economic performance of the AVERAGE Holstein farm. However, under the MODIFIED price option, the decline of the PVENW with bST was greater than under the BASELINE option (−19.8% vs. −2.6%) yielding a negative NPV and an IRR below 10%, suggesting that for the AVERAGE Holstein farm the effects of milk price decline could not be compensated for by the use of bST with MEDIUM milk response level. For the TOP Holstein farm under either milk price options, the PVENW increased without and with bST, with the latter showing an average of 10 percentage points above the PVENW levels of no bST scenario. The IRR values for all Holstein scenarios were relatively high and ranged from 18.4% with no bST under MODIFIED option to 24.7% with bST under BASELINE option.

In general, differences in PVENW between bST and no bST under the BASELINE option and no bST under BASELINE-plus-premium option, and for both breeds, were comparable to those observed with net cash farm income. In addition, PVENW for scenarios with bST showed smaller coefficients of variation compared to similar farms

Table 3a. Mean and Coefficient of Variation of Cash Returns, Cash Expenses, Net Cash Farm Income, and Farm Net Worth Variables for Representative AVERAGE Jersey and Holstein Dairy Farms: Effects of MEDIUM Milk Response to bST Under Two Milk Price Scenarios (10-year Average; 1993–2002)

	Baseline Milk Price Projections[1]					
Breed/bST Scenario	Jersey No bST	Jersey W/ bST	Jersey No bST*	Holst. No bST	Holst. W/ bST	Holst. No bST*
Total returns (×$1000)	139.9	155.4	144.1	173.8	193.4	179.7
	(2.9)	(2.9)	(2.9)	(3.3)	(3.3)	(3.3)
% change due to bST	100.0	111.1	103.0	100.0	111.3	103.4
Total expenses (×$1000)	125.1	136.6	124.0	151.7	162.8	150.2
	(1.3)	(1.3)	(1.3)	(1.1)	(1.1)	(1.1)
% change due to bST	100.0	115.0	99.1	100.0	107.3	99.0
Net cash income (×$1000)	14.8	18.8	20.0	22.1	30.5	29.5
	(36.5)	(32.1)	(27.8)	(32.6)	(25.8)	(25.0)
% change due to bST	100.0	127.0	135.1	100.0	138.0	133.5
Cost of milk ($/Cwt.)[2]	17.34	16.64	17.19	14.63	13.74	14.49
% change due to bST	100.0	95.9	99.2	100.0	93.9	99.0
PVENW (×$1000)	154.5	180.4	190.4	244.1	293.2	289.6
	(24.7)	(22.9)	(20.1)	(20.1)	(16.5)	(15.6)
% of Initial Net Worth[3]	64.3	75.1	79.2	81.1	97.4	96.2
NPV (×$1000)	−15.28	−85.5	−65.7	−63.9	61.9	45.7
	(−62.5)	(−119.8)	(−144.4)	(−183.6)	(188.1)	(240.8)
IRR (%)	3.9	7.6	8.4	7.3	12.3	11.1

	Modified Milk Price Projections[1]			
Breed/bST Scenario	Jersey No bST	Jersey W/ bST	Holst. No bST	Holst. W/ bST
Total returns (×$1000)	135.8	150.7	167.9	186.6
	(2.9)	(2.9)	(3.3)	(3.3)
% change due to bST	100.0	111.0	100.0	111.1
Total expenses (×$1000)	126.2	137.8	153.1	164.5
	(1.3)	(1.3)	(1.1)	(1.1)
% change due to bST	100.0	109.2	100.0	107.4
Net cash income (×$1000)	9.7	12.9	14.7	22.1
	(54.5)	(45.5)	(42.7)	(34.7)
% change due to bST	100.0	133.0	100.0	150.3
Cost of milk ($/Cwt.)[2]	17.49	16.79	14.79	13.88
% change due to bST	100.0	96.0	100.0	93.8
PVENW (×$1000)	115.1	138.3	194.1	241.6
	(41.8)	(34.4)	(27.2)	(21.3)
% of Initial Net Worth[3]	47.9	57.6	64.4	80.2
NPV (×$1000)	−241.2	−183.7	−180.8	−61.9
	(−39.5)	(−56.2)	(−66.2)	(−198.1)
IRR (%)	−2.4	1.8	1.9	7.5

[1]BASELINE projections are price forecasts by the Food Agricultural Policy Research Institute; MODIFIED option takes BASELINE prices and subtract $0.10 annually.
[2]Total cash expenses divided by the 10-year mean of the annual average milk sold per farm.
[3]Initial farm net worth for Jersey and Holstein farms was $240,256 and $301,113, respectively.
*: No bST under BASELINE-plus-premium option (BASELINE price plus $.10 annually); Coefficient of variation are in parentheses.

without bST indicating that bST technology can improve profitability while reducing financial risk.

Effects of bST on Profitability Under a Range of Milk Response Levels

The effects of bST for various milk response levels are summarized in Table 4a for Jersey farms and Table 4b for Holstein farms. For the Jersey farm, the LOW milk response to bST (3 lbs/d) actually lowered net cash farm income. This translated into increasing the cost per hundredweight of milk by $0.58 (+3.3%) for the AVERAGE farm and by $0.64 (+4.3%) for the TOP farm. Achieving only this level of increased milk production from bST use is not economically attractive.

Table 3b. Mean and Coefficient of Variation of Cash Returns, Cash Expenses, Net Cash Farm Income, and Farm Net Worth Variables for Representative TOP Jersey and Holstein Dairy Farms: Effects of MEDIUM Milk Response to bST Under Two Milk Price Scenarios (10-year average; 1993–2002)

	Baseline Milk Price Projections[1]						Modified Milk Price Projections[1]			
Breed/bST Scenario	Jersey No bST	Jersey W/ bST	Jersey No bST*	Holst. No bST	Holst. W/ bST	Holst. No bST*	Jersey No bST	Jersey W/ bST	Holst. No bST	Holst. W/ bST
Total returns (×$1000)	155.2	170.7	159.9	199.7	219.4	206.7	150.6	165.4	192.7	211.5
	(2.9)	(3.0)	(3.0)	(3.3)	(3.3)	(3.3)	(2.9)	(3.0)	(3.3)	(3.3)
% change due to bST	100.0	110.0	103.0	100.0	109.9	103.5	100.0	109.8	100.0	109.7
Total expenses	122.2	134.3	121.1	149.4	161.7	148.4	123.3	135.4	150.6	162.8
(×$1000)	(2.9)	(1.2)	(1.2)	(0.7)	(0.6)	(0.6)	(1.3)	(1.3)	(0.9)	(0.7)
% change due to bST	100.0	109.9	99.2	100.0	108.2	99.3	100.0	109.8	100.0	108.1
Net cash income	33.0	36.4	38.7	50.3	57.7	58.2	27.3	30.1	42.1	48.8
(×$1000)	(17.8)	(17.4)	(15.1)	(14.9)	(13.8)	(12.9)	(20.9)	(20.8)	(17.7)	(16.3)
% change due to bST	100.0	110.3	117.3	100.0	114.7	115.7	100.0	110.2	100.0	115.9
Cost of milk ($/Cwt.)[2]	14.90	14.61	14.78	12.11	11.70	12.04	15.04	14.73	12.21	11.78
% change due to bST	100.0	98.0	99.2	100.0	96.6	99.4	100.0	97.9	100.0	96.5
PVENW (×$1000)	270.5	284.5	301.1	391.1	422.6	426.5	235.5	247.7	352.0	381.7
	(12.7)	(12.6)	(10.3)	(9.2)	(8.8)	(8.0)	(15.6)	(15.7)	(11.3)	(10.5)
% of Initial Net Worth[3]	112.6	118.4	125.3	129.9	140.3	141.6	98.0	103.1	116.9	126.8
NPV (×$1000)	138.4	177.7	212.3	304.4	370.5	371.7	54.9	89.4	214.6	289.7
	(60.1)	(48.5)	(35.3)	(26.3)	(19.4)	(17.7)	(161.1)	(104.7)	(44.2)	(31.2)
IRR (%)	18.0	20.1	20.7	21.4	24.7	23.8	14.7	17.2	18.4	21.7

[1]BASELINE projections are price forecasts by the Food Agricultural Policy Research Institute; MODIFIED option takes BASELINE prices and subtract $0.10 annually.
[2]Total cash expenses divided by the 10-year mean of the annual average milk sold per farm.
[3]Initial farm net worth for Jersey and Holstein farms was $240,256 and $301,113, respectively.
*: No bST under BASELINE-plus-premium option (BASELINE price plus $.10 annually); Coefficient of variation are in parentheses.

Under the BASELINE price option, the HIGH milk response to bST (10 lbs/d) resulted in higher net cash farm income for both the AVERAGE and the TOP Jersey farm compared to no bST use. Net savings in the cost of hundredweight of milk were $2.15 for the AVERAGE farm and $1.33 for the TOP farm. Similar results were observed under the MODIFIED price option. In addition, the comparison of the coefficient of variation across scenarios showed that, with the exception of the economically unattractive LOW milk response level to bST scenario, the higher the milk response level to bST, the lower the variability of net cash farm income and PVENW compared to no bST scenario. Overall, for the AVERAGE Jersey farm (11,000 lbs/cow/year) the best scenario is the HIGH milk response level to bST with improved PVENW, positive NPV, and a relatively high IRR (over 12%) under BASELINE price option. For the TOP Jersey farm (12,500 lbs/cow/year) at least the MEDIUM level of milk response to bST is needed to improve all the economic performance variables analyzed, regardless of the milk price option considered.

For Holstein farms, the LOW level of milk response (5 lbs/d) resulted in a marginal decrease in net cash farm income for both AVERAGE and TOP farms and under both milk price options. These results indicate that the break-even response rate for Holstein farm is between 5 to 6 lbs of milk/day for herds with average annual production ranging from 15,800 to 18,800 pounds of milk. Under the BASELINE price option, the HIGH level of milk response to bST (15 lbs/d), resulted in increasing net cash farm income by 50.0% ($44,200 vs $22,100) for the AVERAGE farm and by 40.0% ($70,300 vs $50,300) for the TOP farm compared to no bST use (141.1% and 45.0%, respectively, under the MODIFIED price option). For the AVERAGE (TOP) Holstein farm, the savings in costs per hundredweight of milk were $2.02 ($1.16) under the BASELINE price option and $2.07 ($1.20) under the MODIFIED price option. Overall, the Holstein farms would substantially benefit from bST use when the milk response level to bST is at 9 lbs/d or higher under the BASELINE option and at 15 lbs/d level under the MODIFIED option.

Table 4a. Sensitivity Analysis: Effects of bST on JERSEY Farms Under Three Levels of Milk Response, Two Price Forecasts, and Two Milk Yield-per-cow Levels (10-year average; 1993–2002)

	Baseline Milk Price Projections[1]				
bST Scenario (lbs milk/d)	0	3	6	10	0*
Average Milk Yield[2]					
Cost of milk production ($/Cwt)	17.34	17.92	16.64	15.19	17.19
% change due to bST	100.0	103.3	95.6	87.6	99.1
Net cash farm income (×$1000)	14.8	9.5	18.8	30.9	20.0
	(36.5)	(60.4)	(32.1)	(20.3)	(27.8)
% change due to bST	100.0	64.2	127.0	208.8	135.1
PVENW (×$1000)[3]	154.5	112.8	180.4	256.5	190.4
	(24.7)	(45.8)	(22.9)	(14.9)	(20.1)
% of initial net worth[4]	64.3	46.9	75.1	106.8	79.2
Net Present Value (×$1000)	−152.8	−248.9	−85.5	105.8	−65.7
	(−62.5)	(−40.9)	(−119.8)	(87.8)	(−144.4)
Internal Rate of Return (%)	3.9	−2.7	7.6	16.8	8.4
Top Milk Yield[2]					
Cost of milk production ($/Cwt)	14.90	15.54	14.61	13.57	14.78
% change due to bST	100.0	104.3	98.0	91.1	99.2
Net cash farm income (×$1000)	33.0	27.8	36.4	47.3	38.7
	(17.6)	(22.5)	(17.4)	(13.6)	(15.1)
% change due to bST	100.0	84.2	110.3	143.3	117.3
PVENW (×$1000)[3]	270.5	237.7	284.5	335.4	301.1
	(12.7)	(16.7)	(12.2)	(9.3)	(10.3)
% of initial net worth[4]	112.6	98.9	118.4	139.6	100.0
Net Present Value (×$1000)	138.4	58.6	177.7	304.3	212.3
	(60.1)	(164.7)	(48.5)	(27.8)	(35.3)
Internal Rate of Return (%)	18.0	14.6	20.0	26.1	20.7

	Modified Milk Price Projections[1]			
bST Scenario (lbs milk/d)	0	3	6	10
Average Milk Yield[2]				
Cost of milk production ($/Cwt)	17.49	18.04	16.29	15.32
% change due to bST	100.0	103.1	96.0	87.6
Net cash farm income (×$1000)	9.7	4.0	12.9	24.7
	(54.5)	(131.5)	(41.5)	(24.9)
% change due to bST	100.0	41.2	133.0	254.6
PVENW (×$1000)[3]	115.1	69.2	138.3	217.6
	(41.8)	(81.7)	(34.4)	(18.5)
% of initial net worth[4]	47.9	28.8	57.6	90.6
Net Present Value (×$1000)	−241.2	−340.8	−183.7	12.7
	(−39.5)	(−26.1)	(−56.2)	(771.4)
Internal Rate of Return (%)	−2.4	−14.9	1.8	12.8
Top Milk Yield[2]				
Cost of milk production ($/Cwt)	15.04	15.68	14.73	13.66
% change due to bST	100.0	104.2	97.9	90.8
Net cash farm income (×$1000)	27.3	21.5	30.0	40.8
	(20.9)	(28.2)	(20.9)	(15.7)
% change due to bST	100.0	78.7	110.2	149.4
PVENW (×$1000)[3]	235.5	197.4	247.7	304.4
	(15.6)	(20.6)	(15.7)	(11.1)
% of initial net worth[4]	98.0	82.2	103.1	126.7
Net Present Value (×$1000)	54.9	−37.7	89.4	233.2
	(161.1)	(−263.7)	(104.7)	(34.8)
Internal Rate of Return (%)	14.7	10.4	17.2	21.9

[1]BASELINE is derived from the baseline forecasts by the Food Agricultural Policy Research Institute; MODIFIED milk price option takes BASELINE prices and subtract $0.10 annually.
[2]First-year AVERAGE and TOP yields for Jersey farms were 11,000 and 12,500 lbs/cow/year, representing 1992 Pennsylvania State and DHIA State averages, respectively.
[3]Present Value of Ending Net Worth.
[4]Initial farm net worth for Jersey farms was $240,256.
*: No bST under BASELINE-plus-premium option (BASELINE price plus $.10 annually); Coefficient of variation in parentheses.

Table 4b. Sensitivity Analysis: Effects of bST on HOLSTEIN Farms Under Three Levels of Milk Response, Two Price Forecasts, and Two Milk Yield-per-cow Levels (10-year average; 1993–2002)

	Baseline Milk Price Projections[1]				
bST Scenario (lbs milk/d)	0	5	9	15	0*
Average Milk Yield[2]					
Cost of milk production ($/Cwt)	14.63	14.67	13.74	12.61	14.49
% change due to bST	100.0	100.3	93.9	86.2	99.0
Net cash farm income (×$1000)	22.1	20.5	30.5	44.2	29.5
	(32.6)	(37.5)	(25.7)	(18.0)	(25.0)
% change due to bST	100.0	92.7	138.0	200.0	133.5
PVENW (×$1000)[3]	244.1	232.1	293.2	361.9	289.6
	(20.0)	(22.5)	(16.5)	(11.4)	(15.9)
% of initial net worth[4]	81.1	77.0	97.4	120.2	96.2
Net Present Value (×$1000)	−63.5	−91.8	61.9	235.9	45.7
	(−183.6)	(−136.8)	(188.1)	(41.0)	(240.8)
Internal Rate of Return (%)	7.3	6.1	12.3	18.9	11.1
Top Milk Yield[2]					
Cost of milk production ($/Cwt)	12.11	12.22	11.70	10.95	12.04
% change due to bST	100.0	100.9	96.6	90.4	99.4
Net cash farm income (×$1000)	50.3	50.2	57.7	70.3	58.2
	(14.9)	(15.8)	(13.8)	(11.8)	(12.9)
% change due to bST	100.0	99.8	114.7	139.8	115.7
PVENW (×$1000)[3]	391.1	389.7	422.6	476.7	426.5
	(9.2)	(8.7)	(8.7)	(7.6)	(8.0)
% of initial net worth[4]	129.9	129.4	140.3	158.3	141.6
Net Present Value (×$1000)	304.4	301.7	370.5	463.6	371.7
	(26.3)	(28.3)	(19.4)	(12.3)	(17.7)
Internal Rate of Return (%)	21.4	21.3	24.7	29.9	23.8

	Modified Milk Price Projections[1]			
bST Scenario (lbs milk/d)	0	5	9	15
Average Milk Yield[2]				
Cost of milk production ($/Cwt)	14.78	14.76	13.88	12.71
% change due to bST	100.0	100.0	93.8	86.0
Net cash farm income (×$1000)	14.7	12.5	22.1	35.5
	(42.7)	(59.8)	(34.7)	(22.2)
% change due to bST	100.0	85.0	150.3	241.5
PVENW (×$1000)[3]	194.1	176.7	241.6	316.6
	(27.2)	(33.6)	(21.3)	(14.6)
% of initial net worth[4]	64.4	58.7	80.2	105.1
Net Present Value (×$1000)	−180.8	−219.9	−61.9	127.6
	(−66.2)	(−58.4)	(−198.1)	(86.6)
Internal Rate of Return (%)	1.9	−.2	7.5	15.3
Top Milk Yield[2]				
Cost of milk production ($/Cwt)	12.21	12.32	11.78	11.01
% change due to bST	100.0	100.9	96.5	90.2
Net cash farm income (×$1000)	42.1	41.4	48.8	60.9
	(17.7)	(19.0)	(16.3)	(13.1)
% change due to bST	100.0	98.3	115.9	144.6
PVENW (×$1000)[3]	352.0	347.4	381.2	435.7
	(11.3)	(12.3)	(10.5)	(8.5)
% of initial net worth[4]	116.9	115.4	126.8	144.7
Net Present Value (×$1000)	214.6	203.9	289.7	399.7
	(44.2)	(49.9)	(31.2)	(16.8)
Internal Rate of Return (%)	18.4	18.2	21.7	27.3

[1]BASELINE is derived from the baseline forecasts by the Food Agricultural Policy Research Institute; MODIFIED milk price option takes BASELINE prices and subtract $0.10 annually.
[2]First-year AVERAGE and TOP yields for Holstein farms were 15,600 and 18,800 lbs/cow/year, representing 1992 Pennsylvania State and DHIA State averages, respectively.
[3]Present Value of Ending Net Worth.
[4]Initial farm net worth for Holstein farms was $301,113.
*: No bST under BASELINE-plus-premium option (BASELINE price plus $.10 annually); Coefficient of variation in parentheses.

Effects of bST on the Probability of Economic Success (Probability of Increased Net Worth)

All 36 farm scenarios analyzed showed 100% probability of economic survival over the 10-year planning period, hence only data for the probability of economic success (PES) are reported in Table 5. For the AVERAGE Jersey farm (11,000 lbs/cow/year), the PES was zero with the LOW level of milk response to bST and very low without bST (4%). Regardless of bST scenario, the PES was below 100% and reaching 88% only with the HIGH level of milk response to bST (+10 lbs/d) under BASELINE option. For the TOP Jersey farm, the PES reached 100% only with HIGH milk response to bST under BASELINE option and with no bST under BASELINE-plus-premium option. As expected, the Jersey farm using bST with only a LOW level of milk response, showed a decline in the PES regardless of the initial average milk yield of the milk price option.

For the AVERAGE Holstein farm (15,800 lbs/cow/year), using bST with MEDIUM milk response substantially improved the PES from 25 to 80% under the BASELINE price option, but could not raise the PES beyond 27% under the MODIFIED price option. No farm scenario reached 100% PES; only the HIGH milk response to bST came very close under the BASELINE option (97%). Under the MODIFIED price option all scenarios showed less PES, except for HIGH milk response to bST scenario. For the TOP Holstein farm (18,800 lbs/year/cow), all scenarios showed a PES at or close to 100%, except for bST scenario with LOW milk response level under the MODIFIED option.

Table 5. Probability of Economic Success[1] (Increased Net Worth) for Simulated Pennsylvania Jersey and Holstein Farm Under Three Levels of Milk Response to bST, Two Milk Price Forecasts, and Two Milk Yield Per Cow Levels (10-year average; 1993–2002)

	bST Scenario[4]	Milk Price Option BASELINE[2]	MODIFIED[2]
AVERAGE Farm[3]			
Jersey	No bST	4.0	0.0
	Low	0.0	0.0
	Medium	16.0	3.0
	High	88.0	60.0
	No bST*	91.0	—
Holstein	No bST	25.0	5.0
	Low	22.0	4.0
	Medium	80.0	27.0
	High	97.0	88.0
	No bST*	96.0	—
TOP Farm[3]			
Jersey	No bST	92.0	78.0
	Low	77.0	39.0
	Medium	95.0	85.0
	High	100.0	98.0
	No bST*	100.0	—
Holstein	No bST	100.0	97.0
	Low	99.0	94.0
	Medium	100.0	99.0
	High	100.0	100.0
	No bST*	100.0	—

[1]All farm scenarios showed 100 percent probability of economic survival.
[2]BASELINE is derived from the baseline forecasts by the Food Agricultural Policy Research Institute; MODIFIED milk price option takes BASELINE prices and subtract $0.10 annually.
[3]AVERAGE = 1992 Pennsylvania State average milk output/cow; TOP = 1992 Pennsylvania State DHIA average milk output/cow.
[4]Low, Medium, and High are 3, 6, and 10 lbs/day for Jersey and 5, 9, and 15 lbs/day for Holstein.
*: No bST under BASELINE-plus-premium option (BASELINE price plus $.10 annually).

Summary and Conclusions

The objective of this study was to evaluate the impacts of bST technology on the profitability of representative Holstein and Jersey dairy farms in the Northeast. Three levels of milk response to bST were compared to a no bST scenario under two initial milk yield per cow levels and three milk price forecast scenarios. A whole-farm stochastic simulation model that incorporates yield and price risk was used in this analysis.

The use of bST by the Jersey farm under the LOW level of milk response assumption (+3 lbs/d) had negative impacts on costs per hundredweight, net cash farm income, present value of ending net worth, and consequently the probability of economic success under both the AVERAGE and TOP milk yields and under the BASELINE and MODIFIED milk price scenarios. For the AVERAGE Holstein farm, the use of bST under LOW milk response (+5 lbs/d) had a small negative impact on the farm's economic performance compared to no bST use under both BASELINE and MODIFIED price options. For the TOP Holstein farm, there was no impact on the economic performance by the use of bST under LOW milk response (+5 lbs/d) compared to no bST use under either milk price option.

Under the MEDIUM level of milk response to bST (+6 lbs/d), the AVERAGE Jersey farm saw a decrease in the cost per hundredweight of milk by $0.70 and an increase in net cash farm income by 27% (BASELINE option) and 33% (MODIFIED option) compared to no bST use. However, the impact was not high enough to ensure an increase in the present value of ending net worth. For this farm, only the assumption of HIGH level of milk response to bST (+10 lbs/day) could substantially increase the probability of economic success. However, the farm scenario without bST under the BASELINE-plus-premium option had similar impact on the probability of economic success than with HIGH level of milk response to bST. Hence, the long term viability of the Jersey farm averaging 11,000 lbs per cow is suspect, even with the adoption of bST. With no bST use as a base, the TOP Jersey farm with MEDIUM level of milk response to bST, showed an increase in net cash farm income by 10.3%, and the present value of ending net worth by 5.8% (118.4% vs 112.6%) compared to 43.3% and 27.0%, respectively, under HIGH milk response to bST (+10 lbs/d). For the TOP Jersey farm, only a HIGH level of milk response to bST under the BASELINE option and the no-bST use under BASELINE-plus-premium option can ensure 100% probability of economic success.

For the AVERAGE Holstein farm with the MEDIUM level of milk response to bST, net cash farm income was increased substantially by 38% under BASELINE and 50% under MODIFIED option. However, only with the HIGH level of milk response to bST (+15 lbs/d) did the internal rate of return reached over 12% and the probability of economic success came close to 100%. The TOP Holstein farm (producing 18,800 lbs) showed between 97 to 100% probability of economic success for all scenarios except the LOW milk yield response to bST under the MODIFIED option.

Overall, this analysis showed that the impacts of bST technology on farm cash flow, income and long term profitability depend mostly on the level of milk response to bST and the farm's average milk yield per cow. As a consequence, the Holstein farms benefited more than the Jersey farms, therefore slightly widening the income gap between the two breeds in favor of the Holstein under the milk price assumptions of the model. In general, bST technology can substantially improve the income and the long-term profitability for dairy farms in the Northeast while also reducing the risks through lower variability of income and farm net worth. However, the gains from bST would depend on good quality of management practices to ensure a high level of milk response to bST.

Farms that can sell their milk as "bST-untreated" for a premium price can improve their economic performance comparable to the effects of bST use under average milk yield response level but below the effects of bST with above-average milk response level. However, it is not known what proportion of all dairy farms will adopt a strategy of marketing "bST-untreated" milk for a premium price. Finally, modest bST-induced milk price declines would have a small offsetting effect on the profitability of bST use. However, the extent of any actual milk price decline will depend on such factors as the rate of adoption of bST, the aggregate level of milk response to bST under varying management conditions, and the government price support policy.

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