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Adoption of Recombinant Bovine Somatotropin and Farm Profitability: Does Farm Size Matter?

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This article analyzes the adoption and profitability of recombinant bovine somatotropin (rBST) in the United States. Probit model results show that location of the farm, farm size, operator age and education, and other technologies adopted influence rBST adoption. Regression model results find that adoption of rBST influences milk yield per cow but not profitability, unless profitability is analyzed by farm-size segment.

Key words: rBST, technology adoption, probit, dairy.

Recombinant bovine somatotropin (rBST) was approved by the US Food and Drug Administration for commercial use by US dairy farmers in November 1993, and subsequently released commercially in February 1994. Many expected wide adoption. The technology had the potential to boost milk production more over a shorter time period than any technology that had recently been introduced in the dairy industry. However, by most accounts, farmers have embraced rBST with less enthusiasm than expected. Indeed, early after its release, Barham (1996) suggested rBST had "little prospect for adoption growth in the near future" since the technology required significant adjustments in dairy management practices and was unlikely to be complementary with other technologies such as pasture-based production. Lesser, Bernard, and Billah (1999) summarized that pre-FDA approval (ex-ante) adoption studies generally estimated greater adoption rates than ex-post adoption studies have found. A number of studies have since found no significant differences in net returns for milk production with or without the use of rBST (e.g., McBride, Short, & El-Osta, 2004; Tauer, 2005; Tauer & Knoblauch, 1997).

Recent developments, including the growing popularity of organic and "hormone-free" milk among consumers, have led some farmers to produce for those markets. In 2008, Kroger transitioned to processing milk only from farms not using rBST. In some cases, buyers are paying premiums for milk produced without the use of rBST. Boucher, Gillespie, and Hutchison (2010) include a $0.54 per hundredweight non-rBST premium in their 2010 dairy cost-of-production estimates for non-rBST milk since the majority of Louisiana milk producers receive that premium amount. Other constraints that may have reduced adoption include an rBST shortage and subsequent rationing in 2004 (Herndon, 2004) and early 2005, under which 9% of California milk farmers disadopted (An & Butler, 2009). Despite these developments, many larger farms have continued to use rBST, suggesting its use is advantageous to them.

Extensive research on rBST adoption on US farms has been conducted, dating back to 1990 (four years before the product was commercially available). The available research includes ex-ante studies (e.g., Kinnucan, Hatch, Molnar, & Pendergrass, 1990; Klotz, Saha, & Butler, 1995; Saha, Love, & Schwart, 1994; Zepeda, 1990) and subsequent ex-post studies analyzing rBST adoption and profitability data (e.g., Foltz & Chang, 2002; Tauer & Knoblauch, 1997). Most previous rBST assessment studies have relied on small numbers of observations, in most cases finding positive but statistically non-significant influences of rBST on farm profitability. The study reported in this article is arguably the most extensive conducted to date on rBST adoption and profitability, as it is based on a national dataset for the years 2000 and 2005, with sample weights that provide the ability to expand estimated results to the US dairy population. Thus, the objective of this study is to estimate the impact of rBST on milk cow productivity and farm profitability using an extensive national dataset, with an emphasis on impact by farm size.

Background

Monsanto marketed rBST under the brand name Posilac beginning in 1994, but sold rBST to Eli Lilly's Animal Health Division, Elanco, in 2008. The Elanco website (accessed July 13, 2009) posted several key claims regarding rBST: (1) it is a scale-neutral technology, (2) one can expect an additional 10 lbs milk/day with use (consistent with Speicher et al., 1994), and (3) it can extend the cow's lactation. Furthermore, rBST use should not significantly increase fixed costs. The price of one dose, given every 14 days, was listed on the website at $6.60. Fetrow (1999) and Butler (1999) provide partial budgeting analyses to show potential increased profit from rBST. Butler (1999), however, points out that there are a number of potential additional costs not included in his analysis such as labor, record-keeping, days open, and health concerns, calling for additional economic analysis of rBST.

Percentages of US farms adopting rBST were estimated at 9.4% in 1996 (US Department of Agriculture [USDA] Animal and Plant Health Inspection Service [APHIS], 2003), 17.3% in 2000 (Khanal, Gillespie, & MacDonald, 2010), 15.2% in 2003 (USDA APHIS, 2003), 16.6% in 2005 (Khanal et al., 2010), and 15.2% in 2007 (USDA APHIS, 2007). The 1996, 2003, and 2007 adoption rates are derived from the National Animal Health Monitoring System survey and the 2000 and 2005 adoption rates are based on the Agricultural Resource Management Survey (ARMS). Additional diffusion is not evident since 2000, as shown in the California-only case, where reduction in use was seen in 2008 (An & Butler, 2009).

Previous studies have provided generally consistent results on which farmers have adopted rBST. Adopters have generally been more highly educated (Barham, Foltz, Moon, & Jackson-Smith, 2003; Foltz & Chang, 2002; McBride et al., 2004; Stefanides & Tauer, 1999; Tauer, 2001, 2005, 2006), younger (Barham et al., 2003; Barham, Foltz, Jackson-Smith, & Moon, 2004; Foltz & Chang, 2002; McBride et al., 2004; Tauer, 2006), and adopters of other productivity-enhancing technologies and systems (Barham et al., 2003, 2004; Barham, Jackson-Smith, & Moon, 2000; Foltz & Chang, 2002; McBride et al., 2004; Tauer, 2006).

Adopters have been larger-scale (Barham et al., 2000, 2003, 2004; Foltz & Chang, 2002; McBride et al., 2004; Stefanides & Tauer, 1999; Tauer, 2001, 2005, 2006), with USDA APHIS showing 6.5% and 38.7% of US dairy operations with < 100 cows and ≥ 500 cows, respectively, using rBST in 1996; 8.8% and 54.4%, respectively, using rBST in 2003 (USDA APHIS, 2003); and 9.1% and 42.7%, respectively, using rBST in 2007 (USDA APHIS, 2007). Adoption has also differed by region (Barham et al., 2003, 2004; McBride et al., 2004; USDA APHIS, 2003, 2007). McBride et al. (2004) found lower 2000 US rBST adoption rates in the Appalachian, Southwest, and Pacific regions. Adoption rates were highest in the West in 1996 and 2002, according to USDA APHIS (2003).

Previous studies based on survey data have been mixed on the impact of rBST on dairy farm economics, though most have not shown statistically significant differences. Tauer and Knoblauch (1997), Stefanides and Tauer (1999), and Tauer (2001, 2005) showed non-significant impacts of rBST on profit for New York dairy farms over the periods, 1993-1994, 1993-1995, 1994-1997, and 1998-1999, respectively. Foltz and Chang (2002) found non-significant impacts of rBST on Connecticut dairy-farm profits for 1999. Likewise, McBride et al. (2004) found non-significant impacts of rBST on returns over operating margins for US dairy farms using the 2000 ARMS data. Tauer (2006) found that rBST use on New York dairy farms over the period 1994-2002 significantly reduced cost of production by \$0.31/cwt, which would imply increased profit. Using a matching-samples approach, Tauer (2009) found further evidence of reduced cost per unit of milk produced using rBST.

Of notable interest is that, although rBST has been argued to be scale neutral, it has consistently been found to be more extensively adopted by larger farms. Given that more highly educated, larger producers are greater technology adopters in general (and, thus, are likely rBST adopters), a simple comparison of profitability of adopting versus non-adopting farms is not expected to provide a good estimate of the true impact of rBST. Such a comparison would likely show that rBST adopters attain higher profit, but one must question whether (1) the greater profit is a result of rBST or another technology and (2) the higher-educated adopting farmers would have been the more profitable ones regardless of whether rBST had been adopted. These concerns call for a careful analysis of the impacts of rBST on farm profitability and productivity.

A Recombinant Bovine Somatotropin Adoption and Impact Model

The impacts of rBST on dairy farm profitability and productivity are modeled using two-stage equation systems. In the first equation, factors influencing rBST adoption are assessed using a probit model. In the second-stage equations, the impacts of rBST and other factors on farm profit and productivity are assessed. Inverse Mills ratios estimated from the first equation are used as regressors in the second-stage equations to correct for selection bias. Details follow.

The rBST Adoption Decision

The representative dairy farmer will adopt a new technology, such as rBST, if the utility associated with adoption exceeds the utility associated with non-adoption.

$$U(0, y_0 - C_0, m_0, x) \leq U(1, y_1 - C_1, m_1, x), \tag{1}$$

where $U(.)$ is the utility operator; 0 and 1 represent the base (non-adoption) and adoption states, respectively; y represents income; C represents the costs of production;

m represents management requirements associated with the technology; and x represents farmer characteristics. The farmer's utility function $U(i, y_i - C_i, m_i, x)$ is unobservable. However, with adoption (i=1) or non-adoption (i=0), what is estimable is $V(i, y_i - C_i, m_i, x)$. Thus, the decision to adopt may be expressed as

$$V(0, y_0 - C_0, m_0, x) + e^0 \leq V(1, y_1 - C_1, m_1, x) + e^1, \quad (2)$$

where V is estimable utility and e^i is the error term. Equation 2 implies that the adoption decision depends on profit associated with adopting the technology, management considerations, and farmer characteristics influencing utility.

The probit model, employed in cases where the dependent variable takes values of either 1 or 0 (adopt or not adopt), is used to determine the influence of explanatory variables on the probability of adopting rBST. As presented by Greene (2000, p. 814), the probit model is:

$$prob\ (Y = 1) = \int_{-\infty}^{\beta' x} \phi\ (t)\ dt = \Phi\ (\beta' x), \quad (3)$$

where Y is the dependent variable and Φ (.) denotes the standard normal distribution.

Factors Influencing the Adoption of rBST

Independent variables included in the probit model can be categorized into four groups: (1) regional identifiers; (2) farm size, specialization, and financial; (3) farmer characteristics; and (4) farmer use of other technologies and management practices. Regional dummy variables include SOUTHEAST, NORTHEAST, APPALACHIA, SOUTHPLAINS, CORNBELT, WEST, and PACIFIC, with the base region being LAKE (the Lake States).[1] Farm size, specialization, and financial variables include the number of cows on the farm (COWS); the number of cows, squared (COWSSQU); and the percentage of total farm revenue coming from milk (%INCMILK). Farmer characteristics included are farmer age (AGE), whether the farmer holds a 4-year college degree (COLLEGE), and whether the farmer plans to remain in dairy production at least five more years (FIVEYEARS). Planning horizon is included to examine whether those with longer planning horizons would be more likely to adopt.

The use of other farm technologies and management practices is of interest to determine whether these have complementary or substitute relationships with rBST. Technologies and management practices include acres of pasture grazed per cow (PASTURE) and dummy variables indicating whether cows are milked three times versus twice per day (THREETIMES), whether the farmer is a member of the Dairy Herd Improvement Association (DHIA), whether a computerized feed delivery system is used (COMPFEED), if the milking system is computerized to gather data about each milking (COMPMILK), and if a milking parlor is used (PARLOR). PASTURE and rBST use are expected to have substitute relationships, while the remaining technologies are expected to have complementary relationships with rBST. Previous rBST adoption studies have similarly included other technologies (e.g., Foltz & Chang, 2002; McBride et al., 2004).

Two models are estimated—one a 2005 year-only version and the other using pooled data for years 2000 and 2005. Poolability for the latter model was tested using the likelihood ratio test, where the unrestricted model included all independent variables plus interaction terms involving each of the independent variables interacted with a dummy variable for year 2005 (YEAR2005). The restricted model did not include the interaction terms. Statistical tests conclude it would be inappropriate to pool years 2000 and 2005 without including interaction terms. Thus, in the results, interaction terms for the pooled model are designated as YEAR*, where * is the independent variable of interest.

Profitability Measures

A series of second-stage ordinary least squares regression equations are estimated to determine the impact of rBST use on farm productivity and financial performance. Seven profitability and productivity measures commonly utilized in the farm-management literature are used as dependent variables: dairy enterprise net returns over total expenses per cow (NETTOT/COW), enterprise net returns over total expenses per hundredweight of milk produced (NETTOT/CWT), enterprise net returns over operating expenses per cow (NETOPER/COW), enterprise net returns over operating expenses per hundredweight of milk produced (NETOPER/CWT), whole-farm net farm income per

1. *Regions and the states included in the ARMS dairy survey include (1) NORTHEAST: Maine, New York, Pennsylvania, and Vermont; (2) LAKE: Michigan, Minnesota, and Wisconsin; (3) CORNBELT: Illinois, Indiana, Iowa, Missouri, and Ohio; (4) APPALACHIA: Kentucky, Tennessee, and Virginia; (5) SOUTHEAST: Georgia and Florida; (6) SOUTHERN-PLAINS: Texas; (7) WEST: Arizona, Idaho, and New Mexico; and (8) PACIFIC: California, Oregon, and Washington.*

cow (NFI/COW), whole-farm net farm income per hundredweight of milk produced (NFI/CWT), and annual hundredweight of milk produced per cow (MILK/COW).

NETTOT/COW, NETTOT/CWT, NETOPER/COW, and NETOPER/CWT include revenue and expenses associated with just the dairy enterprise. These include revenues from milk sales, dairy cattle sales, and other dairy revenue. Operating costs include purchased, homegrown, and grazed feed; veterinary services and medicine; bedding and litter; marketing expenses; custom services; fuel, lube, and electricity; repairs; other operating costs; and interest on operating costs. Homegrown feeds are priced at their market value rather than their cost of production, representing opportunity costs. In addition, NETTOT/COW and NETTOT/CWT include allocated overhead expenses for hired labor, opportunity cost of unpaid labor, capital recovery of machinery and equipment, opportunity cost of land (the rental rate for grazing), taxes and insurance, and general farm overhead. NFI/COW and NFI/CWT are whole-farm measures of net farm income, constructed as (gross cash farm income adjusted by changes in inventory, estimated value of home-consumed products, and rental value of dwellings on the farm) less total operating expenses, including interest payments and depreciation on capital stock. These represent the net returns shown on the farm's income statement. The enterprise measures of profitability provide insight on how rBST affects the dairy enterprise, while the whole-farm measures provide insight as to how it affects the entire farm. The influence of rBST on dairy profitability has been examined using various combinations of similar measures: Tauer and Knoblach (1997) included both whole-farm net farm income and enterprise (milk returns less operator expense) measures; Foltz and Chang (2002) used a whole-farm net farm income measure; and McBride et al. (2004) used the NETOPER/CWT enterprise measure.

Factors Influencing Farm Profitability

The ordinary least squares second-stage regression equations are modeled as

$$Profit = f\,(Location, Farm\ Size, rBST, Other\ Technology, Price), \quad (4)$$

where profitability is a function of farm location, farm size, use of rBST, and other technologies and prices. Specifically, independent variables used in each of the equations include all of the regional variables included in the rBST adoption equation; whether rBST was used on the farm (rBST); COWS; COWSSQU; a dummy variable indicating whether the farmer grazed cows on pasture (PASTURE); %INCMILK; THREETIMES; DHIA; a dummy variable indicating whether the farmer used artificial insemination and/or embryo transfers (GENESELECT); and PARLOR. PRICEMILK, the average annual price per hundredweight of milk received by the farmer, is included in all of the profitability equations. The MILK/COW productivity equation is modeled the same as the profit equations, except PRICEMILK is not included.

Estimation of rBST profitability or productivity may entail the existence of selection bias. The concern is that farms using rBST may be more or less profitable even without the use of rBST. If this is indeed the case, then the impact estimated from the rBST variable will be biased, as the error term will be correlated with the rBST variable. One method to correct for potential selection bias, as used by Tauer (2006), is to estimate the correlation between the rBST variable and the error term using the inverse Mills ratio and then correct for this correlation. In the present analysis, the inverse Mills ratio was first estimated in the rBST adoption equation and included in the profit and MILK/COW equations along with the rBST variable to test for treatment bias. Similar to Tauer (2006), the estimate for the inverse Mills ratio was non-significant at the 10% level for all profit and MILK/COW equations.[2] Pooled 2000 and 2005 second-stage results provided few significant variables and, thus, provided minimal additional insight. Thus, only 2005 results are reported.

In addition to the two-stage models estimated for all farms in the dataset, separate models were also estimated for specific size segments of the dairy farm population: ≤ 100 cows, 100 < cows ≤ 500, 500 < cows ≤ 1,000, and ≥ 1,000 cows. These runs are made because of the observation that larger farms are the more likely

2. *Several alternative specifications were run for this model before deciding upon the current specification. The first specification used an instrumental variable for the probability of adopting rBST, based on the probit model and similar to the analysis by McBride et al. (2004). This analysis resulted in unusually large estimates for the impact of rBST on MILK/COW, likely the result of most probabilities being clustered in the 0.25-0.75 range, with few predicted probabilities close to the extremes of 0 and 1. This analysis was then run assuming all probabilities ≥ 0.50 = 1 and < 0.50 = 0, resulting in extreme underestimates of the impact if previous studies are correct in the impact being in the approximate 1,500 to 3,000 lbs/cow/year range.*

adopters of rBST than smaller ones. Thus, segmenting the group by size would have the potential to show whether the influence of rBST on profit differs by farm size. With 24 runs (4 size categories × 6 profit measures), reporting all results would require extensive space and provide little additional insight in cases where the rBST variable is non-significant (all but two cases). Therefore, results are reported only for those models where rBST had a significant relationship with profit.

Data

This study utilizes data from the 2000 and 2005 ARMS Phase III dairy survey, conducted by the USDA's National Agricultural Statistics Service and Economic Research Service. The 2000 and 2005 versions include 872 dairy farm observations from 22 states and 1,814 observations from 24 states, respectively. Weights are included for each observation, which allow the sample to be expanded to represent 90% of the US commercial dairy farm population. The minimum size for inclusion was 10 cows, limiting the size to what are believed to be commercial operations. Estimates for 2000 and 2005 are comparable due to consistencies in collecting and processing the data: collected by the same organization using similar methods involving a complex sampling scheme and representing the same population with broad national coverage. McBride et al. (2004) previously analyzed the 2000 version of ARMS. The ARMS includes data on land use, agricultural production, revenue, expenses, and detailed information on input usage.

Weighted regression procedures were used to estimate all models reported in this article. The multi-phase sampling underlying ARMS data provides challenges in estimating variances using classical methods; thus the delete-a-group jackknife estimator is used, as discussed by the National Research Council of the National Academies, Committee on National Statistics (2008).[3]

Results

Means tests indicate that rBST was adopted by 17.3% and 16.6% of dairy producers in 2000 and 2005, respectively. The difference is not statistically significant at the 10% level; however, it is evident that rBST use was not on the rise on a per-farm basis over the period. Examination of Table 1 shows significant differences among rBST users and non-rBST users in 2000 and 2005. Herd size increased for both users and non-users from 2000 to 2005, and larger operations were the greater users of rBST during both years. Of further interest is that, in 2000, the percentage of producers with 250 or fewer cows adopting rBST was 15.3%, while the percentage with > 250 cows was 42.7%. The percentages for these size categories in 2005 were 13.3% and 43.7%, respectively. Additional differences are seen by region, financial and farmer characteristics, as well as use of other technologies and management practices.

Examination of the profitability measures shows that in both years, enterprise net returns over total expenses per cow and per hundredweight of milk produced, as well as net returns over operating expenses per cow, were higher for rBST users than non-users. On the flipside, whole-farm net farm income per hundredweight of milk produced was lower for rBST users than non-users in 2005. Differences in the enterprise and whole-farm measures can be attributed to differences in methods of measuring profit. The enterprise NETTOT measures include charges for operator and unpaid family labor and land, and value all forage and feed at their market value rather than their cost of production. On the other hand, the whole-farm measure does not include charges for operator and unpaid family labor and land and values forage and feed at their cost of production or procurement, whichever holds. Therefore, low-input, pasture-based operations that raise their own forage and feed, are land-intensive, and substitute unpaid family labor for hired labor would fare relatively better using the whole-farm measure. As shown by Khanal et al. (2010), grazers are lower adopters of most technologies and advanced management practices, including rBST (Table 1).

The previous explanation does not, however, fully explain different results for the NETTOT and whole-farm results because, like the whole-farm measures, NETOPER also does not include operator and unpaid family labor and land (though it does include the same feed expense as NETTOT). In the whole-farm versus

3. *The empirical regression results reported in the tables in the results section are derived using farm-level annual data. The data come from a complex survey design (both an area and list frame), not a model-based random sample commonly used in econometric analysis. Hence, a jackknifing procedure was used with 15 replicates to estimate sample variances (to get t-statistics on the coefficients from the base-run regressions) in order to make inferences to the population. For a further explanation as to why "non classical" econometrics must be employed to achieve sensible inferences to the population of the sample, see National Research Council of the National Academies, Committee on National Statistics (2008). In particular, see Chapter 4 on survey design and Chapter 7 on methods for analysis of complex surveys.*

Table 1. Means of variables used in the regression equations.

Variable	Units	No rBST 2000 (a)	rBST use 2000 (b)	No rBST 2005 (c)	rBST use 2005 (d)
SOUTHEAST	0-1	0.007 bd	0.015 a	0.007	0.013 a
NORTHEAST	0-1	0.251	0.306	0.257	0.268
APPALACHIA	0-1	0.057 b	0.025 ac	0.057 bd	0.039 c
SOUTHPLAINS	0-1	0.017	0.012	0.016 d	0.008 c
CORNBELT	0-1	0.214 c	0.170	0.143 a	0.183
LAKE	0-1	0.384	0.384	0.401	0.363
WEST	0-1	0.019 bcd	0.033 ac	0.070 ab	0.068 a
PACIFIC	0-1	0.049	0.056	0.048	0.058
COWS	No.	91.915 bcd	207.888 acd	119.840 abd	325.455 abc
%INCMILK	%	81.811 cd	85.204	86.940 a	88.454 a
AGE	Years	49.981 bc	44.681 ac	51.864 abd	47.954 c
COLLEGE	0-1	0.089 bcd	0.180 a	0.138 ad	0.278 ac
FIVEYEARS	0-1	0.651 bd	0.810 ac	0.718 bd	0.854 ac
PASTURE	0-1	0.549 bd	0.329 ac	0.469 bd	0.321 ac
THREETIMES	0-1	0.014 bd	0.128 acd	0.210 bd	0.311 abc
DHIA	0-1	0.381 bd	0.762 ac	0.392 bd	0.764 ac
COMPFEED	0-1	0.065 bd	0.159 ac	0.043 bd	0.213 ac
COMPMILK	0-1	0.044 bd	0.141 ac	0.036 bd	0.137 ac
PARLOR	0-1	0.366 bcd	0.459 ad	0.433 ad	0.762 abc
PASTURE	0-1	0.727 bd	0.481 ac	0.683 bd	0.455 ac
GENESELECT	0-1	0.608 bcd	0.813 ad	0.787 ad	0.956 abc
PRICEMILK	$	12.580 cd	12.590 cd	15.213 ab	15.154 ab
NETTOT/COW	$	-1612.701 bcd	-800.441 ac	-1360.240 abd	-641.785 ac
NETTOT/CWT	$	-15.861 bcd	-6.337 ac	-10.902 abd	-3.306 ac
NETOPER/COW	$	626.672 bcd	1083.192 ac	847.238 abd	1070.241 ac
NETOPER/CWT	$	2.559	4.659	5.010	4.699
NFI/COW	$	622.477 cd	625.658 cd	795.098 ab	818.918 ab
NFI/CWT	$	4.280	4.568	4.992 d	3.691 c
MILK/COW	cwt	148.799 bcd	191.141 acd	158.670 abd	220.568 abc

Note. Superscript letters indicate the estimate differs from those in the indicated column at the 0.10 level of significance.

NETOPER comparison, however, diversification into other enterprises favors the whole-farm measure, as net returns from multiple enterprises cover milk production. Though significant differences were not found in diversification (%INCMILK) between rBST users and non-users (Table 1), there were small numerical differences, which—if combined with other factors such as grazing—could influence relative profitability between rBST adopters and non-adopters. The higher profitability with rBST using the enterprise measures is at least partially attributed to the higher production of milk on a per-cow basis, as shown by MILK/COW results, but the true impact of rBST on profitability should be further examined using the two-stage multivariate selection model. Differences in profitability cannot be attributed to a particular factor, such as rBST, without a complete multivariate analysis.

Table 2 presents results of the probit estimation of probability of adoption.[4,5] Results of both the pooled and 2005-only analyses show that Southern Plains and

4. *Multicollinearity diagnostics were run for each of the equations using variance inflation factors and the condition index. In neither case was multicollinearity found, with variance inflation factors <10 and condition indexes <30, as discussed by Kennedy (1992). Thus, the original specification was used.*
5. *A convenient property of the delete-a-group jackknife procedure is that it is robust to unspecified heteroscedasticity.*

Table 2. Probit results on rBST adoption.

	rBST adoption 2005 only		rBST adoption pooled 2000-2005	
Variable	**Estimate, ß**	**|t-Value|**	**Estimate, ß**	**|t-Value|**
Constant	-0.9766*	-1.7096	-0.3385	-1.0620
YEAR2005			-0.6381	-0.9929
SOUTHEAST	-0.4076	-0.6183	-0.2518	-0.6664
YEARSOUTHEAST			-0.1558	-0.2294
NORTHEAST	-0.0661	0.1919	0.0361	0.1307
YEARNORTHEAST			0.0300	0.0843
APPALACHIA	-0.3561	-1.6419	-0.2349	-0.9222
YEARAPPALACHIA			-0.1212	-0.4255
SOUTHPLAINS	-1.1581**	-2.3651	-1.0148*	-1.7332
YEARSOUTHPLAINS			-0.1433	-0.1813
CORNBELT	0.0056	0.0138	0.0969	0.5103
YEARCORNBELT			-0.0913	-0.2055
WEST	-0.6051	-1.4015	-0.0389	-0.1018
YEARWEST			-0.5663	-1.0158
PACIFIC	-0.8241**	-2.3780	-1.0096***	-3.1028
YEARPACIFIC			0.1855	0.4129
COWS	0.0003	1.1213	0.0024*	1.8838
YEARCOWS			-0.0020	-1.5230
COWSSQU	-2.85E-8	-0.4000	-8.83E-7*	-1.7200
YEARCOWSSQU			8.54E-7*	1.6874
AGE	-0.0206**	-2.0936	-0.0223***	-3.9383
YEARAGE			0.0018	0.1610
COLLEGE	0.2544*	1.8510	0.2047	0.9500
YEARCOLLEGE			0.0497	0.1837
%INCMILK	-0.0003	-0.2237	-0.0024	-0.4855
YEAR%INCMILK			0.0021	0.4017
PASTURE	-0.2436	-1.5511	-0.3159***	-2.6144
YEARPASTURE			0.0723	0.3295
THREETIMES	0.1660***	2.7991	0.6786***	-0.2667
YEARTHREETIMES			0.4874	1.0051
DHIA	0.6813***	3.7668	0.8038***	4.3198
YEARDHIA			-0.1225	-0.5852
COMPFEED	0.6059***	4.2054	0.2285	1.0206
YEARCOMPFEED			0.3774	1.6002
COMPMILK	0.0212	0.1088	0.4042	1.2032
YEARCOMPMILK			-0.3830	-0.9530
PARLOR	0.8662***	3.7604	-0.0156	-0.1148
YEARPARLOR			0.8818***	2.7664
FIVEYEARS	0.0825	0.3578	0.0976	0.7038
YEARFIVEYEARS			-0.0151	-0.0574
% Correctly predicted	82.25		82.45	

*Notes: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively.*

Table 3. Ordinary least squares estimates, milk per cow, and net farm income, 2005.

	Milk per cow cwt milk/cow/yr		Net farm income per cow (whole farm)		Net farm income per cwt milk (whole farm)	
Variable	**Estimate, β**	**|t-Value|**	**Estimate, β**	**|t-Value|**	**Estimate, β**	**|t-Value|**
Constant	124.9825***	9.2709	986.6418*	1.7433	7.0328	1.2068
rBST	33.6229***	3.5165	83.8324	0.8356	-0.3045	-0.6387
SOUTHEAST	-12.8685	-1.0107	-622.2775***	-3.7562	-3.7840***	-3.2418
NORTHEAST	0.5281	0.0572	-314.9719**	-2.5617	-1.9656	-1.6070
APPALACHIA	-1.5662	-0.1463	-451.6712**	-2.5063	-2.9508*	-1.7424
SOUTHPLAINS	-3.1166	-0.3487	-681.1543***	-3.6884	-0.9462	-1.1659
CORNBELT	-4.3240	-0.5180	-228.4705**	-2.1493	-0.9462	-1.1659
WEST	2.8039	0.3133	-478.3753***	-4.8196	-2.9639***	-3.2856
PACIFIC	18.6637*	1.6597	-409.8509***	-4.8788	-2.5987***	-4.1094
COWS	-0.0022	-0.2859	0.0174	0.0981	-0.0002	-0.1503
COWSSQU	-2.50E-7	-0.2990	5.65E-6	0.1095	7.31E-8	0.2598
PASTURE	-6.3380	-1.2071	73.4686	0.8349	0.5037	0.7519
%INCMILK	0.0730	1.0220	-3.7490	-1.1231	-0.0248	-1.1559
THREETIMES	14.1802	0.8790	-228.9341	-1.2196	-0.9597	-0.9702
DHIA	16.0453**	2.1095	-48.1991	-0.4539	-0.6794	-1.0616
GENESELECT	26.7880***	2.8773	-26.8704	-0.1414	-1.2330	-0.6849
PARLOR	33.6229***	3.5165	-91.7054	-1.0725	-0.5187	-0.7885
PRICEMILK	n/a	n/a	22.6587	1.0255	0.1638	0.6584
λ(α)	24.3342	1.2859	146.8424	0.7402	0.1321	0.1278

*Note: ***, **, and * indicate statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.*

Pacific farmers were less likely to adopt rBST relative to Lake States farmers. These results are consistent with McBride et al. (2004) for 2000. The pooled results show that larger farms were the most likely adopters of rBST, consistent with previous studies.

Both models show the negative influence of operator age and the positive influences of milking three times per day and DHIA membership on rBST adoption. In addition, adoption of a computerized feeding system and parlor are positively related with rBST adoption in the 2005 analysis, while pasture usage is negatively related to adoption in the pooled analysis. These results show particularly strong correlation of adoption of rBST with adoption of other, potentially technically complementary technologies. The YEAR* interaction terms were significant in two cases, suggesting changes in the effects of those variables from 2000 to 2005. Almost-equal, yet opposite-in-sign estimates for COWSSQU and YEARCOWSSQU suggest no plateau on adoption rate with size in 2005. Overall, results are generally consistent with previous rBST adoption research.

Table 3 shows ordinary least squares estimates on MILK/COW for 2005 only. Results suggest that rBST use increased milk production per cow by 3,362 pounds. Producing in the Pacific region, use of DHIA, utilization of genetic selection technologies, and having a dairy parlor also influenced MILK/COW. Overall, as expected, technology usage appears to be the major determinant of milk produced per cow.

Tables 3 and 4 show ordinary least squares estimates for whole-farm net farm income and enterprise returns over total expenses and operating expenses, all using the aggregate 2005 dairy data. Though the coefficient for rBST is positive for returns over enterprise total expenses and whole-farm net farm income per cow, and negative for enterprise returns over operating expenses and whole-farm net farm income per hundredweight of milk produced, results do not show a statistically significant influence of rBST on profitability when all farms are included, as found by many previous studies (e.g., Tauer, 2001, 2005). Furthermore, the non-significant inverse Mills ratio does not suggest a self-selection issue with respect to rBST adoption and farm profitability.

A number of remaining variables were significant in the analysis. All regions were shown to be less profitable than the Lake States region for at least two profitability measures. Of interest are the magnitudes of some

Table 4. Ordinary least squares estimates, enterprise returns over expenses.

Variable	Estimate, β	|t-Value|	Estimate, β	|t-Value|
	Returns over total expenses per cow		**Returns over total expenses per cwt milk**	
Constant	-3338.6970***	-7.7317	-24.5878**	-2.1179
rBST	23.1366	0.1247	1.7039	1.2500
SOUTHEAST	-240.9299	-0.3165	-0.7724	-0.2006
NORTHEAST	-189.4577	-1.2466	-1.2820	-0.3866
APPALACHIA	-491.0533***	-3.5094	-3.3398**	-2.1861
SOUTHPLAINS	-11.4381	-0.0426	0.8375	0.3170
CORNBELT	-325.7743**	-2.1463	-2.2847*	-1.8932
WEST	-475.8356***	-3.0611	-3.3338**	-2.2095
PACIFIC	50.3995	0.2412	0.1387	0.0572
COWS	1.3576***	4.8667	0.0085***	3.5781
COWSSQU	-0.0001**	-2.3964	-1.01E-6*	-1.8548
PASTURE	-122.3008	-1.0078	-1.9770	-1.5509
%INCMILK	1.2816	1.0069	0.0126	1.2142
THREETIMES	-91.5216	-0.2009	0.4257	0.1279
DHIA	297.9838	1.2392	3.7800	1.5569
GENESELECT	154.4150	0.6616	4.5215	0.9000
PARLOR	626.0927***	4.4613	4.9372**	2.2279
PRICEMILK	91.7748***	2.7737	0.4474	0.9765
λ(α)	279.5986	0.5494	0.4927	0.1083
	Returns over operating expenses per cow		**Returns over operating expenses per cwt milk**	
Constant	-316.2995	-0.9670	-0.8190	-0.1486
rBST	-87.3505	-0.5343	-1.2540	-1.4226
SOUTHEAST	-307.2486*	-1.9514	-1.2435	-1.1373
NORTHEAST	-343.7179**	-2.3297	-2.2064	-1.5951
APPALACHIA	-286.2001**	-2.1365	-1.4798	-1.5921
SOUTHPLAINS	-288.0011**	-2.2124	-1.3881*	-1.8421
CORNBELT	-171.2007	-1.3220	-0.6168	-0.9440
WEST	-351.4238***	-4.0274	-2.3822***	-5.0522
PACIFIC	-221.7517	-1.4496	-1.5697*	0.0643
COWS	0.2183	1.5168	0.0010	1.6433
COWSSQU	-2.10E-5	-0.8235	-8.17E-8	-0.8008
PASTURE	48.4097	0.5836	0.1364	0.2274
%INCMILK	0.3608	0.4209	-0.0035	-0.6733
THREETIMES	-154.299	-0.4640	-0.3838	-0.3106
DHIA	47.3593	0.2731	-0.0064	-0.0062
GENESELECT	165.5985	1.1408	0.1074	0.0534
PARLOR	128.2613	1.1738	0.8469	0.8260
PRICEMILK	62.5455***	2.6961	0.4106*	1.8051
λ(α)	459.2227	1.5540	1.2195	0.8316

*Note. ***, **, and * indicate statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.*

of the coefficients, indicating NETTOT/COW of $475.84, NETOPER/COW of $351.42, and NFI/COW of $478.38 were less in the WEST region than in the Lake States. It is noted that regional variables were the only variables that were significant in the whole-farm net farm income models. Farm size (COWS and

Table 5. Ordinary least squares estimates of profitability by size category.

	Returns over operating expenses per cwt milk ≤ 100 cows (enterprise)		Net farm income per cow ≥ 1,000 cows (whole farm)	
Variable	Estimate, β	|t-value|	Estimate, β	|t-value|
Constant	1.1828	0.0879	4713.0401	1.5026
rBST	-3.7220*	-1.8386	408.5001*	1.8836
SOUTHEAST&APPALACHIA	-1.1233	-0.9814	-968.4166**	-2.1461
SOUTHPLAINS&WEST	-3.3967***	-3.9180	-233.2695	-0.4551
NORTHEAST	-2.0290	-0.7610	-343.3444	-0.7973
CORNBELT	-0.6879	-0.9583	-194.4150	-0.5056
PACIFIC	-1.2414	-0.4690	-62.5843	-0.1034
COWS	-0.0173	-0.0532	0.3071	0.9048
COWSSQU	-8.26E-6	-0.0035	-2.90E-5	-0.5547
PASTURE	-0.1884	-0.1450	48.5292	0.1898
%INCMILK	-0.0034	-0.4964	-63.3528	-1.6270
THREETIMES	-9.6031	-0.8761	89.7470	0.3535
DHIA	-0.3620	-0.2767	-199.4033	-0.9188
GENESELECT	0.2946	0.1392	-105.9497	-0.3629
PARLOR	1.2851	1.3824	-493.5298	-1.2027
PRICEMILK	0.3338*	1.8457	156.3976**	1.9706
λ(α)	4.7371	1.2522	-275.8296	-0.6428

Note. ***, **, and * indicate statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

COWSSQU) was significant in the NETTOT runs, indicating significant economies of size in dairy production. Use of a dairy parlor increased returns over total expenses. Overall, however, the major determinants of dairy farm profitability appear to be region, milk price, and farm size, with system (PASTURE) and technology usage showing less impact.

The results up to this point present further evidence of a lack of significance of rBST with farm profitability. The evidence provided in this study and others, however, suggests that the larger dairy producers are more likely to adopt rBST, suggesting a potential size component of rBST and profitability. The ARMS dataset, with large numbers of observations that can be extended to the dairy population via weighting, allows for segmentation of the dataset by region and size. While breaking the dataset into regional segments did not result in findings that suggest differences in rBST versus non-rBST users by region, breaking the dataset into size segments did provide some interesting findings. Due to a reduction in observations associated with segmentation, the SOUTHEAST and APPALACHIA regions were combined (SOUTHEAST&APPALACHIA), as were the SOUTHPLAINS and WEST regions (SOUTHPLAINS&WEST). Otherwise, the same independent variables were used as those included in the aggregate models.

Table 5 presents results of enterprise net returns over operating expenses per hundredweight of milk produced for the ≤ 100 cow size category and whole-farm net farm income per cow for the ≥ 1,000 cow size category—the two size categories that produced statistically significant rBST impacts.[6] Results suggest—at the 10% level of significance—that rBST increased whole-farm net farm income per cow for the ≥ 1,000 cow farms by $408.50, while it decreased enterprise returns over operating expenses per hundredweight of milk produced for the ≤ 100 cow farms by $3.72. As expected, with more homogeneous farms included within the size category runs, fewer other independent variables are significant in these runs.

A couple of observations are noted with respect to the size runs. First, rBST was not found to impact profitability using any of the other 22 profitability measures in these size categories, and the level of significance is not high in the two reported runs, suggesting that even these impacts may be spurious. Type I error on 24

6. *In the interest of space, individual probit analyses for the rBST adoption equations for these two runs—from which the inverse Mills ratios were estimated—are not presented.*

regressions could produce the two statistically significant results, although probably not at the smallest and largest farm sizes. Thus, strong evidence was not found that differences in profitability exist within size categories; but, weak evidence suggests the impacts of rBST on farm profitability depend upon farm size and the profitability measure of interest. Second, the small and large dairy farm size categories are likely to be quite different in technology. Using the same dataset as the present study, Gillespie, Nehring, Hallahan, Morrison-Paul, & Sandretto (2008) found a significant proportion of pasture-based, low-input farms that are arguably economically competitive with other similarly-sized farms within the ≤ 100 cow size category. Profitable use of rBST in these low-input pasture-based systems would not be expected. Very large dairy farms generally fall into the "intensive" or "conventional" categories, where pasture is not used.

Discussion

Farmer use of rBST in dairy production has been, and continues to be, quite modest—our results indicate adoption by roughly 17% of farmers over the 2000 to 2005 period. This relatively flat adoption curve is consistent with results of the present study that do not show industry impacts of rBST use on profit, either on per-cow or per hundredweight of milk-produced bases. The users of rBST are more profitable on a dairy-enterprise basis and less profitable on a whole-farm basis, as shown from the simple t-tests, but the differences cannot be attributed to rBST use on an industry-wide basis. The rBST adoption drivers are farm size, region, farmer age and education, and the use of pasture and other technologies that have complementary or substitute relationships with rBST. The profitability equations in this analysis suggest that farm size, region, and selected technology other than rBST are the profit drivers in the industry as a whole.

Although these results do not show rBST to increase farm profitability across the dairy industry, evidence indicates that it may be associated with profitability under some conditions, a finding that would be expected given that 17% of the farmers had adopted it, with higher percentages on large farms. This study's results provide limited evidence of lower profitability associated with rBST use on smaller farms, and higher profitability associated with rBST use on larger farms. Though only two of the 24 profitability × size category runs resulted in significant results at the 10% level, these findings provide some help in explaining why some farmers continue to use rBST even though previous rBST studies that have not broken the dairy industry into size segments have not found significant impacts of rBST on profit. Use of rBST technology is unlikely to be complementary with low-input systems, which are used by a substantial proportion of the small farms. It is noted, however, that the period of this study is mostly prior to the premiums paid for milk produced without the use of rBST that have been introduced since, so any additional profit larger producers might have realized with rBST are likely to have been reduced with these premiums.

Several factors other than profitability are likely to explain the relative stagnation in diffusion of rBST technology. Factors such as increased management requirements associated with its use may cause it to be unattractive to some producers. Perhaps as important as management issues is the recent increase in negative press that rBST has received in the marketplace, along with an increase in organic products and rBST-free-labeled milk making their way to the dairy shelf. Currently, a number of major bottlers no longer accept milk from cows that have been given rBST. However, many of these developments have occurred post-2005—when the data for this study were collected—a result that would suggest even lower adoption post-2005, as seen recently in California (An & Butler, 2009). The period of the current study was also on the heels of the rBST shortage of 2004 and early 2005. Given the very limited impact of rBST on dairy farm profitability, competitiveness of US dairy farms is unlikely to be highly influenced by its use. These results are generally consistent with other studies that have shown little impact from rBST on profitability, though this is the first that has shown evidence of differing impacts by farm size.

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Authors' Notes

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