THE EMPIRICAL IMPACT OF BOVINE SOMATOTROPIN ON A GROUP OF NEW YORK DAIRY FARMS

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ABSTRACT

Data from a panel of New York Dairy farms were used to estimate rbST adoption functions, and to measure the impact of rbST on milk output and profitability per cow. Adoption results are consistent with previous rbST adoption studies. Farm size, productivity and education of the principal operator are the most important explanatory variables influencing adoption. The use of rbST was found to significantly increase milk output per cow net of other explanatory variables, correcting for self-selection with respect to rbST use. The impact on profits, was, however, not statistically different from zero at any conventional statistical significance level.

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Recombinant Bovine Somatotropin (rbST), a synthetic version of a naturally-occurring bovine growth hormone, is one of the first commercial agricultural technologies from recombinant DNA technology research. In numerous experimental trials, rbST increased milk production by 2.5 to 30 percent depending on dairy management practices (Jarvis). The most productive herds treated with rbST were projected to see an increase in profit up to $200 per cow each year. The question of whether such profit increases can be attained on operating farms is yet to be answered. Tauer and Knoblauch analyzed profitability changes brought from rbST use for a group of New York dairy farms during the first year of its availability (1994). While their study found a significant milk production increase for farms using rbST, the impact on profit, although substantial and positive, was not statistically different from zero. This article extends their analysis and examines rbST impact on milk production and profitability during the first two years of commercial availability of the product.

A panel data set of 211 NY dairy farms participating in the New York Dairy Farm Business Summary (NYDFBS) program for the years 1993-1995 was used in the analysis. The data provide information about pre-rbST behavior of the farms (1993) and two years of rbST experience (1994-1995). Apart from assessing whether or not rbST has been profitably used on these farms, this study identifies the socioeconomic characteristics of the farmers related to their adoption decisions. Such analysis serves a dual purpose here. First, the predictions from the rbST adoption models are used as a means for correcting the self-selection bias inherent in estimating rbST production and profitability impacts based upon farmers themselves deciding whether or not to use the product. Second, the adoption predictions from this ex-post study can serve as a means of evaluating the efficacy of numerous ex-ante rbST adoption predictions (see for example Barham, 1995).

Ex-Ante Research

Since rbST has been commercially available only since 1994, published adoption studies have been ex-ante in nature. Most studies used a producer survey, which asks farmers whether or not, and to what extent they plan to adopt the new technology (Lesser, Magrath and Kalter; Zepeda; Kinnucan et al., Saha, Love and Schwart; Klotz, Saha and Butler). The primary purpose of these studies was to identify the socioeconomic characteristics of farmers and relate these to their adoption intentions. The data were then used to predict aggregate adoption levels and to assess potential rbST impacts. The predicted aggregate adoption rates range from 8 to 41 percent for early adopters, and from 33 to 92 percent for eventual adopters (Caswell, Fuglie, and Klotz).

Predicting ex-ante expected profits required assumptions about the effects of rbST on input use, yields, costs and the milk price. One of the first studies on rbST profitability by Fallert et al. predicted a $157 profit per cow per year from rbST use at a milk production increase of 8.4 lbs/day. Schmidt's estimate of rbST profit at a milk production base of 13,500 lbs and an rbST production response rate of 10 percent was negative $2. At 20,000 lbs of milk and a 15 percent rbST response rate, his profit estimates ranged from $83 to $163 depending upon the price of rbST and other input costs. Butler's estimate of net revenues from rbST also ranged from negative values on poorly managed farms with low production, to almost $250 per cow on farms with a base production of 20,000 lbs and an 18 percent response rate. Marion and Wills predicted a $10 rbST profit for a 12 percent response rate at 16,000 lbs base production. Jarvis re-estimated the model by Marion and Wills using different price and rbST response assumptions and came up with a $198 rbST profit estimate at a 15 percent response rate and a base production of 20,000 lbs.

Models

The rbST impact on milk production and profitability is estimated within a linear regression framework by placing a dummy variable for rbST use among other explanatory variables. The potential endogeneity of the rbST dummy variable, however, is acknowledged and corrected. Given the panel nature of the data, both fixed and random effects specification of the regression equations are examined.

The linear regression equation to be estimated is:

$$Y_{it} = X_{it}\beta + \delta R_{it} + e_{it} \qquad (1)$$

where Y_{it} is a milk output or profit variable, X_{it} is a vector of explanatory variables, R_{it} is a dummy variable for rbST use (R_{it}=1 if rbST is used, 0 otherwise), and e_{it} is a random disturbance assumed to be normally distributed.

If δ is to measure the impact of rbST on the output or profitability of a representative farm, farmers should be randomly assigned whether or not to use rbST. However, since farmers themselves decide whether or not to adopt rbST this assignment is by self-selection. As suggested by the rbST adoption literature the typical farmer who chooses to adopt rbST will likely have relatively high milk output and profit per cow whether or not rbST is used. It follows that the dummy variable R cannot be treated as exogenous. If equation (1) is estimated by Ordinary Least Squares (OLS) inconsistent estimates of the parameters will result.[1] Correction for this self-selection bias is usually done by including an additional equation explaining the sample selection. In our case this is an adoption decision equation relating the farmers' adoption decision to their individual characteristics, as well as some production features of their farms. The predictions from the adoption equation serve as instrumental variables for the rbST use variable R in equation (1).

The adoption equation in this study is a binary probit model. The model is put in the following latent regression framework:

$$R_{it}^{*} = Z_{it}\gamma + u_{it}, \qquad (2)$$

where R_{it}^{*} is an unobserved index variable, Z_{it} represents explanatory variables, and u_{it} is an error term. The observed dummy variable is the farmer's decision to adopt ($R_{it}=1$) or not adopt ($R_{it}=0$), where $R_{it}=1$ if $R_{it}^{*}>0$ and $R_{it}=0$ if $R_{it}^{*}\leq 0$. The error term u_{it} is assumed to be normally distributed with zero mean and variance equal to one. The probability of adoption is: $P(R_{it}=1)= P(R_{it}^{*}>0)= P(Z_{it}\gamma+u_{it}>0)= P(u_{it}<Z_{it}\gamma)= \Phi(Z_{it}\gamma)$, where Φ is the cumulative distribution function of the standard normal. Estimation of this model is based on the method of maximum likelihood (see Greene or Maddala).

Given the binary probit adoption model the rbST bias in equation (1) is:

$$E[Y_{it}] = E[Y_{it}|R_{it}=1]P(R_{it}=1) + E[Y_{it}|R_{it}=0]P(R_{it}=0)$$

$$= \left[X_{it}\beta + \delta + \sigma\left(\frac{\phi(Z_{it}\gamma)}{\Phi(Z_{it}\gamma)}\right)\right]\phi(Z_{it}\gamma)$$

$$+ \left[X_{it}^{M}\beta - \sigma\left(\frac{\phi(Z_{it}\gamma)}{(1-\Phi(Z_{it}\gamma))}\right)\right]\left(1-\phi(Z_{it}\gamma)\right)$$

$$= X_{it}\beta + \delta\Phi(Z_{it}\gamma),$$

where use has been made of the definition of incidentally truncated bivariate normal distribution (see Greene, p.707). It follows that upon obtaining the estimates of $\Phi\ (Z_{it}\gamma)$ from the binary probit model one can use these estimated probabilities of rbST adoption as the instrumental variable for R_{it} in equations (1) to correct for the self-selection bias.

Data

The data come from 211 farms that participated in the New York Dairy Farm Business Summary (NYDFBS) for the years 1993 through 1995. The NYDFBS extension program is primarily meant to assist dairy farmers by analyzing their business and financial records. These farm data are also used in dairy economics research.

The farms in the program are larger than the average New York dairy farm. Farms participating in the program in 1995 had an average herd size of 160 cows, 20,269 pounds of milk were sold per cow, and the net farm income excluding appreciation averaged \$50,593 per farm. This compares to a NY state average of 70 cows and 16,562 pounds of milk per cow (NY Agricultural Statistics).

It is clear that the data are not representative of New York dairy farms. They may be representative of the better managed farms that many believe are necessary to use rbST successfully (Patton and Heald). Extending any conclusions outside this group or to farmers in other states would be unsound.

Recombinant bST became commercially available during February of 1994. The DFBS surveys for 1994 and 1995 asked farmers to indicate their use of rbST in one of the five categories as (0) not used at all, (1) stopped using in 1994 (1995 respectively), (2) used on less than 25 percent of the herd, (3) used on 25-75 percent of the herd, (4) used on more than 75 percent of the herd. This rbST use coding has limited information content. Neither age nor production level of individually treated cows are known. Although most of these farms are DHIA (Dairy Herd Improvement Association) members, that organization does not code rbST use on individual cow records. This lack of detailed rbST management information precludes analysis on rbST use tactics, which may be complex and unique by farm. We simply infer that any farmer using rbST believes that it is profitable on his farm. As such, the farms were simply sorted into rbST users and non-users. Farms using rbST on some proportion of their herds during the whole year were labeled as users (i.e., the categories 2-4). Farms which either did not use rbST at all or stopped using it were labeled as non-users. Table 1 provides a two-way classification of the farms sorted in this way.

Profit is defined as milk receipts minus the operating cost of producing milk. The operating cost of producing milk only is constructed by subtracting non-milk receipts (cull cows, calves, excess feed sold) from the total accrual operating expenses including expansion livestock. This procedure assumes that the cost of producing non-milk products is equal to their value. Such an approximation to estimating non-milk operating expenses can be justified by noting that the value of non-milk products can not exceed 10 percent of the milk receipts for the farmer to be included in the NYDFBS final data set (Smith, Knoblauch, and Putnam). Milk production per cow is the average milk sold per cow. As a herd average, it also includes milk from cows not treated with rbST.

Other used data in the NYDFBS survey are: herd size, milking system, number of milkings per day, age and education of the principal operator of the farm. Farm size is considered a surrogate for other advanced technology use (Feder, Just and Zilberman) and is measured here as the average number of cows on the farm (COWS). The milking system (MILKSYS) used on the farm can also be associated with production and profit differences among different farms. In the analysis it is coded as a dummy variable equal to 1 if the milking system is a parlor, 0 if a stanchion system is used (bucket and carry, dumping station, pipeline). The number of milkings per day (TIMES) is also coded as a dummy variable equal to 1 if the farm milks more than twice a day, 0 if it milks twice a day. Milk price is calculated implicitly for each farm as milk receipts divided by pounds of milk sold. Ex ante adoption research has shown age and education to influence rbST adoption. Education, but not age, is hypothesized to influence milk production and profits per cow. Education is coded as a dummy variable equal to 1 if the principal operator of the farm has more than a high school education, 0 otherwise.

To capture the effect of learning-by-doing, an experience variable is included among the set of explanatory variables. An ideal experience variable would be constructed as the accumulated product of average number of cows on the farm and the average proportion of them treated with rbST prior to the analyzed year. In this study, however, the experience variable is simply a 1995 dummy variable indicating whether a farmer used or did not use rbST in 1994.

Results

Adoption Function Estimates

Besides the binary probit model, an ordered probit model and a censored regression model were also estimated to explain adoption behavior of the farmers. The results were similar to the binary probit analysis so only the results of that simpler model are reported. The explanatory variables for the 1994 adoption equation come from 1993, and those explaining the 1995 adoption decision are from 1994. The 1995 data were also split into groups of 1994 rbST non-users and 1994 rbST users to determine if the second-year adoption decisions were different given the first-year decision. Because the likelihood ratio test statistics for the equality of the 1994 binary probit model, and the model explaining the 1995 adoption behavior of 1994 non-users was 0.8, the null hypothesis of equality of the two models was not rejected at the 5 percent significance level. This result effectively defines only two sub-samples for the adoption model: one is the pooled sample of previous rbST non-users, which includes all farms in 1994, and 1994 non-users in 1995. The other sample studies 1995 adoption behavior of the group of 1994 users.

In general, the results from the binary probit adoption functions shown in Table 2 are consistent with other studies' findings. The larger (number of cows) and more productive (milk production per cow) the farm, the greater the probability of rbST adoption. Farms using a parlor type of milking system are also more likely to adopt rbST. The negative coefficient for age suggests that younger farmers may be more likely to adopt rbST than older farmers but that effect is not statistically significant. Farmers with more than a high school education are more likely to adopt rbST. The negative coefficient for a 1995 year dummy (YEAR95) suggests that farms not using rbST in 1994 are, on average, less likely to use it in 1995 than the group of all farms in 1994. If a farmer did not use rbST in 1994, he probably will not use it in 1995.

The marginal effects (slopes) for the binary probit model represent the expected change in probability of adoption as the explanatory variable is increased by one unit. For example, if a farm has 10 more cows than the average (131 cows for the pooled sample) and otherwise all characteristics of the average farm, one would expect the probability of this farm to adopt rbST will increase by about 1.2 percent compared to the average farm. The slopes for the dummy variables (EDUC, MILKSYS) reflect the change in probability of adoption as the dummy value changes from 0 to 1.

A comparison of actual and predicted adoption for the three models summarized in Table 2 are shown in Table 3. Prediction was good but not exceptional. For the 1994 adoption function, 152 of the 211 farms were predicted correctly as users or non-users of rbST. The prediction for 1995 for 1994 non-users was better, probably because most adoption decisions appear to have been made in 1994. The pooled sample of previous non-users predicted rbST use or non-use correctly in 77 percent of the cases.

Milk and Profit Equation Estimates

Coefficient estimates of the milk production per cow regression equations with fixed effects and a binary rbST use variable are reported in Table 4. The estimates listed under the heading adoption exogenous are the estimates of equation (1) alone. i.e., these results are conditional upon farmers' decision with respect to rbST use, and thus potentially subject to self-selection bias. The estimates of endogenous adoption are the estimates of the systems of equations (1) and (2) and are corrected for self-selection bias. Random effects specifications of the same models were estimated but rejected by the Hausman test at the 5 percent significance level, so only the fixed effects model estimates are presented. The dependent variable in the milk equation is cwt. of milk per cow. This is the herd average and thus includes both rbST treated and non-treated cows.

The coefficient for the milk price variable in the milk equation had an illogical negative sign similar to the study of Tauer and Knoblauch. Although there are plausible theoretical explanations for an output price having a negative sign in the short-run (Tauer and Kaiser), in this study, we opted to drop the milk price variable from the model. The milk price in our data set is a realized price and is not necessarily the same as the expected price which farmers use for decision making. We assume that farm and time dummies capture the information about the expected milk price more adequately than the imputed realized milk price available in the studied data set.

The estimated coefficients for BSTUSE suggest that the use of rbST indeed increased milk production per cow on these farms even when controlling for other explanatory variables and farm and time specific effects. Farms which used rbST on some portions of their herds during the whole year saw on average their herd average milk per cow increase by about 1000 lbs. a year compared to the farms which did not use or stopped using rbST. Replacing the rbST variable with the predictions from the adoption model to correct for self-selection bias increased the corrected BSTUSE coefficient slightly in value from 10.0 to 11.3, implying there was, contrary to a priori expectation, a negative self-selection bias in the milk equation. Tauer and Knoblauch, who did not correct for self-selection bias, estimated a herd milk increase of 1125 lbs. for rbST users in the first year of rbST availability.

Table 5 presents analogous estimates of the profit equation. The dependent variable in these equations is dollars of milk receipts over operating costs per cow. The estimated coefficients for the BSTUSE variable in the profit equations are negative and not statistically different from zero at any conventional significance level. This implies that on average these farms are not making money using rbST. Since rbST use increased milk output, the use of additional inputs (i.e. rbST, feed, labor, power, veterinary expenses, and milk hauling) needed to produce rbST induced milk consumed most, if not all, of this incremental milk revenue. Tauer and Knoblauch estimated profit over variable cost to increase by $120 per cow with rbST use, but this estimate had a t-statistic of only 1.5, implying their estimate was also not statistically different from zero at the 5 percent significance level.

Replacement of the original BSTUSE variable by the predictions from the adoption models decreased the numerical value of the estimated coefficient, implying there was a positive self-selection bias in the profit equation with respect to rbST use. This coefficient is again, however, not statistically different from zero at any conventional significance level either.

The additional explanatory variable measuring the learning-by-doing effect was insignificant at the 5 percent significance level in both milk and profit equations. Experience with rbST in 1994 appears to have no significant impact on either milk or profit per cow in the second year of rbST availability.