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The Adoption and Profitability of rbST on Connecticut Dairy Farms

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Preface

This work estimates probit and tobit models of the adoption of rbST on Connecticut dairy farms and then endogenizes that adoption in estimates of milk production and farm profit rates. The work improves on the current literature by allowing the rbST decision to be both continuous and contingent on other technology adoption decisions. The results show that larger farms, with more productivity technologies, and with younger, more educated farmers are more likely to adopt rbST. While rbST is shown to significantly increase milk production there is no evidence it increases profits on a per cow basis.

1. Introduction

A large number of studies have assessed rbST's early adoption probability (see for example: Lesser, Magrath, and Kalter 1986; Larson and Kulcher, 1990; Zapeda, 1990; Saha, Love, and Schwart, 1994; Lesser, Bernard, and Billah, 1999) and many have assessed the on-going adoption pattern as well as the technology's profitability and productivity (see for example: Barham, 1996; Stefanides and Tauer, 1997; Tauer and Knobloch, 1999). That extensive literature has identified a number of gaps in our understanding of rbST adoption and profitability, that this paper tries to fill. At the same time this work extends the current literature on rbST adoption: by providing an estimation methodology that considers the degree of adoption in the productivity and profitability functions, and by using data from a representative sample of a state's dairy producers.

The literature suggests a number of key issues:

Scale and Complementary Technologies: A-priori one would expect rbST to be scale neutral because of its ease of use; small start up costs; and lack of significant capital investments necessary. Studies (e.g. Zepeda, 1990; Koltz, 1995; Stefanides and Tauer, 1999; see also a review in Barham, Jackson-Smith, and Moon, 2000) find that, in fact, herd size does matter in the case of rbST adoption. Many suggest, but do not adequately test, the idea that complementary technologies account for the scale bias in adoption patterns.

Technical studies do show that farmers may not get a productivity response from rbST without changing their management, having better feeding, and having a healthier herd (Muller, 1992; Patton and Heald, 1992; Moore and Hutchinson, 1992). Larger farms may have better management and complementary technologies that could increase the effect of rbST on milk productivity and profitability. Thus, the relationship between adopting rbST and using complementary technologies will not be independent and estimates of adoption, productivity, and profitability should take this into account.

Productivity: More than sixty years ago scientists proved that bovine somatotropin (bST) could substantially increase milk production in cows (Asimov and Krouse, 1937). Recent studies have shown recombinant bST increases productivity on both experiment station farms and in on-farms samples (Office of Management and Budget, 1994; Zinn and Bravo-Ureta, 1996). A number of the on-farm samples have used data from participants in farm management programs who, because of the complementarity of management and rbST, are likely to have a larger productivity response from rbST's use. This study seeks to solve this weakness in the literature by trying to confirm, in a representative sample of producers, the productivity effect found in experiments and select samples.

Profitability: While clearly productivity increasing, the increase in milk production due to rbST will require an increase in input costs such as labor, medications, feed and rbST itself, making its profitability less certain. Despite the large number of studies and the rapid adoption of the technology among certain sectors of producers, studies of rbST profitability remain inconclusive. One reason could be that studies done in the first one to three years after rbST introduction had profitability data that captured "learning by doing" costs as farmers mastered this new technology. The more recent data used here have a sufficient distance, six years, to the original introduction of the technology so as to render this "learning by doing" effect inconsequential.

Degree of Adoption: While Saha, Love, and Schwart's seminal 1994 study pointed out the importance of different degrees of adoption, the literature has ignored this issue in estimating productivity and profitability. This work estimates the degree of adoption and uses it in productivity and profitability estimates allowing a comparison with simple adoption probability models.

Discontinuance: This paper also addresses the issue of farms that have tried rbST and discontinued using it, which has as yet not received much notice in the literature. Knowing the characteristics of those farmers who have tried rbST and stopped using it can help us better understand the adoption process.

The remaining parts of this paper are organised as follows. The next two sections develop an econometric model of rbST adoption as a function of complementary technologies and discuss the data used in the paper. Section 4, which follows, presents the results of the empirical estimations and evidence on rbST discontinuance users. The conclusion is presented in Section 5.

2. An Adoption Model with Technology and Self-Selectivity

The basic set-up for estimating the impact of adopting rbST on milk production and farms' profitability assumes that milk production per cow or profit per cow (Y_i) is a linear function of explanatory variables (X_i) and an rbST dummy variable (R_i), see Tauer and Knoblauch (1997). The linear regression equation can be written as:

$$Y_i = X_i'\beta + \delta R_i + e_i \qquad (1\text{-}1)$$

where e_i is a normal random disturbance and R_i is a 0 or 1 dummy variable for the use of rbST; $R_i=1$ if rbST is adopted, $R_i=0$ otherwise. The variable X_i represents farm characteristics (owner's age, education, number of cows on the farm, milking system, number of milkings per day, etc.).

Note that how farmers decide whether to adopt rbST is dependent on the characteristics of farms and farmers, so the decision of a farmer to adopt rbST is based on each farmer's self-selection instead of random assignment. Thus, R_i should be endogenized using an index function model (e.g. Heckman, 1990; Maddala, 1983; Greene, 1999). The index function to estimate farmers' rbST adoption is:

$$R_i^* = Z_i'\gamma + u_i \qquad (1\text{-}2)$$

where R_i^* is an unobservable index variable denoting the difference between the utility of using rbST (U_{i1}) and the utility of not using rbST (U_{i0}). If $R_i^* = U_{i1} - U_{i0} > 0$, then the individual farmer *i* would use rbST. The term $Z_i'\gamma$ provides an estimate of $U_{i1}-U_{i0}$, using farm characteristics, Z_i, as explanatory variables, while u_i is an error term unobserved by the researcher and assumed to be normally distributed $u_i \sim N(0,1)$[1]. This model can then be estimated with a standard Probit log-likelihood function.

From equation 1-1 and 1-2, the expected milk production and/or profits, Y_i, can be obtained by:

$$\begin{aligned} E[Y_i] &= E[Y_i | R_i=1]*Prob(R_i=1)+E[Y_i | R_i=0]*Prob(R_i=0) \\ &= (X_i'\beta + \delta + E[u_i | R_i=1]) * Prob(R_i=1) + (X_i'\beta + E[u_i | R_i=0]) *Prob(R_i=0) \\ &= X_i'\beta + \delta \, Prob\,(Z_i'\gamma + u_i > 0) \\ &= X_i'\beta + \delta\,\Phi(Z_i'\gamma). \end{aligned}$$

where Φ is cumulative standard normal density function for u_i. Thus, $\Phi(Z_i'\gamma)$, the probability of rbST adoption by farm *i*, serves as the instrumental variable for R_i in equation 1-1 to avoid biasing the estimators.

This model with self-selectivity, **Model 1**, is:

$$Y_i = X_i'\beta + \delta R_i^* + e_i$$
$$R_i^* = Z_i'\gamma + u_i .$$

[1] The other assumption of the distribution u_i is logistic, generating the logit model. Estimates with the logit model done to check the importance of this assumption to our results were essentially the same as the results presented here.

Model 2:

According to the Office of Management and Budget (1994), in order to have a high production response using rbST, farmers need to have better feeding technology, farm management, and cow health. Thus estimates of rbST's effects should take into account other complementary technology and management practices, *G*, in investigating rbST adoption behavior. Under this model (Model 2), the assumption is that farmers' rbST adoption decision is based on the farmers' current level of adoption of other technologies.

Model 2: farmers who have technology G_i are more likely to adopt rbST.

$$Y_i = X_i'\beta + \delta R_i + G_i'\theta + e_i \qquad (2\text{-}1)$$

$$R_i^* = Z_i'\gamma + G_i'\omega + u_i \qquad (2\text{-}2)$$

where R_i is 0 or 1 dummy variables:

$$R_i = 1 \quad \text{if} \quad R_i^* > 0 \quad \text{(adopt rbST)},$$
$$R_i = 0 \quad \text{if} \quad R_i^* \leq 0 \quad \text{(not adopt rbST)}.$$

Note that the other technologies, *G*, enter into both the adoption decision and the productivity/profit equation. From equation 2-1and 2-2, the expected milk production and profits, Y_i, can be obtained by:

$$\begin{aligned} E[Y_i] &= E[Y_i | R_i=1]*Prob(R_i =1)+E[Y_i | R_i=0]*Prob(R_i= 0) \\ &= X_i'\beta + \delta\,\Phi(Z_i'\gamma + G_i'\omega) + G_i'\theta. \end{aligned}$$

Model 3:

As Saha, Love, and Schwart (1994) demonstrate, the degree of adoption can be as important as whether a farmer adopts at all. Thus a further question should be asked: what is the rbST adoption intensity effect on milk production and farm profitability. In other words, what is the effect of the percentage of a herd treated with rbST on milk production and farm profitability? Using the Tobit model and the framework developed in the last section, Model 3 is given by the following:

$$Y_i = X_i'\beta + \Omega T_i + G_i'\iota + \varepsilon_i \qquad (3\text{-}1)$$

$$T_i^* = D_i'\lambda + G_i'\varphi + \psi_i \qquad (3\text{-}2)$$

where

$$T_i = T_i^* \quad \text{if} \quad T_i^* > 0\,,$$
$$T_i = 0 \quad \text{if} \quad T_i^* \leq 0;$$

and T_i is the rbST adoption intensity, percentage of a herd using rbST. Equation 3-2 is a censored regression, which we can estimate as a Tobit model in the following manner:

$$E[T_i|\ T_i = T_i^*] = E[T_i^*|\ T_i^* > 0]$$
$$= D_i'\lambda + G_i'\varphi + E[\psi_i \mid \psi_i > - D_i'\lambda]$$
$$= D_i'\lambda + G_i'\varphi + \sigma_{\psi i}\ [\phi(D_i'\lambda + G_i'\varphi) / \sigma_{\psi i}] / [\Phi(D_i'\lambda + G_i'\varphi) / \sigma_{\psi i}].$$

Further more, we can estimate Y_i using the predicted T_i^* as an instrument by:

$$E[Yi] = X_i'\beta + \Omega\ \{E[T_i|T_i=T_i^*] * Prob(T_i=T_i^*) + E[T_i|T_i=0] * Prob(T_i=0)\} + G_i'\iota$$
$$= X_i'\beta + \Omega\ \{E[T_i|T_i=T_i^*] * Prob(T_i=T_i^*)\} + G_i'\iota$$
$$= X_i'\beta + \Omega\ \{\ D_i'\lambda + G_i'\varphi + \sigma_{\psi i}\ [\phi(- D_i'\lambda + G_i'\varphi) / \sigma_{\psi i}] / [\Phi(D_i'\lambda) / \sigma_{\psi i}]\ \} * \Phi(D_i'\lambda + G_i'\varphi) / \sigma_{\psi i} + G_i'\iota\ .$$

Using this framework, one can estimate the estimators by using the following procedures:

1. Use maximum likelihood to estimate the rbST adoption intensity tobit model (equation 3-2) in order to obtain $E[T_i|\ T_i = T_i^*]$ and $Prob(T_i=T_i^*) = \Phi(D_i'\lambda + G_i'\varphi)/\sigma_{\psi i.}$
2. Use OLS with X_i, $E[G_i]$ and $E[T_i|\ T_i = T_i^*]^* Prob(T_i=T_i^*)$ as the regressors to estimate the milk production and profitability equations (equation 3-1).

3. The Data

In 1999, six years after the approval of rbST by the FDA, the University of Connecticut conducted a survey of dairy farmers in the state in order to examine the competitiveness of Connecticut dairy farms and their adoption of new technologies including rbST. All 245 Connecticut dairy farms received a survey, and 124 returned useable information on their dairy farms, representing a 51% response rate.[2] Connecticut dairy farms are relatively small-scale businesses, with more than 60% having under 100 milk cows. The farmers are on average well educated, productive farmers, with a rolling herd average of 19,800 lbs per cow.

The general characteristics and technology differences between rbST users and non-users are shown in Table 1. Between rbST adopters and non-adopters, it shows that:

(i) The number of cows per farm, milk production per cow, years of education of owners, parlor milking system, predip teats, regularly scheduled veterinary services, balance feed ration 4 times a year, total mixed ration (TMR) machinery, freestall housing for milking herd, milk cows 3 times a day, and computer use are significantly different at 1% level;
(ii) use of a dairy record program is significantly different at 5% level; and
(iii) average age of owners is significantly different at 10% level.

In this study, milk production is defined as average milk production per cow. Profit is defined on a per cow basis as 1998 total farm receipts (including milk, livestock, crop sales, and all other farm receipts) minus total farm expenses (including all operating costs and depreciation costs claimed on farmers' taxes). Other variables used in the estimations are farm size, owners' age and years of formal education, milking cow ratio, rbST-related technologies (TMR, milk cows 3 times a day, use a computer for farm record-keeping, regularly scheduled veterinary service, balance feed rations at least 4 times a year, and use a dairy record program) and the number of the eleven key technologies used on the farm (*Sumtech* measures this from 0-11). Farm size is measured as total number of cows, including dry cows, on the farm. Owners' age and years of formal education are the average of all owners weighted by the percentage of ownership as method to capture each owner's influence on the farm. Milking cow ratio is defined as the number of milking cows per farm divided by total number of cows on that farm, as a measure of management quality.

Table 2 contains the sample means and standard deviations of the variables used in the estimations. The relationship between variables is shown in Figure 1. It demonstrates how the farm and farmer characteristics affect the usage of technologies and rbST and how these factors and quality of management affect milk production and profits.

4. Estimations

Table 3 shows the estimates of the adoption models for rbST. For the probit models (1 and 2) the coefficients represent the expected changes in utility index if explanatory variables change one unit, $\partial R_i^* / \partial Z_i$. From the coefficients in Model 1, one can see that in Connecticut, as found elsewhere, the younger and more educated farmers who own larger farms are more

[2] An estimate of the sample inclusion probability using a list of all Connecticut dairy farmers and their size, productivity, and location, found no significant parameters.

likely to use rbST, and the effects are all statistically significant at least at a 1% level. The negative coefficient of *Farmsiz2* implies that the relationship between *Farmsize* and the expected probability of using rbST (*Prbst)* exhibits diminishing marginal effects. Figure 2 shows this concave curve by graphing the relationship between *Farmsize* and the predicted probabilities from Model 1, *Prbst*, using locally weighted scatter plot smoothing (LOWESS), see Hardle, 1990.

Model 2, presented in the second column of the tables, expands the model with self-selectivity by adding the technology variables into the rbST adoption probit model. The model correctly predicts rbST adoption in 89% of the cases, which is higher than for the model ignoring complementary technologies, suggesting that the previous technology adoption plays an important role in the decision to use rbST. Despite the improved fit, only three-times milking (Milk3) among the technology variables had a coefficient significantly different from zero. This may be due to a high degree of correlation among technology choices. Of particular note in comparing Models 1 and 2 is the fact that the farmsize effect on rbST adoption remains essentially constant across the equations even when technology differences are accounted for. The persistence of a scale effect suggests that it cannot be fully accounted for in correlated technology choices.

The third column in table 3 shows the rbST usage intensity tobit model estimates. From the coefficients one can see that *Edu*, *Farmsize,* and *Milk3,* have a positive effect on rbST usage intensity; *Age* and *Farmsiz2* have a negative effect on it. Thus, it suggests that younger and more educated farmers who own larger farms and have more technologies are more likely to use rbST more intensively. In effect the results from the adoption intensity equations confirm our conclusions from the adoption probability models.

4.1 Productivity

The milk production per cow estimates, shown in Table 4, have rbST usage endogenous (Model 1 and 2) in column 1 and 2, and rbST intensity endogenous in column 3.[3] The estimates of Model 1 only shows the coefficient of *Sumtech* significant at a 5% level and the coefficient of Ag*e* statistically significant at a 10% level. The Model 2 productivity equation estimates show the coefficients of *Prbst* and *DHIA* are statistically significant at 5% level and the coefficient of *Edu* is significant at a 10% level. Model 2 results suggest that the use of rbST can increase milk production per cow by 4,142.lbs per year, or more than 20% over average production levels.

The estimates of Model 3, using the predicted intensity of adoption, show coefficients of *Edu* and *Milk3* statistically significant at 10% level and the coefficient of *DHIA* significant at a 5% level. To milk cows three times a day could increase milk production per cow by 3,202 lbs per year, that is about 8.77 lbs per day. Participation in DHIA or other similar programs could increase milk production per cow by 2,665 lbs per year, that is 7.3 lbs per day. In sum the productivity equations confirm that rbST has a positive effect on productivity, although this effect is not always as statistically strong as one might expect.

4.2 Profits

Table 5 shows profit per cow equation estimates with rbST usage and intensity endogenized, using the same methods as in the productivity estimates. Model 1 suggest that *Prbst*, *Sumtech*, and *Age* have negative effects on profit per cow and *Prod98*, *Edu*, *Milkrate*, and *Farmsize* have positive effects on profit per cow. The coefficients imply that using rbST could decrease profit per cow by $507 per year, which, while large, is consistent with the results of Stefanides and Tauer's 1999 study from New York.

Model 2 shows the profit per cow equation estimates when *Sumtech* are replaced by 6 technology variables (*TMR*, *Parlor*, *PC*, *Milk3*, *DHIA* and *Vet*). The results show that participation in DHIA increases profit per cow while regularly scheduled veterinary service (*Vet)* decreases profit per cow. The coefficient on *Prbst*, though not statistically different from zero, is non-positive at a 10% level.

The Model 3, profit per cow estimates using rbST intensity shown in column 3 of Table 5 suggest that *DHIA*, *Milkrate* and *Farmsize* have positive effects on profit per cow while *Age*, *Parlor*, *PC* and *Vet* have negative effects on profit per cow[4]. Estimate of the coefficient on rbST intensity is not significant, though in sign and magnitude it suggests the same type of effect as the predicted adoption variable in models 1 and 2.

[3] Due to significant heteroskedasticity, the production and profit equations all use robust standard errors generated through White's procedure (Greene, 1999).

[4] A possible reason for the negative signs of *Parlor* and *PC* could be that the profit per cow was defined as total farm receipts minus total farm expenses (including all operating costs and depreciation costs claimed on farmers' taxes). Thus, the depreciation costs could be larger if the technologies were installed during recent years and it is also possible that farmers have different tax strategies that claimed the depreciation of the capital differently.

4.3 Characteristics Of Farmers Who Discontinued Using rbST

The characteristics of the 11 farmers (9%) who discontinued using rbST relative to adopters and non-users are shown in Table 6. Both rbST users and discontinuance users have quite similar characteristics, with larger herd size, more education, and using more production enhancing technologies than non-users. Though not statistically significant, rbST users have on average higher production per cow, but lower profit overall and per cow than discontinuance users. Also the percentage of rbST discontinuance users owning and using a computer for personal use is significantly lower than for rbST users. The results of the previous models have shown that *rbST* and *PC* have negative effects on profit per cow, suggesting why the rbST discontinuance users have higher profits per cow. Perhaps the older (more experienced) dairy farmers who are more educated have tried rbST and not seen a major profitability increase. Another possible reason for discontinuance users to stop using rbST, in a non-agricultural state, may be that, since they are less likely to have a parlor milking system, it might be harder for them to hire enough labor to handle the higher milk production.

5. Conclusion

All models show that the younger and more educated farmers who own larger farms are significantly more likely to use rbST. This result is consistent with other rbST adoption studies, such as Zepeda (1990) and Klots, Saha, and Butler (1995) in California, Stefanides and Tauer (1999) in New York, Saha, Love, and Schwart (1994) in Texas, and Barham (1996) in Wisconsin. The results of Models 2 and 3 add to that literature by demonstrating that the scale effect of rbST adoption does not disappear when one accounts for previous technology adoption patterns. Thus, there still remains some type of scale economy in rbST use, despite the low start-up costs of the technology. The estimates of Model 3 suggest that intensity of rbST use follows the same pattern as the original adoption question.

The results all show that using rbST has a positive effect on milk production and this positive effect is significant in Model 2. On the other hand, the evidence presented here does not find that this productivity enhancement leads to higher profits for farmers. The non-positive effect of rbST on profits is especially surprising in that the high milk prices of 1998 should have biased the results from this data in favor of finding profitability in a productivity enhancing technology. It is perhaps the case, at current combinations of milk and feed prices, that rbST may be profitable for only a small minority of Connecticut dairy farmers.

The issue of discontinuance users needs further study beyond the small sample size used here. A study with more data points on discontinuance users, for example from a larger dairy state, could provide a new understanding of the adoption process. In that case in order to take into account this third category, a multinomial probit or logit model (Zepeda, 1990) can replace the probit model that is used in Model 2 to study the technology adoption behavior thoroughly.

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Table 1. The general characteristics and technology differences between rbST adopters and non adopters.

General characteristics and technologies	rbST users	RbST nonusers
Sample size	37	85
Average number of cows per farm***	207.6	95.9
Average milking / total cows ratio	0.86	0.85
Average milk production per cow*** (1,000 lbs)	22.7	18.4
Average profit ($1,000)	53.1	38.1
Average profit per cow ($1,000)	0.25	0.41
Owners:		
Average age (weighted by percentage owned)*	48.87	52.91
Years of formal education (weighted by percentage owned)**	14.03	12.57
Uses of various technologies (percent of farms):		
Parlor milking system***	94.59	48.24
Predip all teats before milking***	89.19	48.15
Postdip all teats after milking	100.00	96.43
Regularly scheduled veterinary services***	97.22	73.17
Balance feed rations at least 4 times a year***	88.89	62.50
Total mixed ration (TMR) machinery***	94.44	49.38
Artificial insemination (AI) on at least 75% of the herd	97.30	91.67
Freestall housing for the milking herd***	97.30	61.73
Milk cows three times a day***	32.35	1.25
Seasonal milking program	5.88	6.41
Own and use a computer for personal or family use***	91.89	47.06
Own and use a computer for farm record-keeping***	80.00	35.71
Access information for the farm over the internet***	63.89	20.99
Use a dairy record program (DHIA or other)**	80.56	58.54

***, **, * sample means or sample proportions of rbST users and nonusers are significantly different at 1, 5, or 10 % level.

Table 2. The sample means of regressors.

Variable name	Explanation	Mean	Standard deviation
Farmsize	Number of cows per farm	129.92	115.49
Prod98	Average milk production per cow	19.85	5.59
Profcow	Profit per cow	0.36	0.45
rbST	Use of rbST	0.30	0.46
Age	Owners' age weighted by percentage owned	51.74	10.99
Edu	Owners' years of education weighted by percentage owned	13.04	2.72
Parlor	Use of parlor milking system	0.63	0.49
Vet	Regularly scheduled veterinary services	0.81	0.40
TMR	Total mixed ration machinery	0.63	0.49
Milk3	Milk cows three times a day	0.10	0.31
PC	Own and use a computer for farm record-keeping	0.48	0.50
DHIA	Use a dairy record program (DHIA or other)	0.66	0.48
Milkrate	Milking cows / total cows	0.85	0.11
Sumtech	Total number of 11 key technologies used	7.33	2.50
percrbST	Percentage of a farm's herd using rbST	17.35	29.62

Table 3. rbST Adoption Models.

Variable	Model 1: Probit	Model 2: Probit with Technology	Model 3: Tobit, adoption intensity
Age	-.0490124***	-.056477**	-2.442704***
	(.0174969)	(.0231795)	(.5548829)
Edu	.2209431***	.159397*	4.854936*
	(.0786135)	(.0946284)	(2.585263)
Farmsize	.0207036***	.023147**	.471786***
	(.0046467)	(.009437)	(.1720713)
Farmsiz2	-.0000273***	-.000050**	-.000777***
	(8.86e-06)	(.0000239)	(.0002918)
TMR		.908117	29.0935
		(.7026762)	(20.37892)
Parlor		2.591006	44.1025*
		(2.473318)	(23.24237)
PC		.311459	9.9031
		(.4321391)	(11.96146)
Milk3		5.214278*	69.6277***
		(3.138852)	(15.9638)
DHIA		.528027	22.6298
		(.6672405)	(15.57384)
Vet		.458552	33.0803
		(.686493)	(23.18774)
Constant	-3.0321**	-6.276414*	-117.7295**
	(1.354286)	(1.775039)	(53.72474)
Log Likelihood	-44.615224	-25.077981	-170.48959
Pseudo R^2	0.3691	0.5997	0.2093

* Significant at a 10 % level.
** Significant at a 5 % level.
*** Significant at a 1 % level or less.

Table 4. Productivity (Milk per cow).

Variable	Model 1 predicted probability	Model 2 predicted probability with Technology	Model 3: predicted % of cows treated
Prbst	1.95925	4.14161**	.01882
	2.212957	2.012964	.037619
Age	.07467*	.05033	.02493
	.043514	.037548	.0035945
Edu	.25429	.33254*	.36479*
	.211232	.194510	.2126329
Farmsize	.00526	.00535	.00614
	.005463	.005282	.0057339
Milkrate	4.17266	4.81493	4.77457
	4.838239	3.993191	4.516541
Sumtech	.73595**		
	.283901		
TMR		.08310	.57303
		1.238872	1.214846
Parlor		.44745	1.11840
		1.275352	1.146132
PC		-.51100	-.18128
		1.273457	1.306053
Milk3		1.85944	3.20249*
		1.703525	1.72463
DHIA		2.52746**	2.66509**
		1.219798	1.21811
Vet		-.69627	-.24425
		1.459116	1.51847
Constant	2.29954	5.59547	5.99059
	5.391024	4.515235	4.89923
R^2	0.3013	0.3513	0.3311

* Significant at a 10 % level.
** Significant at a 5 % level.
*** Significant at a 1 % level or less.
Robust standard errors are used since the test of heteroscadasticity is significant at a 5% level.

Table 5. Profits Per Cow.

Variable	With Model 1 predicted probability	With Model 2 predicted probability and Technology	With Model 3 predicted % of cows treated
Prbst	-.507927*	-.34493	-.0050062
	.3012213	.258238	.0043306
Prod98	.019380**	.01221	.0103237
	.0094538	.010281	.0101656
Age	-.013533***	-.00874*	-.0083422*
	.0051011	.004524	.0044772
Edu	.060025***	.04864	.0488241
	.0174578	.030211	.0303522
Farmsize	.001578*	.00127**	.0012158**
	.0008367	.000548	.0005696
Milkrate	.900379**	.73614*	.7652927*
	.3627052	.439988	.4576564
Sumtech	-.080889***		
	.0251663		
TMR		-.06090	-.0872184
		.114152	.1102866
Parlor		-.20900	-.2403962*
		.139793	.1308286
PC		-.15479	-.1678989*
		.095434	.0963116
Milk3		.13827	.1188706
		.209332	.1956384
DHIA		.24943**	.2344226*
		.123630	.1222317
Vet		-.33451**	-.3456190**
		.149965	.1476891
Constant	-.324581	-.41869	-.4091828
	.446616	.632970	.6407849
R^2	0.2863	0.3779	0.3736

* Significant at 10 % level.
** Significant at 5 % level.
*** Significant at 1 % level or less.
Robust standard errors are used since the test of heteroscadasticity is significant at a 5% level.

Table 6. Characteristics and Technology of RbST Adopters And Non-Adopters .

General characteristics and technologies	Users	Dis-continuance users	Non-users
Sample size	37	11	68
Average number of cows per farm	207.66	179.73	80.15
Average milk production per cow	22.74	20.82	17.67
Average profit	53.14	66.5	33.36
Average profit per cow	0.25	0.45	0.40
Owners:			
Average age (weighted by percentage owned)	48.87	52.43	53.14
Years of formal education (weighted by percentage owned)	14.03	13.88	12.40
Uses of various technologies (percent of farms):			
Parlor milking system**	94.59	73.73	42.65
Predip all teats before milking***	89.19	54.55	44.62
Postdip all teats after milking	100.00	100.00	97.06
Regularly scheduled veterinary services	97.22	90.91	69.23
Balance feed rations at least 4 times a year	88.89	90.91	57.81
Total mixed ration (TMR) machinery	94.44	100.00	39.40
Artificial insemination (AI) on at least 75% of the herd	97.30	100.00	91.04
Freestall housing for the milking herd	97.30	90.91	55.38
Milk cows three times a day	32.35	10.00	0
Seasonal milking program	5.88	0	7.94
Own and use a computer for personal or family use**	91.89	63.64	44.12
Own and use a computer for farm record-keeping	80.00	72.73	29.85
Access information for the farm over the internet	63.89	50.00	16.67
Use a dairy record program (DHIA or other)	80.56	81.82	53.03
Average milking / total cows ratio	0.86	0.86	0.85

** sample means or sample proportions of rbST “Users” and “Dis-continuance users” are significantly different at 5 % level.
*** sample means or sample proportions of rbST “Users” and “Dis-continuance users” are significantly different at 1 % level.

Figure 1. The relationship among variables.

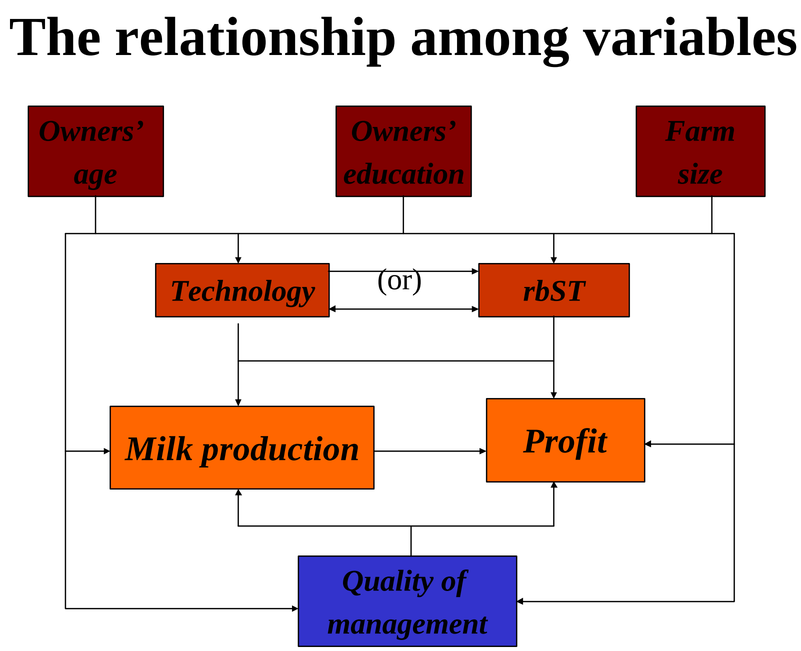
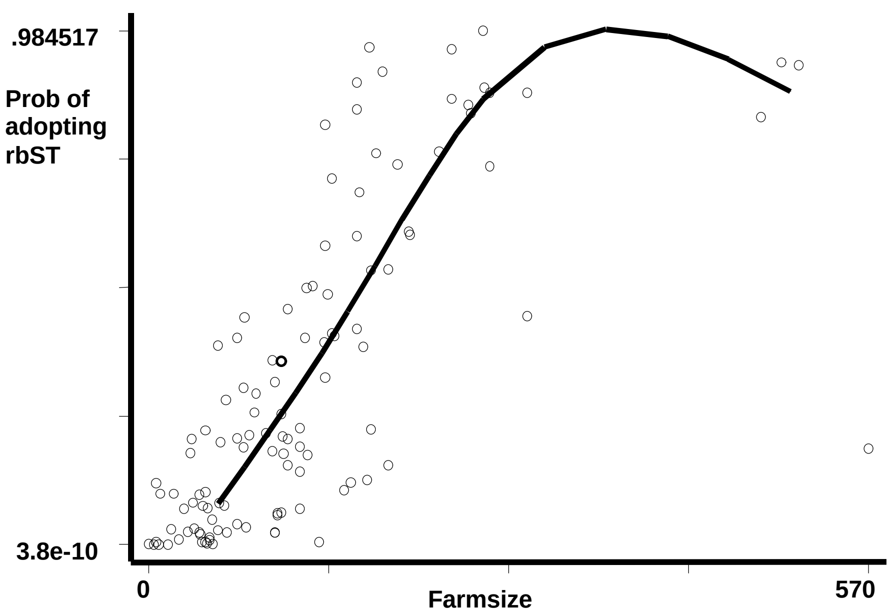


Figure 2. Adoption Probabilities as a Function of Farmsize.
(LOWESS Smoothed line from predicted probabilities)



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