Scale Neutrality of Bovine Somatotropin: *Ex Ante* Evidence from the Southeast

Henry Kinnucan, Upton Hatch, Joseph J. Molnar, and Meenakshi Venkateswaran

Abstract

Bovine somatotropin (BST), a new technology capable of enhancing a cow's ability to produce milk by 7-23 percent, is expected to be available for commercial use soon. *Ex ante* survey procedures are used to determine the potential effect of BST on the size distribution of dairy farms in the Southeast. Results of logit analysis indicate a positive link between farm size and (1) farmers' knowledge of BST and (2) intentions to adopt early, suggesting BST will not be scale neutral. An estimated "price elasticity" of -1.8 to -2.1 indicates an elastic demand for the input. Price, therefore, may be an effective instrument for attenuating the scale bias.

Key words: bovine somatotropin, scale bias, biotechnology, dairy policy, technology adoption, *ex ante* surveys

Bovine somatotropin, an injectable protein capable of enhancing a cow's ability to produce milk by 7-23 percent (Kronfield), is expected to be available for commercial use soon. Because of the unprecedented yield-enhancing potential of this technology and the difficulties the diary industry has had with surpluses, bovine somatotropin (BST) is controversial.

One aspect of that controversy is the effect of BST on the size distribution of dairy farms (Comstock; Buttel and Geisler). The demand for dairy products is price inelastic, meaning that BST-induced declines in price will have minimal effect on consumption.[1] As domestic consumers are unable to absorb the additional supply of milk made possible by BST, and increased exports are an unlikely prospect, cow numbers will need to be reduced, possibly by as much as 30 percent (Kalter *et al.*). But how will attrition occur? Will reduction in cow numbers be accomplished by small farmers' leaving dairying altogether, or will the impact be spread more evenly?

Questions about how BST will affect the size distribution of dairy farms are important for several reasons. First, because BST is a variable input, the answer to the size-bias question *a priori* is not obvious. The resulting ambiguity has led to differing assumptions by researchers about the rate of adoption of BST by size of farm. Fallert *et al.*, for example, assume that all size categories will adopt BST at the same rate. Kalter *et al.*, in contrast, assume that larger farmers will adopt first. Conclusions about BST's effect on smaller dairies, not surprisingly, differ substantially between the two studies.

Second, identifying the size bias of BST (if any), and the reasons for the size bias, will shed light on the likely pattern and rate of BST adoption. Such insights will help policy makers anticipate the long-run effects of the technology, permitting more informed policy choices. For example, if BST favors larger farms, policymakers may want to consider programs that help small- and medium-sized dairies adapt. Finally, Kuchler and McClelland maintain that the empirical evidence showing a link between farm size and early adoption—a key factor in determining scale bias—is scant or nonexistent for U.S. agriculture.

The major objective of the research reported in this paper is to determine the potential scale bias of BST. The objective is accomplished by analyzing data on farmers' intentions to adopt BST obtained through an *ex ante* survey procedure which elicits adoption intentions and related information from a group of

[1] As pointed out by a reviewer, non-price factors such as consumers' attitudes toward milk produced with BST might also affect consumption, offsetting and perhaps negating the effects of any price decline. In this case, the adjustment problems arising from the introduction of BST discussed later will be even more severe.

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potential BST users. Because the price of BST is a potential policy instrument for influencing the rate and pattern of adoption, a secondary objective is to determine farmers' likely response to changes in the price of BST.

The research reported here differs from past research on BST adoption in several ways. First, while potential adoption rates and related information about BST have been obtained for other regions or states (Lesser *et al.*, Hammond, Zepeda), such information is lacking for the southeast. Second, this study focuses on the question of the scale neutrality of BST, an issue not explicitly addressed in previous studies. The rate of adoption *per se* is not emphasized because the politicized nature of BST (Molnar *et al.*), coupled with its expected low per-unit cost (Kalter *et al.*) and regulatory delay (Hatch and Kuchler), implies rapid adoption once BST is available (e.g., see Kinnucan *et al.*). Third, no information exists about how farmers in the Southeast are likely to respond to the price of BST, a potentially important question for policy purposes.

A brief review of the literature on technology adoption sets the stage for developing hypotheses about the role of farm size in early adoption of BST. Data collection procedures are then summarized. Based on these data, a logit model is specified to test the scale-neutrality hypothesis. The paper concludes with an analysis of price sensitivity and a discussion of the policy implications the authors' findings.

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Discussions of scale neutrality start with a determination of whether the input in question represents a fixed or a variable cost. A fixed-cost input requires a large capital outlay, such as a mechanical tomato picker. It has a useful life that extends over a number of years, it is "lumpy," and the cost of varying the quantity of the input within a production cycle is prohibitive, especially for smaller farmers. Technological innovations involving fixed inputs work to the disadvantage of the smaller farmer because per-unit costs of the new technology are higher. A Variable-cost input requires a small initial investment, is not "lumpy," and is used up in one production cycle. Hybrid seed might represent such an input. Because variable inputs do not confer cost advantages related to size, technological innovations representing strictly cost have no inherent size bias, save those connected with price discounts for volume purchases.

This treatment of the scale-neutrality question is correct from a static perspective. Broadening the analysis to include consideration of the dynamics of adoption, however, brings to light new factors that might cause size-bias, even for a variable input. Dynamics of adoption refers to the pattern of diffusion from the time of introduction through market saturation. If the pattern is such that larger farmers populate the ranks of early adopters and smaller farmers comprise the laggards, the end result, according to Cochrane's treadmill theory, is a greater concentration of large farms. In other words, whether a technology is scale-neutral depends not only on whether the input is variable or fixed but on the pattern of the diffusion process. If "early bird" innovative farmers also happen to operate large farms, new technology *de facto* is biased in favor of the large farmer, regardless of input type.

The crucial question then is whether larger farmers have additional incentives or natural propensities to adopt early. The literature on technology adoption in agriculture provides insight bearing on this question. Of particular relevance are the works of Rogers; Just and Zilberman; Lindner; and Feder and Slade. These studies identify two variables central to understanding the link between early adoption and farm size: risk preferences and knowledge.

Because all new technologies involve an element of risk, especially in the early stages of diffusion when on-farm experience is limited, the willingness of a farmer to accept risk influences his decision about when to adopt. Compared to his less cautious neighbor, the farmer who is averse to assuming risks is expected to delay longer in adopting a new technology (or might refuse to adopt altogether). Theory and related empirical work suggest an inverse relationship between risk aversion and wealth (Pratt), implying that the larger farmer, because of his greater wealth and more diverse portfolio of financial assets, will be more willing to accept the risk associated with early adoption and hence will adopt sooner than the smaller farmer.[2]

Careful consideration of the role of knowledge in technology adoption leads one to a similar con-

[2]Some research points to a logistical relationship between size and risk taking, identifying a "middle-class conservatism" (Cancian). Still, risk-taking propensity appears to be greater for larger farmers. Just and Zilberman provide a rigorous theoretical analysis of the linkages between risk aversion, farm size, and technology adoption.

clusion about the relationship between farm size and early adoption. The farmer's unfamiliarity with the new input and uncertainty about whether the technology can be used profitably can only be overcome by acquiring information. Information can be acquired in two ways, passively or actively.[3] The purposeful acquisition of information, as emphasized by Feder and Slade and by Lindner, entails a cost. An important aspect of the cost of obtaining information is its fixed character *i.e.*, the absolute expenditure required to obtain the requisite information is the same for small and large farms.

Because large farmers can spread search costs over a larger volume of production, the incentive to become informed is greater for the larger farmer. Further, the level of information is a critical factor in the farmer's decision of when (or even if) to adopt. In particular, the dynamic decision model developed by Feder and Slade indicates the farmer's state of knowledge about a new (variable) input must be at a certain critical level before adoption will occur. Because the larger farmer has a greater incentive to acquire information, the information threshold is reached sooner, leading to differential rates of adoption. Large farm operators may also be in a better position to purchase the necessary information and expertise.

A third and related factor theoretically linked to early adoption is human capital (Feder and Slade). Farmers with higher levels of schooling, training and experience can be expected to interpret information more accurately. Greater information-processing ability implies that for any given level of knowledge, the marginal cost of processing additional information is lower. Thus, the farmer with a greater endowment of human capital has more incentive to invest in information. For these farmers, moreover, the level of information that must be attained before adoption will occur is lower. Thus, farmers with higher levels of human capital are expected to adopt earlier, *ceteris paribus*, and to use the new input more intensively.[4]

HYPOTHESES

The dynamic theory of technology adoption leads to several hypotheses about the role of farm size in determining the pattern of adoption. First, because the average cost of acquiring information is less for the larger farmer, we expect the larger farmer to be more informed about the technology at any given stage in the innovation cycle. Second, because knowledge is a critical aspect of the adoption decision, the inherent incentive for larger farmers to be better informed implies a positive link between farm size and early adoption. Third, to the extent that larger farmers have greater endowments of human capital and are less risk averse, we would expect larger farmers not only to be more informed and adopt sooner, but to use the new input more intensively in the early stages of diffusion.

DATA

An *ex ante* survey methodology described by Lesser *et al.* was used to collect the data for hypothesis testing. The survey, developed and pretested at Cornell for use in New York, was modified slightly for use in the Southeast. In the survey packet, farmers were given information about BST, describing its effects on milk production, animal health, feed requirements, and potential profitability. The dairy farmer was to assume that BST would be administered by daily injections. The farmer was told that, depending on the actual level of production response, gross daily returns (milk value less feed cost) from use of BST would average 43¢-$1.29 per treated cow; 17¢ was suggested as the average daily cost of treatment. Internal experiments were conducted by asking the farmer how alternative prices of BST would influence his decision about when to adopt and related issues.[5] To explore further the question of price sensitivity, the farmer was asked to indicate the maximum price he was willing to pay for BST given the estimates of gross returns.

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[3] Listening to a news story or cursory examination of readily available farm magazines are examples of information gathered passively. Active gathering of information might include seeking advice from an extension agent, hiring a private consultant, or visiting a farm already using the technology.

[4] The conclusion that farmers with higher levels of human of capital will use new input more intensively than farmers less well endowed is a direct result of the Feder and Slade (p. 310) model. The new input is used at a higher level because, for any given level of usage, the new input's marginal product is higher for the farmer with superior knowledge and understanding of the input. The nexus between human capital and factor productivity appears to be especially important in cases where management ability or other factor complementarity is required if an input is to be used effectively, as appears to be the case for BST because feed rations and other factor must be carefully balanced for the hormone to "work" (e.g., see Kalter *et al.*).

[5] "Internal experiments" are auxiliary questions incorporated into a survey to determine the sensitivity of responses to such items as the sequencing and wording of questions and background information provided by the researcher. Buttel and Geisler (p. 145) urge that such questions be included in ex ante surveys because responses are highly conditional on the assumptions, either implied or explicit, held by survey designers.

Table 1. Sample Means of Socio-Economic Variables from Mail Versus Telephone Surveys of Southeastern Dairy Farmers, 1984-1985

Survey Type	Herd Size	Herd Productivity (lbs./day/cow)	Artificial Insemination[a]	Dairy as Income Source[b]	Age of Owner	Years of Experience	Education Level[c]
Mail	219.3	42.9	1.18	1.09	46.7	23.2	4.7
	(490.4)	(7.8)	(.38)	(.29)	(11.7)	(14.5)	(1.3)
Telephone	154.4	43.9	1.28	1.12	49.9	26.6	4.3
	(202.8)	(8.4)	(.45)	(.38)	(11.3)	(14.7)	(1.2)
t-value[d]	-1.61	.78	1.48	.61	1.84	1.52	-2.1

Note: Numbers in parentheses are standard errors.

[a] If the dairy farmer used AI the answer was coded 1; otherwise 2.

[b] If dairying is the most important source of household income the answer was coded 1: otherwise 2.

[c] The number 4 corresponds to a high school education.

[d] Computed under the null hypothesis that sample means are equal. The critical value of Bonferroni-t for testing 7 hypotheses at the nominal 5 percent level is 2.69.

An initial mailing of the survey instrument was made in October 1984 to 1,000 randomly selected dairy farmers residing in Alabama, Florida, Georgia, and Mississippi. Post card reminders and two additional mailings to nonrespondents resulted in a cumulative response rate of 32 percent.

The question of nonrespondent-bias was examined by telephoning a random sample of 50 nonrespondents. Seven questions were asked about farm and personal characteristics. The differences in sample means for the respondents and nonrespondents were tested for significance using the Bonferroni t-test for multiple hypothesis testing (Savin). Results indicate differences among sample means are not significant at the nominal 0.05 Bonferroni significance level for any of the selected socio-demographic characteristics (Table 1). Based on these results, it was concluded that nonrespondent bias is not a problem with these data, at least with respect to these seven variables.

The representativeness of the sample was checked by comparing the age distribution of respondents with 1982 census data. Results showed the survey data tending to over-represent younger farmers and under-represent older farmers. But the data are representative of the age categories containing the largest number of commercial dairy farmers, age 45 - 65. Cross-checking the herd size and production figures against state averages revealed consistency in farm size but systematic overstatement of herd production. Thus it appears the sample is skewed toward producers with better management ability.

Survey respondents from each state are similar in most respects (Table 2). They are on average 47 years of age, with about 23 years of dairying experience and some formal schooling beyond high school. Productivity of the dairy herd is about the same in each state, averaging 43 pounds of milk per cow per day.

Table 2. Mean Socio-Economic and Production Characteristics of Southeastern Dairy Farmers, 1984

State	Age of Owner	Number of Years Dairying	Herd Productivity (lbs./day/cow)	Herd Size [a]	Education Level [b]	N
Alabama	46	21	43	122	4.8	90
Florida	47	26	44	534	4.6	78
Georgia	46	22	44	127	4.6	80
Mississippi	47	24	41	95	4.7	65
All states	47	23	43	219	4.7	313

[a] The figure for Florida includes one farm of 7,000 head. Excluding this farm reduces the average herd size in Florida to 445.

[b] The education variable was coded as follows: 1 = Some grade school; 2 = Grade school graduate; 3 = Some high school; 4 = High school graduate; 5 = Some college; 6 = College graduate; and 7 = Graduate school.

Herd size is the one factor showing considerable differences across the states. In the sample, Mississippi has the smallest average herd size—95 head. Florida dairy farms, with an average herd size of 533 head, are the largest in the Southeast. Alabama dairy farms are about the same size as Georgia dairy farms, averaging 125 head.

HYPOTHESIS TESTING

The hypothesized link between farm size and early adoption was tested using a logit model. Three equations were estimated, one explaining the respondent's self-described level of awareness of BST, another explaining the rate of adoption, and a third explaining the intensity of adoption, *i.e.*, whether the producer would initially experiment with a few cows or with many. The dependent variable of each equation is defined to be dichotomous, assuming a value of zero or one (see Table 3 for precise definitions). Explanatory variables include: the level of human capital of the farm operator (age, education, experience); risk aversion (the importance of dairying as a source of income); innovativeness (use of artificial insemination, use of alternative milking systems and barn types); and management ability (average productivity of the herd). Number of cows serves to measure farm size.

Because access to information was identified by Feder and Slade as an additional factor influencing early adoption, and states differ in their budget allocations for extension services (Table 4), state dummy variables were specified as additional control variables. Maximum-likelihood estimation of the resulting multivariate logit model yields estimates that are consistent and asymptotically efficient. Because logit parameter estimates are asymptotically normal, conventional tests of significance apply (Kmenta, p. 553).

Whether human capital reinforces or offsets the impacts of risk aversion and information-acquisition costs in determining the pattern of adoption depends on the correlation between farm size and the farmer's endowment of human capital. If the correlation is negative, *i.e.*, smaller farmers have more schooling, experience and training, *ceteris paribus*, then the human capital effect would be offsetting, weakening the theoretical link between farm size and early adoption. If, as seems more plausible, larger farmers have higher levels of human capital, the theoretical link between farm size and early adoption is strengthened.[6]

The risk-aversion variable (importance of dairying as a source of income) is expected to be negatively correlated with early adoption because without the protection offered by alternative sources of income the dairy farmer would be less willing to experiment with a new input before more is known about its on-farm performance. The variables serving as proxies for innovativeness are expected to have positive signs. Use of technologies such as artificial insemination would indicate a predisposition toward trying new methods. No *a priori* expectations are placed on the variable for management ability (herd productivity). Farmers with more productive herds may be more progressive but, at the same time, they may be more wary of a technology that might upset a successful production regime. Because Georgia spends about 30 percent more per rural resident on cooperative extension than the other three states included in the survey (Table 4), we expect farmers in Georgia to have a higher level of knowledge of BST and therefore to be more likely to adopt BST early. The crucial variable relative to the research objectives of this paper, herd size, is expected to have a positive sign across all equations if the theory of a positive link between early adoption and farm size is correct.

RESULTS

Logit estimates of the awareness, adoption rate, and adoption intensity equations are presented in Table 5. The equations were estimated with 244 observations, the number of surveys having complete information for all variables. Mean values of the dependent variables, listed in the last row of the

[6]The postulated link between human capital and farm size was examined by estimating the following regression (*t*-ratios in parentheses):

$$\text{Herd Size} = \underset{(2.9)}{223.4} - \underset{(-.6)}{25.8}\ \text{Educ 1} + \underset{(1.5)}{70.6}\ \text{Educ 2} + \underset{(5.0)}{6.9}\ \text{Experience}$$

$$-\underset{(-2.4)}{4.1}\ \text{Age} \qquad R^2 = .0941 \qquad N = 317$$

where variables are as defined in Table 3. The regression lends support to the notion that larger farmers have more human capital, though the link between formal schooling and farm size is weak. But experience, even after controlling for age, is strongly correlated with farm size. (The critical value of the Bonferroni *t* for $p < 0.05$, $K = 5$, and infinity degrees of freedom is 2.58 [Miller, p.238, Table II.]). Interpreted literally, the estimated coefficient indicates each additional year of experience dairying is associated with an increase in herd size of approximately seven cows.

Table 3. Definition of Variables

Variable Name	Definition	Coding
Awareness	Self-rated familiarity with BST	1 - somewhat or very familiar 0 - otherwise
Adoption Rate	Opinion as to speed of adoption	1 - adopt immediately upon availability 0 - otherwise
Adoption Intensity	Expected initial extent of adoption	1 - use on half of herd or more 0 - otherwise
Age	Age of farm owner	Actual years
Experience	Number of years dairying	Actual years
Educ 1	Educational level of farm operator	1 - high school graduate/some college 0 - otherwise
Educ 2	Educational level of farm operator	1 - college graduate or above 0 - otherwise
Productivity	Average production of herd in first half of 1984	Pounds per cow per day
Herd Size	Average milking herd size second half of 1983	Number of cows
Art. Insem.	Use of artificial insemination	1 - presently use 0 - otherwise
Dairy Income	Importance of dairying as a source of household income	1 - most important source 0 - otherwise
Herbone	Herringbone parlor milking system	1 - use this system 0 - otherwise
Side Opening	Side opening milking system	1 - use this system 0 - otherwise
Free Stall	Free stall type of barn	1 - have this type 0 - otherwise
Loose Housing	Loose housing barn type	1 - have this type 0 - otherwise
Fla.	State in which dairy operates	1 - Florida 0 - otherwise
Ga.	State in which dairy operates	1 - Georgia 0 - otherwise
Miss.	State in which dairy operates	1 - Mississippi 0 - otherwise
Non-Adopter	Farmer indicating non-adoption of BST	1 - will never adopt 0 - otherwise
Late-Adopter	Farmer indicating late adoption of BST	1 - will adopt 5 years or more after availability 0 - otherwise
Implant	Whether availability of an implant to administer BST would increase willingness-to-pay (WTP)	1 - yes, implant would increase WTP 0 - otherwise
Prior Experience	Whether farmer had prior experience with growth hormones	1 - yes 0 - otherwise
Price	Maximum price farmer is willing to pay for BST	Actual number in cents per dose
Respondent	Whether farmer answered the Price question	1 - yes, answered the question 0 - otherwise

table, indicate that 16.7 percent of the sample were "somewhat or very familiar" with BST; 37.5 percent would adopt BST immediately upon availability; and 31.9 percent would apply BST to one-half or more of the herd in the initial adoption period.

Awareness Equations

Signs of the coefficients in the awareness equation generally agree with *a priori* expectations. Age, education, herd size, productivity, and use of artificial insemination are all positively related to the level of awareness of BST. The coefficient for the herd size variable is significant at better than the five percent level according to a one-tail t-test. Its sign supports the hypothesized positive relationship between farm size and farmers' knowledge about a new technology.

Table 4. State Appropriations for Cooperative Extension Services, Four Southeastern States, 1984-1986 Annual Average

State	State Appropriation[a]	Appropriation Per Rural Resident [b]
	(mil. dollars)	($/person)
Alabama	15.1	9.69
Florida	16.3	10.65
Georgia	28.3	13.78
Mississippi	13.9	10.46

[a]Source: Personal communication with Dr. J.H. Yeager, Associate Dean, College of Agriculture, Auburn University.

[b]Based on 1980 census counts obtained from the - *Statistical Abstract of the U.S. 1988.*

Adoption Equation

Herd size is positively related to early adoption, suggesting "early bird" adopters of BST will consist mostly of larger farmers. The coefficient is significant at the five percent level. The finding that large dairies plan to adopt BST earlier than small dairies agrees with *a priori* expectations. It calls into question the assertion by Kuchler and McClelland (p.11) that "No documented evidence shows that farm size and innovation go hand-in-hand in U.S. agriculture," not to mention an established literature of repeated findings of relationships between farm size and a wide variety of innovations (Bohlen).

The negative sign associated with the productivity variable, literally interpreted, means that farmers with more productive herds will be slower to adopt BST, *ceteris paribus.* The finding of a negative coefficient between early adoption and productivity contradicts assumptions made in several studies that more productive farmers will be the first to adopt BST (e.g., Kalter *et al.*) but is consistent with the findings of Zepeda. The inverse relation between productivity and early adoption may reflect concern about Dairy Herd Improvement Association (DHIA) recordkeeping, as some respondents questioned the impact of BST on these records. (Dairy farmers with above average yields participate to a greater extent in the DHIA.) Alternatively, below-average producers might view BST as a means of overcoming deficiencies in management practices or genetic potential of the herd.

The Georgia variable has a positive coefficient, indicating that Georgia producers anticipate adopting BST sooner than other Southeastern producers. The positive coefficient for Georgia may reflect a

Table 5. Logit Analysis of Factors Influencing Awareness, Adoption Rate and Adoption Intensity of Bovine Somatotropin. Southeastern Dairy Farmer Survey Data, 1984

Independent Variable	Awareness		Adoption Rate		Adoption Intensity	
	Coef.	St. Error[a]	Coef.	St. Error	Coef.	St. Error
Intercept	-8.265	2.11	.3781	1.239	-.6687	1.271
Age	.0436	.023	-.0138	.016	.0122	.016
Experience	-.0015	.019	.0066	.014	.0107	.015
Educ 1	.8206	.851	-.6526	.448	.8463	.530
Educ 2	1.9385	.842	.0793	.484	.6589	.578
Productivity	.0487	.027	-.0375	.019	-.0477	.020
Herd Size	.0021	.0009	.0015	.0008	.0006	.0008
Art. Insem.	1.3849	.795	.7626	.405	.5171	.406
Dairy Income	-.3662	.564	.6581	.500	-1.0606	.472
Herbone	—	—	.1250	.335	.2860	.353
Side Opening	—	—	-.6345	.524	-.3670	.562
Free Stall	—	—	-.7991	.431	-.1512	.443
Loose Housing	—	—	-.0433	.421	.2980	.437
Florida	-.0123	.587	-.2322	.479	.3695	.523
Georgia	.8167	.615	.7688	.413	1.4954	.445
Mississippi	.3934	.533	.4795	.424	.7332	.458
P[b]	.167		.375		.319	

[a] Standard errors are asymptotic.

[b] P is the mean value of the dependent variable.

higher level of knowledge on the part of Georgia producers about the potential advantages of BST due to the larger expenditures for extension in that state.

The artificial insemination factor positively influences the adoption rate. This result conforms to expectations because artificial insemination serves as a proxy for innovativeness.

Adoption Intensity Equation

The Georgia variable is positively related to the intensity of adoption, while productivity and dairy income are negatively related. The negative coefficient for the productivity variable indicates that more productive farmers are extra cautious about introducing BST. The inverse relationship between dairy income and adoption intensity is consistent with the hypothesis that more risk-averse farmers will have a lower probability of adopting BST and will use it less intensively. The insignificance of the herd size variable does not support the hypothesis that larger farmers will use BST more intensively.

The positive coefficient associated with Georgia is consistent with results for adoption rate: Georgia dairy farmers not only plan to adopt sooner than other southeastern producers, they plan to apply BST to a greater number of cows in the trial period.

THE PRICE OF BST AND ITS INFLUENCE ON ADOPTION

In an attempt to determine how the price of BST might affect the adoption decision, respondents were asked to indicate the maximum price they would be willing to pay for the hormone. In answering the question, the farmer was asked to study a "fact sheet" indicating the potential returns from BST for alternative levels of production response and to consider that a retail price of 17¢ per cow per day had been proposed. The question posed was as follows:

Table 6. Willingness to Purchase BST at Alternative Prices, Southeastern Dairy Farmers, 1984

Price Level	Cumulative Percent Willing to Purchase (N = 178)
(¢/dose)	(%)
< 10 or higher	95
15 or higher	78
20 or higher	59
25 or higher	32
30 or higher	11
35 or higher	7
40 or higher	2

What is the *maximum* price you would pay for the hormone given the gross return figures discussed in the Fact Sheet? (Remember, the substance must be injected daily.)[7]

______¢ per cow per day.

Perhaps because of the speculative nature of the question and the fact that not all the respondents planned to use BST, only about one-half of the respondents elected to give an answer. For these individuals, the distribution of responses are indicated in Figure 1, which shows most farmers selecting a maximum price between 20 and 24¢ per dose.[8] But the distribution is skewed in favor of lower prices. Given the estimated gross returns to BST of 43¢ - $1.29 per treated cow per day, few farmers were willing to pay more than 40¢.[9]

Market sensitivity to the price of BST was determined by studying the cumulative distribution of maximum willingness-to-pay prices. Assuming BST will not be purchased if the actual price exceeds the maximum pay price, Table 6 shows the percentage of dairy farmers planning to use BST at different price levels. For example, at the average maximum

[7] Recent developments point to the coming availability of products with seven, 14, and 28 injection periods. Had this information been available to survey respondents, estimated maximum prices probably would be greater than those reported below.

[8] A reviewer questioned whether zero values are affecting the willingness-to-pay measure because any non-adopters answering the question would logically indicate zero for their maximum pay price. Apparently this is not a problem because the percent of respondents indicating a pay price below 10¢ per dose is less than five percent (see Figure 1). (The question of potential selectivity bias arising form nonresponse is addressed later.)

[9] The wide divergence between the expected value of the marginal product of BST and expected marginal costs implies a relatively large risk premium associated with its use. Alternatively, farmers may be understating their true willingness-to-pay in the belief that their response will have little effect on the introduction of BST and, once it is introduced, they want to pay as little as possible for it.

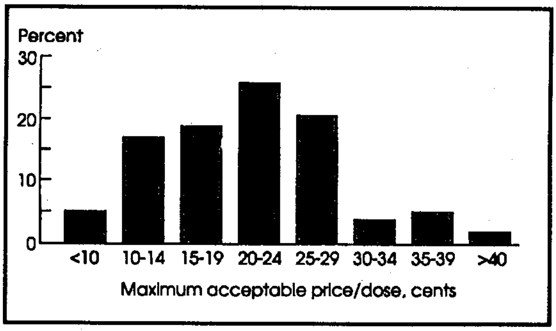

Figure 1. Maximum Acceptable Price for BST, Southeastern Dairy Farmers, 1984

pay price of 21¢, BST achieves about 59 percent market penetration.

The data in Table 6 highlight the dynamics between adoption and expected profitability of the technology. For example, if dairy farmers are required to pay 30¢ per daily dose instead of 20¢, potential adoption declines from 59 percent to 11 percent. Conversely, lowering the price to 10¢ (which would still yield a 17.6 percent gross manufacturing margin if BST could be produced and sold for 8.5¢, see Kalter *et al.*) increases the rate of adoption to 95 percent.[10] The sensitivity of the adoption decision to price is consistent with the work of Griliches emphasizing the role of expected profitability in technology adoption.

The relation between price and adoption was quantified further by estimating the following "demand curve" for BST (*t*-ratios in parenthesis):

$$\text{(1)} \quad Q = \underset{(19.0)}{129.21} - \underset{(-13.1)}{3.33\,P} \qquad R^2 = .98$$

where Q = percent of dairy farmers willing to adopt BST and P = price of BST in cents per dose. The equation, estimated using the data in Table 6, has significant coefficients and provides a good fit to the data in the relevant range.

The "price elasticity" for BST, evaluated at data means, is -1.8. (For comparison, when equation (1) is estimated in logarithmic form, the elasticity is -2.1.) The coefficient, being greater than one in absolute value, implies an elastic demand. Pricing of BST, it appears, will be pivotal in determining the percent of farms adopting BST in the Southeast.

The apparent sensitivity of producers to the price of BST warrants further analysis of the willingness-to-pay question. Of particular interest in terms of our research objectives is whether the results are representative of the pool of potential users (given the large number of respondents who did not answer the question) and whether the willingness-to-pay differs by farm size.

An appropriate method for addressing these questions is Heckman's procedure for dealing with sample selectivity bias. Selectivity occurs when an equation is estimated using less than the complete sample because of missing values or other reasons (Heckman). The resulting equation is no longer representative of the population but rather a subset "selected" according to some criterion (e.g., answering a question). If the criterion for selecting the subsample is significantly related to the dependent variable (say willingness-to-pay), the estimated coefficients are biased and inconsistent.

The bias can be avoided by employing a two-step procedure. The first step involves estimating a probit equation to "explain" the selectivity (the dependent variable equals one if the respondent answered the question and zero otherwise). From this equation, the inverse of Mill's ratio $\hat{\lambda}_i$ is computed for each respondent in the full sample (Heckman, p. 156). In the second stage the original equation is estimated by OLS (or GLS as appropriate) for the subsample with $\hat{\lambda}_i$ added as a regressor. Parameter estimates obtained by this two-step procedure are consistent (Lee, Maddala). The significance of $\hat{\lambda}_i$ can be interpreted as a test for selectivity bias.

In applying the Heckman procedure to the questions of representativeness and farm size effects, two equations were specified (Table 7). The equation relevant to the representativeness question is the (first-stage) probit model. Using the Bonferroni test for multiple hypotheses and a nominal significance level of five percent, respondents were found to be similar to non-respondents across all socio-economic categories. As indicated by the coefficients of the variables defining adoption intentions, an important reason for not answering the question is its deemed relevance: those intending never to adopt BST (about nine percent of the sample), or to adopt only after a lengthy waiting period, had the greatest probability of non-response.

The question about farm size effects is answered by reference to the second-stage (OLS) equation. As with the first-stage equation, the farm size variable is not significant, indicating no systematic

[10] Given the relatively low per-unit expected cost and presumed profitability of BST, the sensitivity to price is surprising. Yet Lesser *et al.* obtained similar results in their survey of New York dairy farmers. In particular, when asked how an increase in price from 17¢ to 25¢ would affect their adoption decision, 47 percent of the New York respondents indicated they were less likely to try the product (Lesser *et al.*, p.166). A decrease in price to 10¢ would increase the likelihood of trial for 40 percent of the respondents. Based on these results, Lesser *et al.* (p.166) conclude that the "...market price [of BST] will have a definite impact on adoption rates."

Table 7. Determinants of Willingness-to-Pay (WTP) for BST, Heckman's Two-Stage Estimation Procedure, Southeastern Dairy Farmer Survey Data, 1984

Variable	Stage 1 Equation Probit Analysis of Selectivity	Stage 2 Equation OLS Estimate of WTP Corrected for Potential Selectivity Bias
Intercept	1.5641	25.8160
	(.6221)[a]	(6.4495)
Age	-.0218	.1071
	(.00856)	(.1189)
Experience	.0053	-.0776
	(.0071)	(.0729)
Educ 1	.3285	-5.7907
	(.2097)	(2.8606)
Educ 2	.3944	-4.9249
	(.2296)	(3.2050)
Productivity	-.0106	.1056
	(-.9765)	(.1128)
Herd Size	-.0002	.0058
	(.0003)	(.0038)
Florida	-.2626	-3.0170
	(.2222)	(2.6544)
Georgia	-.1404	-.3299
	(.2031)	(2.1051)
Mississippi	-.3114	.1305
	(.2145)	(2.4188)
Non-Adopter	-.9678	-13.635
	(.2790)	(5.902)
Late Adopter	-1.2410	—
	(.3840)	
Implant	—	-2.7335
		(2.1212)
Awareness	—	4.3581
		(2.0990)
Prior Experience	—	2.8994
		(2.0531)
λ_i	—	-11.644
		(7.1990)
$\bar{R}^2$	—	.1561
Critical value of the Bonferroni t statistic $\alpha = 0.05$[b]	2.88	2.24
N	3.17	178

Note: Dependent variables in stage 1 and stage 2 equations are, respectively, Respondent and Price, as defined in Table 3.

[a]Numbers in parentheses are asymptotic standard errors.

[b]The critical values differ because in the stage 1 equation all variables (including the intercept) are being tested for significance whereas in the stage 2 equation only the herd size and λ_i variables are being tested.

differences in willingness-to-pay among farmers in different size categories. Willingness-to-pay being unrelated to farm size may reflect BST's expected low per unit cost.

The insignificance of the inverse Mill's ratio indicates, despite the large number of non-respondents, selectivity bias is not a problem. This finding corroborates the results of the first-stage equation indicating no differences between respondents and non-respondents. It increases confidence in the validity of the estimated "demand elasticity" and associated analysis presented earlier.

CONCLUDING COMMENTS

The question of scale neutrality of BST has important implications for the design of policies intended to mitigate the potential adverse impacts during the transition period following its introduction. This study finds that the adoption process, and not the nature of the input *per se*, is a major source of scale bias. If information-based biases cause larger farmers to adopt first and early adopters to then enlarge production in part by acquiring the assets of late- or non-adopting neighbors, then it becomes less important whether a new input is fixed or variable: new technologies by definition will favor the larger producer.

Based on previous research and the theoretical literature on technology adoption, there are good reasons to believe early adopters of BST will be larger farmers. Larger farmers enjoy lower per-unit information-acquisition costs and are more able (and possibly more willing) to assume the risks associated with innovation. Moreover, the higher level of human capital usually associated with larger farmers facilitates the learning that must occur to realize the full potential of a new input.

Logit analysis of *ex ante* survey data largely supports the hypothesized link between early adoption and farm size. In particular, the statistical analysis shows a positive correlation between herd size and (1) southeastern dairy farmers' self-described awareness of BST and (2) their intentions to adopt BST early. The only result not consistent with *a priori* expectations is the lack of a relationship between herd size and intensity of use, i.e. the data suggest that although larger farmers plan to adopt sooner than smaller farmers, they plan to apply BST to the same portion of the herd as smaller producers. But the apparent unwillingness of larger producers to commit more fully to BST during the experimental period does not diminish the basic conclusion that BST will provide greater benefits to large-scale operations.

Several *caveats* are necessary in interpreting the results. First, the results pertain to a relatively small segment of the dairy industry, that in the Southeast. A definitive statement about the overall scale bias of BST requires corroborative evidence from other regions, especially the prime milk-producing states of California, New York and Wisconsin. Second, the evidence presented in this paper is based on an *ex ante* survey procedure which contains well-known biases as discussed cogently by Buttel and Geisler. Answers to hypothetical questions are not always a reliable indicator of actual behavior. Farmers may exaggerate their willingness to adopt a technology to appear progressive. Then, too, the ability to respond accurately to a question is greater if the question pertains to the present or recent past than to the (distant) future. Still, we concur with Fishel that economic analysis of biotechnologies must go beyond conjecture to analysis of data, even if these data are of the "soft" variety.

The sensitivity of producers to the price of BST indicated by the survey suggests an avenue for attenuating the scale bias. In addition to tailoring technical assistance and information programs about BST to meet the needs of smaller dairies, policymakers may wish to consider targeted subsidies whereby smaller dairies could purchase BST at a reduced price. To encourage early adoption and limit costs, coupons could be made available to smaller producers for a limited time following the introduction of BST.

REFERENCES

Bohlen, J.M. "The Adoption and Diffusion of Ideas in Agriculture." *Our Changing Rural Society: Perspectives and Trends*. J.H. Capp, ed., Iowa State University Press, 1964.

Buttel, F. and C.C. Geisler. "The Social Impacts of Bovine Somatotropin: Emerging Issues." *Biotechnology and the New Agricultural Revolution*. J.J. Molnar, and H. Kinnucan, eds. Boulder, CO: American Association for the Advancement of Science and Westview Press, 1989.

Cancian, F. "Stratification and Risk-Taking: A Theory Tested on Agricultural Innovation." *Am. Socio. Rev. 32(1967):912-927.*

Cochrane, Willard. *The Development of American Agriculture*. University of Minnesota Press, 1979.

Comstock, G. "The Case Against bGH." *Agriculture and Human Values*. 5(1988):36-52.

Fallert, R., T. McGuckin, C. Betts, and G. Bruner. "bST and the Dairy Industry." Washington, D.C. USDA ERS. Report No. 579, 1987.

Feder, Gershon and Roger Slade. "The Acquisition of Information and the Adoption of New Technology." *Am. J. Agr. Econ.* 66(1984):312-320.

Fishel, W.L. "The Economics of Agricultural Biotechnology: Discussion." *Am. J. Agr. Econ.* 69(1987):438-439.

Griliches, Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica* 25(1957):501-522.

Hammond, J.W. "The Minnesota Dairy Farm Sector: Summary of the 1988 University of Minnesota Dairy Farm Survey." Minnesota Report No. 216-1989, Minnesota Agricultural Experiment Station. St. Paul, 1989.

Hatch, U. and F. Kuchler. "Regulation of Agricultural Biotechnology: Historical Perspectives." *Biotechnology and the New Agricultural Revolution*. J.J. Molnar and H. Kinnucan, eds. Boulder, CO: American Association for the Advancement of Science and Westview Press, 1989.

Heckman, J.J. "Sample Selection Bias as a Specification Error." *Econometrica* 47(1979):153-161.

Just, R., and D. Zilberman. "Stochastic Structure, Farm Size, and Technology Adoption in Developing Agriculture." *Oxford Economic Papers* 35(1983):307-328.

Kalter, Robert J., Robert Milligan, William Lesser, William Magrath, and Dale Bauman. "Biotechnology and the Diary Industry: Production Costs, Commercial Potential, and the Economic Impact of the Bovine Growth Hormone," Cornell University Agricultural Economics Department, A.E. Research 85-20, 1985.

Kinnucan, H., U. Hatch, R. Pendergrast, and J.J. Molnar. "Adoption and Diffusion Potentials for Bovine Somatotropin in the Southeast Dairy Industry." Alabama Agricultural Experiment Station Bulletin No. 605, Auburn University, February 1990.

Kmenta, Jan. *Elements of Econometrics*. 2nd ed. New York: Macmillan Publishing Co., 1986.

Kronfield, D.S. "Biological and Economic Risks Associated with Use of Bovine Somatotropin." *J. Vet. Medicare Assoc.* 192(1988): 1693-1700.

Kuchler, F. and J. McClelland. "Issues Raised by New Agricultural Technologies: Livestock Growth Hormones." USDA ERS. Agricultural Economic Report No. 608, 1989.

Lee, L.F. "Fully Recursive Probability Models and Multivariate Log-Linear Probability Models for the Analysis of Qualitative Data." *Econometrics* 16(1981):51-69.

Lesser, W., W. Magrath, and R. Kalter. "Projecting Adoption Rates: Application of an *Ex Ante* Procedure to Biotechnology Products." *North Central J. Agr. Econ.* 8(1986):159-174.

Lindner, R.K. "Farm Size and the Time Lag to Adoption of Scale-Neutral Innovations." Mimeographed. Adelaide, Australia: University of Adelaide, 1980.

Maddala, G.S. *Limited-Dependent and Qualitative Variables in Econometrics.* New York: Cambridge University Press, 1983.

Miller, R.G., Jr. *Simultaneous Statistical Inference.* 2nd ed. New York: Springer-Verlag, Inc., 1981.

Molnar, J.J., K.A. Cummins, and P.F. Novak. "Bovine Somatotropin: Biotechnology Product and Social Issues in the U.S. Dairy Industry." *J. Diary Science* 73(1990). Forthcoming.

Pratt, J.W. "Risk Aversion in the Small and in the Large." *Econometrica* 32(1964): 122-136.

Rogers, E. *Diffusion of Innovations.* 3rd ed. New York: Free Press, 1985.

Savin, N.E. "Multiple Hypothesis Testing." *Handbook of Econometrics.* Z. Griliches and M.D. Intriligator, eds. Amsterdam: Elsevier Science Publishers, 1984.

Zepeda, L. "A Survey of California Dairy Farmers: Potential Adoption of Bovine Somatotropin." Univ. of California Agr. Issues Center Paper No. 88-1, 1988.