MARKET IMPACTS OF BOVINE SOMATROPIN: A SUPPLY AND DEMAND ANALYSIS

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Abstract

The potential economic impacts of the introduction of bovine somatotropin (bST) on U.S. milk supply and demand are analyzed using a national model of Class I and Class II milk markets. The results indicate that the introduction of bST will lead to lower milk prices, higher milk production, and larger government purchases of dairy products. Unlike previous economic analyses of bST, this analysis considers both supply and demand effects of bST. The implication is that studies that ignore potential demand-side effects may produce misleading results.

Key words: bovine somatotropin, supply effect, demand effect, dairy policy

Bovine somatotropin (bST) is a naturally occurring protein produced in the pituitary gland of dairy cows that regulates milk production. Through advances in recombinant DNA technology, synthetic bST can now be manufactured and injected into cows to increase milk yields. While not yet commercially available, trials in experimental herds throughout the nation have shown that cows in well-managed herds that were given bST experienced increases in milk yields by as much as 25 percent (Animal Health Institute).

Over the past several years, there have been many studies that have analyzed the potential economic impacts of bST (e.g., Fallert et al.; Kaiser and Tauer; Kalter et al.; Lesser et al.; Magrath and Tauer; Marrion and Wills; McGuckin and Ghosh; Schmidt; Tauer and Kaiser; Yonkers et al.). All of these studies have focused on the supply-side effects of bST, while assuming that there would be no demand-side effects. However, several recent reports have suggested that there could be a sizeable decrease in demand for milk if bST is adopted (McGuirk, Preston, and Jones; Preston, McGuirk, and Jones; Smith; McGuirk and Kaiser). These studies have shown that a significant number of consumers perceive milk from cows given bST to be unsafe or undesirable and feel that bST should not be approved. To date, there has not been research linking the potential supply-side effects due to bST with demand-side effects within a market framework. Ignoring one side of the market in favor of the other may bias some of the potential impacts of bST on important market variables, e.g., prices and net government purchases under the dairy price support program.

The purpose of this article is to investigate potential national market impacts due to bST when both supply and demand-side effects are considered. A model of the national dairy industry was developed and used to simulate equilibrium price and quantity values at the farm and retail levels from 1991 to 1995 for several bST scenarios. Four scenarios were examined including (1) bST is not available for the entire period; (2) bST is available beginning in 1992 and there is a supply, but not a demand-side effect; (3) bST is available in 1992, and there is a supply-side effect and a fluid, but not a manufactured, demand-side effect; and (4) bST is available in 1992 and there is a supply-side effect and a fluid and manufactured demand-side effect. For all four scenarios, it was assumed that the policy provisions of the 1990 Food, Agriculture, Conservation, and Trade Act were in place. The supply-side effect due to bST was incorporated into the model using information on adoption rates, yield response, and costs from previous studies. The demand-side effects due to bST were modeled based on the results from two studies: (1) McGuirk, Preston, and Jones, and (2) Kaiser, Scherer, and Barbano.

METHODOLOGY

The methodology used to analyze the various bST scenarios consisted of a dynamic econometric model of the national dairy industry, and a set of simulation procedures that (a) incorporated bST into the supply and demand equations, (b) forecasted all exogenous and predetermined variables, and (c) determined annual equilibrium values for all endogenous variables. It was assumed that the national dairy market consists of an aggregate farm sector and an aggregate retail sector, which is similar to the structure used by Kaiser, Streeter, and Liu. Within this framework, dairy farmers produce and sell raw milk to retailers

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of dairy products. The retail market is subdivided into two groups based on the type of products being processed and sold. Class I (fluid products) retailers process and sell fluid products directly to consumers, and Class II (manufactured products) retailers process and sell manufactured dairy products directly to consumers. Additionally, the two major federal programs that provide economic regulations for the dairy industry—the federal dairy price support and federal milk marketing order programs, were assumed to be in effect.[1]

The econometric model used national annual time series data (1960 through 1989) on retail and farm market variables to estimate supply and demand functions for the U.S. dairy market. To simplify the estimation of the model, it was assumed that farmers expect the milk price in the next year to be the price currently observed. This assumption, which is often used in dairy models (e.g., Chavas and Klemme), allowed the farm supply to be estimated independently from the retail market because the lagged milk price is exogenous. The following describes the results of the econometric model and the simulation procedures in detail.

The Econometric Model

Table 1 presents the econometric results for the estimated equations, and Table 2 defines all variables used in the model. The coefficients for all variables have the expected signs, and the estimated equations appear to fit the data quite well based on the adjusted coefficient of variation.

The two estimated equations in the farm market were cow numbers and production per cow. The cow number equation (CN) was estimated using ordinary least squares (OLS) as a function of cow numbers in the previous period, real average farm milk price lagged one year (P^{fm}_{-1}), real dairy feed costs (FC), and a policy dummy variable corresponding to the years that the Dairy Termination Program (DTP) was in effect.[2] The use of cow numbers in the previous year reflected capacity constraints on the national dairy herd, while dairy feed costs corresponded to the major variable cost faced by dairy farmers. The policy dummy variable captured the significant reduction in cows in 1986 and 1987 due to the DTP. To correct for autocorrelation, a first-order autoregressive error structure was imposed.

The production per cow (PPC) equation was estimated using OLS as a function of production per cow in the previous year, the real average milk price lagged one year, real feed costs, and a trend variable (T). Lagged production per cow was used to reflect dynamic adjustments in milk yields over time, and real feed costs represented the most important variable cost influencing milk yields. The trend variable was used as a proxy for genetic improvements in cows over time.

The retail manufactured market consisted of retail manufactured demand and supply equations, which were estimated simultaneously using two-stage least squares (2SLS) to correct for bias due to price and quantity being determined simultaneously. An instrumental variable was constructed for the retail manufactured price (P^m) by regressing it on two exogenous variables: the support price (SP) and the average hourly wage in the manufactured sector (W). To deal with autocorrelation, a first-order autoregressive error structure was imposed. The resulting predicted value for the retail manufactured price (P^m_{ins}) was used as an instrumental variable in the retail manufactured supply and demand equations instead of the actual retail manufactured price.

Retail per capita manufactured demand (Q^{md}/POP) was estimated as a function of the real retail manufactured price instrument, real retail price for fats and oils (P^{fo}), real per capita disposable income (Y), percent of population under 19 years old (A_1), and a time trend. The real retail price of fats and oils was used as a proxy for manufactured product substitutes, and the percent of people under 19 years old reflected the lower consumption of manufactured dairy products in this age bracket since 1960. The time trend was used as a proxy for changing consumer tastes away from high-fat products.

An important retail manufactured supply determinant is the Class II price (P^{II}) paid by retail suppliers. Because P^{II} was endogenous, an instrumental variable was constructed by regressing it on the support price and a time trend. The resulting predicted value (P^{II}_{ins}) was used in the retail fluid supply function in place of the actual Class II price. Other retail manufactured supply determinants included supply in the

[1] Under the dairy price support program, the government supports the price of manufactured grade milk by agreeing to buy unlimited quantities of storable dairy products at specified purchase (support) prices. By increasing the farm demand for milk, the government thereby indirectly supports the price of raw milk. The basic thrust of federal milk marketing orders is to institute a system of classified pricing for Grade A (fluid eligible) milk, where handlers of milk used for fluid purposes pay a higher price (Class I price) than handlers of manufactured grade milk, who pay Class II of Class III prices. Farmers receive an average of the class prices, weighted by the fluid and non-fluid utilization rates in the marketing area.

[2] The term "real" used throughout this paper means that the nominal measure was deflated by the Consumer Price Index for all items (1967 = 100).

Table 1. Econometric Equations for the Farm and Retail Markets[a]

Cow Numbers Equation

$$\ln CN = 0.9896 \ln CN_{-1} + 0.0617 \ln p^{fm}_{-1} - 0.0760 \ln FC - 0.0391\, DTP + 1/(1 + 0.7073\, L)\, u$$

(76.7) (1.3) (-2.4) (-3.7) (4.7)

$R^2 = 0.99$; $DW = 1.97$

Production Per Cow Equation

$$\ln PPC = 2.4482 + 0.7254 \ln PPC_{-1} + 0.0592 \ln P^{fm}_{-1} - 0.0582 \ln FC + 0.0054\, T + u$$

(2.5) (6.8) (1.9) (-2.3) (2.1)

$R^2 = 0.99$; $DW = 2.30$

Retail Manufactured Price Instrument

$$P^m = 4.9210\, SP + 25.5289\, W + 1/(1 + 0.7816\, L)\, u$$

(3.5) (13.8) (6.6)

$R^2 = 0.99$; $DW = 1.81$

Manufactured Demand Equation

$$\ln Q^{md}/POP = -1.7644 - 0.9467 \ln P^m_{ins} + 0.0911 \ln P^{fo} + 0.4980 \ln Y - 2.8103 \ln A_1 - 0.0461\, T + u$$

(-2.9) (-5.7) (1.3) (2.0) (-6.5) (-4.6)

$R^2 = 0.83$; $DW = 2.08$

Class II Milk Price Equation

$$P^{II} = 0.3555 + 0.7891 SP + 0.0875\, T$$

(2.6) (18.3) (4.7)

$R^2 = 0.99$; $DW = 1.14$

Manufacturing Supply Equation

$$\ln Q^{ms} = 0.6759 + 0.6118 \ln Q^{ms}_{-1} + 0.6163 \ln P^m_{ins} - 0.2832 \ln P^{II}_{ins} + 0.0051\, T + 1/(1 - 0.4975\, L)\, u$$

(2.0) (4.7) (2.5) (-2.6) (3.8) (-2.5)

$R^2 = 0.94$; $DW = 1.82$

Retail Fluid Price Instrument

$$P^f = 8.4176\, SP + 12.2101\, W + 1/(1 + 0.9524\, L)\, u$$

(4.0) (4.3) (17.7)

$R^2 = 0.99$; $DW = 2.23$

Fluid Demand Equation

$$\ln Q^{fd}/POP = -1.0246 - 0.4756 \ln P^f_{ins} + 0.0653 \ln P^b + 0.4562 \ln Y - 0.9811 \ln A_2 - 0.0315\, T + u$$

(-3.0) (-3.4) (1.7) (3.6) (-2.4) (-12.0)

$R^2 = 0.99$; $DW = 1.48$

Fluid Supply Equation

$$\ln Q^{fs} = 0.7200 + 0.7240 \ln Q^{fs}_{-1} + 0.1034 \ln p^f_{ins} - 0.1364 \ln (P^{II}_{ins} + D) - 0.0454 \ln P^e + u$$

(1.9) (7.0) (2.5) (-4.0) (-2.2)

$R^2 = 0.89$; $DW = 1.40$

previous year, the real retail manufactured price instrument, and a time trend. Lagged retail supply was included to capture short term production constraints on manufactured supply, and the time trend was included to capture supply shifters such as changes in technology. To correct for autocorrelation, a first-order autoregressive error structure was imposed.

The retail fluid market consists of retail fluid demand and supply equations, which were also estimated using 2SLS. An instrumental variable was constructed for the retail fluid price (P^f) by regressing it on the support price and on the average hourly wage in the manufactured sector. To deal with autocorrelation, a first-order autoregressive error structure was imposed. As was the case with the instrumental variable for the retail manufactured price, the predicted values for the retail fluid price (P^f_{ins}) replaced the actual fluid price as an instrumental variable in the retail fluid supply and demand equations.

Retail per capita fluid demand (Q^{fd}/POP) was estimated as a function of the real retail fluid price instrument, real price of nonalcoholic beverages (P^b), real per capita disposable income, percent of population between 45 and 64 years old (A_2), and a

Table 2. Definitions of Variables Used in NEMPIS[a]

Variable Name	Unit of Measure	Description
CN	1,000 head	Number of cows in the U. S.
P^{fm}	$/cwt.	3.67% butterfat average farm milk price deflated by the Consumer Price Index for all items (CPI; 1967 = 100)
FC	$/cwt.	Dairy ration costs deflated by the CPI
DTP	1 or 0	Intercept dummy (equals 1 for 1986-87)
PPC	lbs.	National average production per cow
T	integer	Trend variable; 1960 = 1, 1961 = 2,...
P^f	1967 = 100	Retail fluid milk price index
SP	$/cwt.	3.67% butterfat support price
W	$/hour	Average hourly wage rate in manufacturing sector
Q^{fd}	bil. lbs.	Fluid demand
POP	mil.	Civilian population
P^f_{ins}	1967 = 100	Retail fluid price instrument deflated by the CPI
P^b	1967 = 100	Retail nonalcoholic beverage price index deflated by the CPI
Y	$1,000	Disposable per capita income deflated by the CPI
A_1	%	Percent of population under 19 years of age
A_2	%	Percent of population between 45 and 64
Q^{fs}	bil. lbs.	Fluid supply ($Q^{fd} = Q^{fs}$)
P^e	1967 = 100	Fuels and energy price index deflated by the CPI
P^m	1967 = 100	Retail manufactured price index
Q^{md}	bil. lbs.	Manufactured demand
P^m_{ins}	1967 = 100	Retail manufactured price instrument deflated by the CPI
P^{fo}	1967 = 100	Retail fats and oils price index deflated by the CPI
P^{II}	$/cwt.	3.67% butterfat Class II price
D	$/cwt.	3.67% butterfat Class I price differential
Q^{ms}	bil. lbs.	Manufactured supply ($Q^{md} = Q^{fs}$)
P^{II}_{ins}	$/cwt.	Class II price instrument deflated by the CPI
MILK	bil. lbs.	Total milk marketings
CCC	bil. lbs.	Milk surplus purchased by the government
TOTDEM	bil. lbs.	Total commercial demand for milk products

[a]Unless otherwise noted, all quantities are expressed in milk equivalent butterfat basis.

time trend. The real price of nonalcoholic beverages was used as a proxy for fluid substitutes. The percent of people between 45 and 64 captured the decline in fluid milk consumption in this age group, and the time trend was used as a proxy for changing consumer tastes away from high-fat products.

An important retail fluid supply determinant is the Class I price paid by retail suppliers, which was endogenous. At the national level, the Class I price was equal to the Class II price plus a fixed fluid differential (D). As a result, the national average fixed fluid differential ($2.30 per hundredweight) was added to the instrumental variable constructed for the Class II price to obtain the Class I price instrumental variable. The resulting predicted value (P^{II}_{ins} + D) was used in the retail fluid supply function in place of the actual Class I price. Other retail fluid supply determinants include supply in the previous year, the real retail fluid price instrument, and the real energy price index (P^e). Lagged retail supply was included to capture short term production constraints on fluid supply, and the real energy price index was a proxy for energy cost, which is another important determinant of supply.

Simulation Procedures

The farm market was defined by the estimated cow number and production per cow equations, one identity (milk marketings, the product of cow numbers times production per cow times 98.5 percent), and an equilibrium condition requiring milk marketings to equal commercial fluid and manufactured demand plus government purchases of dairy products via the dairy price support program. Based on the cow number equation in Table 1, the number of cows in any year t was defined by the following equation:

$$(1)\ CN_t = CN_{t-1}^{.99}\ P^{m\,.06}_{t-1}\ FC_t^{-.08}.$$

The supply-side effect of using bST was incorporated by multiplying the estimated production per cow equation in Table 1 by one plus the product of the average increase in milk yields of treated cows due to bST (I) times the cumulative adoption rate (C). Production per cow in any year t was therefore defined by the following equation:

$$(2)\ PPC_t = (1 + I\,C)\ 11.59\ PPC_{t-1}^{.73}\ P^{m\,.06}_{t-1}\ FC_t^{-.06}\ T_t^{.005}.$$

The use of bST will increase variable costs as feed and labor costs increase and there is the added cost of purchasing bST. This was incorporated into both the production per cow and cow number equations by increasing feed costs by the assumed percentage increase in variable costs due to bST.

Milk marketings was the product of cow numbers and production per cow. However, because about 1.5 percent of milk production is used on the farm,[3] commercial milk marketings (MILK) were defined as the following:

$$(3)\ MILK_t = .985\ CN_t\ PPC_t\,.$$

It was assumed that any excess of total milk marketings above commercial fluid plus manufactured demand is purchased by the government. Hence, the equilibrium condition between the farm and retail sectors was specified by the following condition:

$$(4)\ MILK_t = Q^f_t + Q^m_t + CCC_t,$$

where Q^f and Q^m were the equilibrium fluid and manufactured quantities in the commercial market, and CCC was net purchases by the Commodity Credit Corporation (CCC) under the dairy price support program.[4]

While processors must pay the class prices, the milk price received by all farmers was equal to the weighted average of P^I and P^{II}, where the weights were the percent of fluid and manufactured market utilization. That is, the average farm milk price in year t was defined by:

$$(5)\ P_t^{fm} = P^{II}_t\ ((Q^m_t + CCC_t)/MILK_t) + P^I_t\ (Q^f_t/MILK_t).$$

The retail fluid market was defined by the retail fluid demand function, retail fluid supply function, and an equilibrium condition requiring demand to equal supply. The equilibrium fluid price (P^f) equation was generated by setting the supply equation (Q^{fs}; see Table 1) equal to the demand equation (Q^{fd}) and solving for the retail fluid price. The equilibrium nominal fluid price for each year was:

$$(6)\ P^f_t = \exp\left[(\beta_{0t} - \alpha_{0t})/(\alpha_1 - \beta_1) \right],$$

where β_{0t} was the fluid supply intercept in year t, α_{0t} was the fluid demand intercept in year t, α_1 was the estimated price coefficient for the fluid demand equation (-0.4756), and β_1 was the estimated price coefficient for the fluid supply equation (0.1034). More specifically, the intercept terms for the fluid demand and supply equations were

$$(7)\ \alpha_{0t} = -1.025 + 0.476 \ln CPI_t + 0.065 \ln P^b_t + 0.456 \ln Y_t - 0.981 \ln A_{2t} - 0.032\,T_t + \ln POP_t, \text{ and}$$

$$(8)\ \beta_{0t} = 0.720 - 0.103 \ln CPI_t + 0.724 \ln Q^{fs}_{t-1} - 0.136 \ln (P^{II}_{ins\,t} + D) - 0.045 \ln P^e_t,$$

where CPI_t was the retail consumer price index for all items, and all other variables were as defined in Table 2. This price was computed for each year and was substituted into either the supply or demand function to obtain the equilibrium quantity of fluid products (Q^f).

[3] It was assumed that the percentage of milk that is used on the farm is the same for the bST scenarios as it is with the no-bST case. While the percent of milk production used on-farm would likely be smaller under bST than no bST, this difference would likely be small relative to total production. Hence, no adjustments were made for this parameter among scenarios.

[4] The government stock policy of selling products back to the market when the market price is high enough was not modeled here, and consequently net CCC purchases were constrained to be greater-than-or-equal-to zero. In years in which the equilibrium values generated negative net CCC purchases (i.e., competitive solutions), the following iterative procedure was performed. One penny was added to the Class II (and hence Class I) price and the equilibruim values were recomputed. If net CCC purchases were still negative, then another penny was added to the two class prices and the process repeated itself until net CCC purchases became zero.

The retail manufactured market was defined by the retail manufactured demand equation, retail manufactured supply equation, and an equilibrium condition that demand was equal to supply. The equilibrium manufactured price (P^m) equation was generated by setting the manufactured supply equation equal to the manufactured demand equation and solving for the retail manufactured price. The equilibrium nominal manufactured price for each year was

$$(9)\ P^m_t = \exp\left[(\delta_{0t} - \gamma_{0t})/(\gamma_1 - \delta_1)\right],$$

where δ_{0t} was the manufactured supply intercept in year t, γ_{0t} was the manufactured demand intercept in year t, γ_1 was the estimated price coefficient for the manufactured demand equation (-0.9467), and δ_1 was the estimated price coefficient for the manufactured supply equation (0.6163). More specifically, the intercept terms for the manufactured demand and supply equations were

$$(10)\quad \gamma_0 = -1.800 + 0.940 \ln CPI_t + 0.091 \ln P^{fo}_t + 0.500 \ln Y_t - 280 \ln A_{1t} - 0.046\, T_t + \ln POP_t, \text{ and}$$

$$(11)\quad \delta_{0t} = 0.340 - 0.610 \ln CPI_t + 0.304 \ln CPI_{t-1} - 0.304 \ln p^m_{t-1} + 1.110 \ln Q^{ms}_{t-1} - 0.305 \ln Q^{ms}_{t-2} - 0.283 \ln p^{II}_{ins\,t} + 0.141 \ln p^{II}_{ins\,t-1} + 0.005\, T_t - 0.003\, T_{t-1},$$

where all variables were as defined above. As before, this price was computed for each year and was substituted into either the manufactured supply or demand function to obtain the equilibrium quantity of products (Q^m).

All scenarios were simulated for 1991 through 1995, which corresponds to the duration of the Food, Agriculture, Conservation, and Trade (FACT) Act. Values for all exogenous variables were forecasted based on the following regression equation:

$$X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \beta_{30} T_t,$$

where

X_t= exogenous variable,

X_{t-1}= exogenous variable lagged one year,

X_{t-2}= exogenous variable lagged two years,

T_t= time trend.

The estimated equations are presented in Table 3. For some equations, variables are omitted because they were not statistically significant. The 1990 values were used to initialize the lagged dependent vari-

Table 3. Estimated Equations for Forecasting the Exogenous Variables in the Farm and Retail Markets[a]

Energy Price Index

$$P^e = 1.424\, P^e_{-1} - 0.590\, P^e_{-2} + 2.508\, T + u$$
(9.02) (-3.88) (2.74)

$R^2 = 0.98$; DW = 2.05

Hourly Manufacturing Wage

$$W = 0.051 + 1.730\, W_{-1} - 0.789\, W_{-2} + 0.021 T + u$$
(1.70) (15.69) (-7.76) (2.63)

$R^2 = 0.99$; DW = 1.96

Retail Consumer Price Index

$$CPI = 1.614\, CPI_{-1} - 0.672\, CPI_{-2} + 0.866\, T + u$$
(11.79) (-5.21) (2.62)

$R^2 = 0.99$; DW = 1.29

Retail Beverage Price Index

$$P^b = 1.148\, P^b_{-1} - 0.289\, P^b_{-2} + 2.777\, T + u$$
(6.060) (-1.62) (2.54)

$R^2 = 0.99$; DW = 2.10

Disposable Per Capita Income

$$Y = 1.008\, Y_{-1} + 0.026 T + u$$
(51.38) (3.31)

$R^2 = 0.99$; DW = 1.50

Percent of Population Under 19 Years Old

$$A_1 = 0.024 + 1.745\, A_{1-1} - 0.805\, A_{1-2} - 0.0002\, T + u$$
(1.96) (17.76) (-9.89) (-1.72)

$R^2 = 0.99$; DW =2.11

Percent of Population Between 45 and 64 Years Old

$$A_2 = 0.012 + 1.910\, A_{2-1} - 0.968\, A_{2-2} - 0.00003\, T + u$$
(6.05) (32.82) (-16.80) (-3.84)

$R^2 = 0.99$; DW = 1.54

Retail Fats and Oils Price Index

$$P^{fo} = 9.670 + 0.764 P^{fo}_{-1} + 2.468\, T + u$$
(1.65) (7.25) (2.46)

$R^2 = 0.98$; DW =1.78

Civilian Population

$$POP = 121.613 + 0.328 POP_{-1} + 1.524\, T + u$$
(3.71) (1.77) (3.63)

$R^2 = 0.99$; DW = 1.89

Dairy Ration Costs

$$FC = 0.583 + 1.111\, FC_{-1} - 0.432\, FC_{-2} + 0.075\, T + u$$
(2.23) (6.04) (-2.38) (2.58)

$R^2 = 0.95$; DW = 1.95

[a] R^2 is the adjusted coefficient of variation, DW is the Durbin-Watson statistic, u is white noise, and t-values are given in parentheses. The intercept is deleted in some equations where it was not statistically significant at the 10% level.

ables appearing in the retail supply, cow number, and production per cow equations.

It was assumed that support price adjustments each year are based on the provisions of the 1990 FACT Act. This Act requires the support price to be no lower than \$10.10 per hundredweight. In addition, the support price is increased by \$0.25 per hundredweight if net CCC purchases are predicted to be below 3.5 billion pounds of milk equivalent for the forthcoming calendar year.[5] Alternatively, the support price is decreased by \$0.35 per hundredweight if net CCC purchases are predicted to be above 5.0 billion pounds, provided that this adjustment does not result in the support price being lower than \$10.10.

In addition, there are two assessments on farmers' milk marketings under the law. The first assessment, authorized by the Budget Reconciliation Act, requires producers to pay \$0.05 per hundredweight in 1991, and \$0.1125 per hundredweight for 1992 through 1995. This assessment is refundable to the farmer the next year if milk marketings do not reach the previous year's level. The assessment and refund were incorporated into the simulation model by subtracting the assessment from the equilibrium farm milk price and adding back the amount of the previous year's assessment when milk marketings decreased from the previous year. The second assessment is a "co-responsibility assessment" that requires producers to pay for the cost of CCC purchases in excess of seven billion pounds. This assessment was incorporated into the simulation by using the following iterative procedures. First, net CCC purchases were calculated using the support price determined by the provisions above. If net CCC purchases were below seven billion pounds, then no co-responsibility assessment was applied. On the other hand, if net CCC purchases were above seven billion pounds, the cost of removing the excess purchases was calculated. This cost was calculated as the product of net CCC purchases in excess of seven billion pounds, times the support price, times a mark-up to reflect the total net monetary costs of removing one hundredweight of milk (i.e., the make allowance plus storage and handling plus transportation minus receipts from any sales back to the domestic or foreign market).[6] This mark-up was set at 30 percent, which corresponds to the historical average of the 1980s. To put this assessment on a hundredweight basis, the total cost was divided by total milk marketings measured in hundredweights.

Model Validation

To determine the validity of the dairy model in evaluating the various scenarios, the model was dynamically simulated to assess its ability to replicate historical values for the endogenous variables. The time period chosen for this dynamic in-sample simulation was 1980-1990, and the following procedures were used. First, all exogenous variables in the model were forecasted for the period 1980-1990 using initial values of 1978 and 1979 in the estimated forecast equations. Second, the actual support price was substituted into the Class II price equation to obtain the Class II and Class I prices. Third, the predicted values for the exogenous variables and the Class prices were substituted into the retail fluid and manufactured supply and demand equations. Equilibrium values for the fluid quantity (Q^f) and price (P^f) were obtained by equating fluid supply to demand, solving for the equilibrium P^f, and substituting the equilibrium P^f into the demand equation. Similar procedures were used to derive equilibrium values for manufactured price (P^m) and quantity (Q^m). Finally, to obtain the raw milk supply for the subsequent year, the average farm milk price (P^{fm}) was generated by substituting the equilibrium values for P^I, P^{II}, Q^f, and Q^m into the all-milk price formula. The resulting farm milk price was then substituted into the cow and production-per-cow equations along with the relevant predicted exogenous variables to determine the next year's milk supply. This process was repeated for each year over the period 1980 through 1990.

The root mean square percentage error (RMSPE) is presented in Table 4. It is clear that the model did a reasonable job in replicating all historical values for endogenous variables except government costs. The RMSPE for all variables except net CCC purchases range from 2 to 7.8 percent. These figures are quite respectable considering that the model was predicting over a ten year time period. The RMSPE on net CCC purchases, however, was 51.5 percent. However, this was due to the relatively small magni-

[5] There is also a new accounting procedure for determining the milk equivalent of net CCC purchases that is based on a new "total milk solids" rather than milkfat basis. Based on recent market trends, this accounting figure should result in a somewhat smaller number than milkfat basis, however, there will not be a large difference. Because the model was estimated on a milkfat basis, it was assumed that the differencs are negligible and that the trigger is based on a milkfat rather than a total solids milk equivalent basis.

[6] The make allowance is a margin added to the support price that represents the cost of manufacturing cheese, butter, and nonfat dry milk net of raw milk cost. The make allowance is used with the farm support price and product yield factors in formulas that determine the price that the government pays for cheese, butter, and nonfat dry milk.

Table 4. Root Mean Square Percentage Error (RMSPE) for Endogenous Variables in the National Dairy Model Based on 1980-90 Dynamic In-Sample Simulation

Variable	Root Mean Square Percentage Error
Milk Production	3.1
Cow Numbers	5.8
Production Per Cow	7.8
Class II Price	3.0
Manufactured Demand	2.0
Class I Price	3.0
Fluid Demand	2.6
Farm Milk Price	3.4
Retail Fluid Price Index	4.1
Retail Manufactured Price Index	6.1
Net CCC Purchases	51.5

tude of the variable in question (i.e., a modest deviation from the historical value would result in a rather high RMSPE). On the basis of dynamic in-sample forecast, it appears that the model did a respectable job of tracking what actually occurred in the market over the 1980s.

The bST Parameters

The impact of bST on milk production will depend upon: (1) the average increase in milk yield in treated cows, (2) the rate of adoption, and (3) the average increase in variable costs due to bST. It was assumed here that the average increase in milk yields due to bST is 10 percent, which is consistent with other published results, e.g., Schmidt. The following cumulative adoption rates in terms of percentage of bST-treated cows were assumed: 5 percent of cows in 1992, 15 percent in 1993, 35 percent in 1994, and 50 percent in 1995. This pattern of adoption followed a logarithmic pattern, which is consistent with the theory of how new technology is adopted. The adoption rates fell between the relatively high rates of Lesser et al. and the relatively low rates assumed by Schmidt. Finally, it was assumed that the increase in variable costs associated with cows treated with bST was 7.5 percent. This percentage was derived by using an increase in feed costs of 3.8 percent and a cost of bST of $55.70 per cow (both are averages of seven previous studies—Marrion and Wills; Fallert et al.; Kaiser and Tauer; Schmidt; Yonkers et al.; Tauer and Kaiser; Magrath and Tauer 1988). The percentage increase was based on a variable cost of $10.92 per hundredweight without bST (which was total cash expenses for 1988, Shapouri et al.).

Retail fluid demand was reduced based on results of two consumer surveys, one in Virginia (McGuirk, Preston, and Jones) and the other in New York State (Kaiser, Scherer, and Barbano). While there have been other studies on consumer perceptions of bST, the two studies of Virginia and New York State are the only ones to estimate the magnitude of how milk consumption would change under bST adoption. In both studies, consumers were presented with a description of bST and were asked several questions regarding their perceptions about bST and how much their weekly purchases of fluid milk would change if bST were approved. After adjusting the results based on whether the respondent was aware of bST prior to the survey, the Virginia results indicated that consumers would decrease milk purchases by an average of 3.0 percent[7], while the New York State study indicated that consumers would decrease milk purchases by an average of 5.5 percent if bST were approved and adopted by farmers. Because there was no national estimate of how milk purchases would decline under bST, the average of these two states (4.25 percent) was used as a proxy for the national average decrease in milk demand in response to bST. Because there is some regional variation in milk consumption throughout the United States, it would be more desirable to have a national estimate of the fluid demand-side effect of bST based on a national survey. However, the two-state average is probably a reasonable proxy for the national average bST demand effect considering that it covered 1,323 consumers from all areas of these two states.

While manufactured demand will probably be affected by bST, there is no estimate of the size of potential impact. To deal with this, two scenarios were considered. In scenario 3, it was assumed that there is no change in manufactured demand, while in scenario 4, it was assumed that there is a decrease in manufactured demand that is equal to 50 percent of the decrease in fluid demand. A scenario with 100 percent of the fluid demand decrease for manufac-

[7]These results were adjusted for consumer awareness of bST by taking the average decrease in fluid milk purchases indicated by survey respondents and multiplying this by the percentage of respondents who had read or heard anything about bST prior to the survey. The rationale for this was that not all consumers will be aware of bST if it is approved and adopted and such consumers will not alter their milk consumption patterns. This adjustment procedure assumed no difference in bST awareness level between the time that the survey was conducted and the time that bST is ultimately approved. For Virginia, only 16.6 percent of respondents had read or heard of bST. The average unadjusted responses for how weekly purchases of milk would decrease were 17.8 percent (McGuirk, Preston, and Jones) for Virginia, and 15.6 percent for New York State (Kaiser, Scherer, and Barbano).

tured demand was not included because manufactured dairy products will not likely have as large a negative demand-side effect as the more visible fluid products.

To incorporate the bST demand-side effect, the intercept terms in the two retail demand functions were reduced so that the reduction in the 1992 equilibrium quantity (first year bST is available) was equal to the assumed decrease in consumption due to bST. For example, for fluid demand the intercept term (α_{0t}) was reduced by an amount which would make the equilibrium fluid quantity for 1992 4.25 percent less than it would be without bST. A similar procedure was used in scenario 4 with the manufactured demand intercept term so that the equilibrium manufactured quantity was 2.13 percent less than it would be without bST.

RESULTS

The results of the first scenario, which are presented in Table 5, suggest that if bST were not available, the 1990 FACT Act would be quite effective in reducing milk surpluses as measured by net CCC purchases under the dairy price support program. In this case, net CCC purchases remained relatively high in 1991, but fell significantly for the rest of the simulation period, eventually approaching zero in 1995. Two assessments were required in 1991 and 1992 to pay for net CCC purchases in excess of seven billion pounds, but for the remaining years net CCC purchases were well below the seven billion pound trigger level. In fact, two consecutive $0.25 increases in the support occurred in 1994 and 1995 because net CCC purchases were predicted to be below 3.5 billion pounds at the previous year's support price for those two years. By 1995, the market became quite competitive, with the government removing no dairy products and the farm milk price rising to $14.78 per hundredweight.

The balance between supply and demand in the first scenario was accomplished by a 1.9 percent decrease in milk marketings, while commercial demand increases by 5.1 percent during the period 1991-1995. The decrease in milk production was caused by cow numbers declining slightly faster than the increase in milk yields. All of the increase in commercial demand occurred in the manufactured market, where demand rose by 8.9 percent compared with a 0.9 percent decrease in fluid demand.

The economic well-being of farmers improved marginally over time in the scenario without bST because of a consistent increase in the effective farm milk price each year. By 1995, the effective farm milk price was 26.9 percent higher than it was in 1991. Gross farm income followed the same pattern, increasing from $17.52 billion in 1991 to $21.80 billion in 1995. These results suggest that if bST were not available, the 1990 Farm Act would lead to a supply-demand balance without causing hardship to farmers as a group.

On the other hand, this conclusion does not hold when bST is available. In the second scenario where there was no demand-side effect, net CCC purchases exceeded six billion pounds in every year of the simulation (see Table 5). Annual net CCC purchases were held somewhat under control due to two triggered assessments of $0.27 and $0.16 per hundredweight in 1991 and 1992, respectively, to pay for excess CCC purchases. Also, the assessments under the Budget Reconciliation Act were triggered each year because milk marketings increased in every year from 1991 to 1995. The situation was significantly worse when a demand-side effect to bST was considered. For example, in the third scenario where there was a negative 4.25 percent shock in fluid demand in 1992, net CCC purchases were ten billion pounds or more throughout 1991-1995 (Table 5). Even with producer assessments, net CCC purchases were above ten billion pounds due to increases in production and decreases in fluid consumption. If one allows for a manufactured demand-side effect, then net CCC purchases were even higher in every year, averaging just under 13 billion pounds for 1992-1995 (Table 5). It appears that the 1990 FACT Act would not be very effective in keeping supply in balance with demand if bST is approved and there is a negative response in demand.

There were gainers and losers due to the introduction of bST. Consumers were better off in the sense that retail prices were lower in all three bST scenarios than they were in the case of the no-bST scenario. This was especially the case for scenarios 3 and 4 where there was a demand- as well as a supply-side effect. This was also more evident for the fluid market because the demand and supply price elasticities were more inelastic than those in the manufactured market. On the other hand, consumers who decrease their purchases of milk and dairy products because of negative perceptions of bST may be worse off under the bST scenarios because they have negative perceptions about milk from cows given bST.

Farmers, as a group, were marginally better off under bST with no demand-side effect in terms of gross income, while marginally worse off under bST if there was a demand-side effect. Farm milk prices were higher without bST because supply was more in balance with demand. However, production was higher with bST and the net effect was that there was little difference in gross income among most scenar-

Table 5. Market Impacts of Various bST Scenarios With the 1990 Food, Agriculture, Conservation, and Trade Act, 1991-95

Year	CCC Net Removals (bil. lbs)	Milk Marketings (bil. lbs)	Effective Milk Price[a] / ($ / cwt)	Fluid Quantity (bil. lbs)	Manufactured Quantiity (bil lbs.)	Total Demand (bil. lbs)	Class II Price ($ / cwt)
(Scenario 1 - Market Impacts Assuming bST is not Available)							
1991	10.1	150.4	11.65	55.4	84.9	140.3	11.13
1992	8.1	151.0	11.86	55.7	87.3	142.9	11.21
1993	3.9	149.7	12.16	55.8	90.0	145.8	11.30
1994	0.5	148.9	12.45	55.8	92.5	148.4	11.59
1995	0.1	147.5	14.78	55.0	92.4	147.4	13.92
(Scenario 2 - Market Impacts Assuming bST is Available Beginning in 1991, but no Demand-Side Effect)							
1991	10.1	150.4	11.65	55.4	84.9	140.3	11.13
1992	8.8	151.7	11.78	55.7	87.3	142.9	11.21
1993	6.5	152.3	12.03	55.8	90.0	145.8	11.30
1994	6.8	155.5	12.10	55.8	92.8	148.7	11.39
1995	7.1	158.8	12.18	55.0	95.7	151.7	11.48
(Scenario3 - Market Impacts Assuming bST is Available in 1991,With Fluid-Only Demand-Side Effect)							
1991	10.1	150.4	11.65	55.4	84.9	140.3	11.13
1992	11.2	151.7	11.55	53.3	87.3	140.6	11.21
1993	9.9	151.9	11.73	52.1	90.0	142.1	11.30
1994	10.5	154.7	11.74	51.4	92.8	144.2	11.39
1995	10.8	157.5	11.80	51.0	95.7	146.7	11.48
(Scenario3-Market Impacts Assuming bST is Available in 1991,With Fluid and Manufactured Demand-Side Effect)							
1991	10.1	150.4	11.65	55.4	84.9	140.3	11.13
1992	13.0	151.7	11.39	53.3	85.4	138.7	11.21
1993	12.2	151.7	11.64	52.1	87.4	139.5	11.30
1994	13.1	154.4	11.52	51.4	89.9	141.2	11.39
1995	13.2	156.8	11.59	51.0	92.5	143.5	11.48

[a]Average milk price net of co-responsibility levy and Budget Reconciliation Act assessment.

ios. The exception to this was comparing the no-bST scenario and the bST with fluid and manufactured demand effects scenario. In this case, gross farm income without bST is 6 percent higher, on average, than it is with bST for the period 1991-1995.

Taxpayers were the principal losers if bST is introduced. Annual net monetary costs of the dairy price support program averaged $436 million from 1991-1995 if bST is not available. If bST was available, the annual average net monetary costs of the price support program were $746 million in scenario 2, $764 million in scenario 3, and $799 million in scenario 4. Under all bST scenarios, the net monetary costs of the dairy price support program were almost double what they would have been without bST.

It is clear from these results that the demand-side effect due to bST has a major effect on market variables. In particular, net CCC purchases and the effective farm milk price are the variables that are significantly affected by the demand-side effect. The demand-side effect also has an impact on all other variables as well, but not as drastic. The major implication of this is that impact analyses of bST should consider the demand- as well as supply-side effects of biotechnology.

SUMMARY

The purpose of this article was to examine the potential market impacts due to bST when both supply- and demand-side effects are taken into account. A model of the national dairy industry was used to simulate equilibrium price and quantity values at the farm and retail levels from 1991 to 1995 for several scenarios involving bST. It was assumed that the provisions of the 1990 Food, Agriculture, Conservation, and Trade Act were in effect.

The results indicate that if bST is not available between 1992 and 1995, then the 1990 FACT Act will be very effective in keeping milk supply in balance with demand. However, if bST is available, milk surpluses will be a major problem for the dairy industry. Furthermore, the potential demand-side effect due to bST is as important to this problem as the production enhancement effects of bST. For example, net CCC purchases under bST with no demand-side effect averaged about 7.8 billion pounds per year in the simulation. In the case where there was a decrease in both fluid and manufactured demand, net CCC purchases were 58 percent higher on average (12.3 billion pounds). The major implication is that impact analyses of bST should consider the demand- as well as supply-side effects of biotechnology.

REFERENCES

Animal Health Institute. "Bovine Somatotropin (bST)." Alexandria, Virginia, 1988.

Chavas, J.P., and R.M. Klemme. "Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms." *Am. J. Agr. Econ.*, 68 (1986): 55-66.

Fallert, R., T. McGuckin, C. Betts, and G. Bruner. "bST and the Dairy Industry: A National, Regional, and Farm Level Analysis." Washington, D. C.: USDA, ERS, October 1987.

Kaiser, H.M., and L.W. Tauer. "Impact of Bovine Somatotropin on U.S. Dairy Markets Under Alternative Dairy Policy Options." *N. Cen. J. Agr. Econ.*, 11(1989): 59-73.

Kaiser, H.M., C.W. Scherer, and D.M. Barbano. "Consumer Perceptions and Attitudes Towards Bovine Somatotropin." *NE. J.Agr. and Res. Econ.*, 21.1 (1992): 10-20.

Kaiser, H.M., D.H. Streeter, and D.J. Liu. "Welfare Comparisons of U.S. Dairy Policies With and Without Mandatory Supply Control." *Am. J. Agr. Econ.*, 70 (1988): 848-858.

Kalter, R.J., R. Milligan, W. Lesser, W. Magrath, and D. Bauman. "Biotechnology and the Dairy Industry: Production Costs and Commercial Potential of the Bovine Growth Hormone."*A.E. Res. 82-22,* Department of Agricultural Economics, Cornell University, 1984.

Lesser, W., W. Magrath, and R. Kalter. "Projecting Adoption Rates: Application of an Ex Ante Procedure to a Biotechnology Product." *N. Cen. J. Agri. Econ.*, 8(1986):159-174.

Magrath, W.B., and L.W. Tauer. "The Economic Impact of bGH on the New York State Dairy Sector: Comparative Static Results." *N. East. J. Agri. and Res. Econ.*, 15(1986): 6-13.

Magrath, W.B., and L.W. Tauer. "New York Milk Supply with Bovine Growth Hormone." *N. Cen. J. Agri. Econ.*, 10(1988): 235-241.

Marrion, B.W., and R.L. Wills. "A Prospective Assessment of the Impacts of Bovine Somatotropin: A Case Study of Wisconsin." *Am. J. Agr. Econ.*, 72 (1990): 326-336.

McGuckin, J.T., and S. Ghosh. "Biotechnology, Anticipated Productivity Increases, and U.S. Dairy Policy." *N. Cen. J. Agri. Econ.*, 11(1989): 277-288.

McGuirk, A.M., and H.M. Kaiser. "bST and Milk: Benefit or Bane?" *Choices.*, 6(1991):20-26.

McGuirk, A.M., W.P. Preston, and G.M. Jones. "Biotechnology and the Consumer: The Case of Bovine Somatotropin." *Staff Paper 90-60,* Department of Agricultural Economics, Virginia Polytechnic Institute and State University, 1991.

Preston, W.P., A.M. McGuirk, and G.M. Jones. "Consumer Response to the Introduction of Bovine Somatotropin."*Economics of Food Safety,* J.A. Caswell, ed. New York: Elsevier Science Publishing Co., Inc., 1991.

Schmidt, G.H. "Economics of Using Bovine Somatotropin in Dairy Cows and the Potential Impact on the U.S. Dairy Industry." *J. of Dairy Sci.*, 72(1989): 737-745.

Shapouri, H., C. Betts Liebrand, W.B. Jesse, T. Crawford, and J. Carlin. "Economic Indicators of the Farm Sector: Costs of Production—Livestock and Dairy, 1988." Washington, D. C.: U.S. Department of Agriculture, Economic Research Service, March 1990.

Smith, B. "Consumer and Public School Perceptions on the bST Issue in Pennsylvania." *Farm Economics.* Cooperative Extension Service, The Pennsylvania State University, March/April, 1991.

Tauer, L.W., and H.M. Kaiser. "Optimal Dairy Policy With Bovine Somatotropin." *N. Cent. J. Agr. Econ.*, 13.1 (1991): 1-17.

Yonkers, R. D. Knutson, and J. W. Richardson. "Dairy Farm Income as Affected by bST: Regional Characteristics." Proceedings, National Invitational Workshop on Bovine Somatotropin, pp. 144-66. St. Louis, MO, September 1987.