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Abstract

New York milk supply functions with and without bovine Growth Hormone were estimated by a sector linear programming model. High government price supports make bGH profitable and induces significant increases in output. Reduction or elimination of price supports greatly diminishes bGH as a viable technology except at low bGH prices.

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The application of recent developments in molecular biology to agriculture is expected to result in significant increases in farm output, possibly within the next several years (NAS). An example is bovine growth hormone (bGH) which has been demonstrated to increase milk output per cow by more than 20 percent per year (Bauman et al). In addition to increased output this level of technical change can be expected to influence input and output prices, land values and the distribution of producer and consumer surpluses. In this paper we present a linear programming model of the New York state dairy sector that allows us to quantify some of these effects. We begin by briefly describing the bGH innovation and proceed to describe the linear programming model. The results of the model, together with reasonable assumptions on the demand for milk, are then used to examine policy issues related to the availability of bGH.

It has been known for over 40 years that injection of extract from the pituitary gland of dairy cattle has a positive influence on milk production. Limited supplies and high costs have prevented use of the hormone in commercial dairy farming. However, recent developments in molecular biology, particularly recombinant DNA technology (gene splicing) enable production at low cost of large quantities of the hormone.

When injected into lactating dairy cows bGH influences the partitioning of nutrients and serves to more efficiently focus energy and resources on milk production. In doing so, the hormone reduces the share of feed and nutrients that simply maintains the animal and reduces overall feed requirements per pound of milk. However, the feed requirements of animal also shift, placing a higher premium on high energy feeds such as corn grain and corn silage, as well as high quality alfalfa. By raising output per animal, bGH also spreads costs for barns, milking equipment and other fixed costs over greater quantities. Currently available information indicates that bGH has no adverse effects on animal health or milk quality, but further tests are required before regulatory approval will be granted for commercial release.

A Dairy Sector Linear Programming Model of New York

Sector linear programming models have been used extensively in agriculture to estimate the impact of policy and technology (Heady and Srivastava). In this paper we model the dairy industry of New York by constructing production activities on a per acre or animal basis without attempting to formulate representative farms. An increasing supply curve is exhibited as marginal land, alternative rations, and additional buildings are used in dairying.

The LP model consists of 55 variables representing crop raising, harvesting, animal raising and milk production activities, and 33 equalities or inequalities representing resource and materials balance constraints. The objective function is the maximization of returns to land, management, and current farm buildings. The model permits land of seven different qualities to be cropped in corn for grain, corn for silage, or either alfalfa or grass hay. Grown feed and purchased supplements are fed in any combination of twelve nutritionally balanced rations to milk cows and in any of three rations for heifers. Corn imports into the state are allowed at market prices. Feed, labor, barn space and replacement heifer requirements are specified on a per hundredweight of milk basis.

Costs of production and crop yields were taken from budgets prepared by the New York State Board of Equalization and Assessment. Costs include all variable expenses for growing and harvesting (seed, fertilizer, chemicals, etc.) and all fixed expenses except property tax which might vary by returns to land. Yields decline and costs rise so that crop costs per ton increase going from the highest quality to the lowest quality land. Land resources were estimated based on the proportions of the various qualities of land from the USDA 1977 National Resource Inventory data and total cropland for New York State as given by the 1982 Census of Agriculture. Areas devoted to more profitable crop enterprises (fruits and vegetables) were allocated on a percentage basis to the top five land classes and that land was removed from the resources available for dairy production. Costs, yields and resource endowments are shown in Table 1.

Table 1. Costs, Yields, and Endowments by Soil Class

Soil Class	Corn Yield[bc] Bushels/Acre	Corn Cost $/Acre	Hay[a] Yield[c] Tons/Acre	Hay[a] Cost $/Acre	Maximum Corn:Hay Rotation	Endowment 1,000 Acres
1	108.2	300	3.80	221	7:3	80.3
2	102.3	289	3.53	207	6:4	678.9
3	94.7	283	3.24	196	5:5	651.1
4	84.7	285	2.80	182	5:5	827.3
5	78.2	274	2.52	160	4:6	1,030.4
6	66.4	268	2.20	144	3:7	1,063.8
7	57.0	256	2.16	136	2:8	560.8

[a]Alfalfa except for classes 6 and 7 Land. Yields adjusted for hay quality differences.

[b]Corn grain yield, to convert from bushels to tons of silage divide by 5.88.

[c]Yields are weighted average of high and low lime soil yields.

Animal rations in the model were calculated from rations formulated for representative dairy farms in a study of the farm management level impacts of bGH (Kalter et al.). The rations represent least cost mixes consistent with National

Research Council recommendations for dairy cows. Rations for cows receiving bGH are based on the assumption that a higher (energy) density ration must be fed in order to realize the potential of the hormone. The cost of producing milk on the various rations was calculated based on dairy cow enterprise budgets prepared by Knoblauch. These were adjusted by updating to 1984 costs and by deleting costs for feeds, labor and housing which are treated as separate activities. The costs associated without bGH rations were calculated for 13,000 lb. production cows which is approximately the 1984 state average (12,250 lbs.). Direct costs for milk produced by cows receiving bGH were estimated by examining budgets for 16,000 lb. cows and incorporating those variable costs which could be expected to change with treatment. This is consistent with the yield increases due to bGH which is assumed to increase output by 19.2%, converting a 13,000 lb producing cow to a 15,490 lb. producing cow. Requirements and costs for milk production were specified on a hundredweight basis and are available from the authors.

Housing of dairy cows was treated as a separate activity on the theory that the likely effect of bGH will be to reduce cow numbers. Thus barn capacity in the state will not constrain production at anticipated levels of output. In order to consider levels of output in excess of current (1984) levels the model is required to build additional barns, and feed storage space as output increases. Annual costs were estimated based on Knoblauch.

The purchase price of bGH is not yet known. A bGH cost of production study shows costs range from $.19 to $.085 per dose (fob) depending critically on the scale of production (Kalter et al.). Strategic marketing considerations and distribution costs will tend to lead toward higher prices while technical improvements (particularly in purification) can be expected to lower costs and price. The cost of bGH was assumed to be $.20 per daily injection and to be required for 210 days per year. Costs of $.50, $.25 and zero ($0.00) per injection were also examined.

By solving the LP model with various milk prices we traced out milk supply curves with and without bGH. Varying the prices of imported grain and bGH indicates the sensitivity of our results to these factors. The principal results are given in Table 2 and are illustrated in Figure 1. These assume corn prices of $2.75 per bushel and bGH costs of $.20/injection. At recent milk prices the availability of bGH increases output by 19 percent. At lower prices, however, the supply shift from bGH is muted and the supply curves converge.

The baseline supply (without bGH) accords closely with the 11,405 million lbs of milk actually supplied by New York State dairy farmers in 1984. Using the 1984 average wholesale milk price of $13.50/cwt. the linear programming model produced 11,700 million lbs. The supply curve for milk is also consistent with data presented by LaDue on the cost structure of the New York State dairy industry. Analyzing 1984 financial records for 402 farms, he found that production cost of milk varied by quintile from $12.30/cwt to $18.85/cwt.

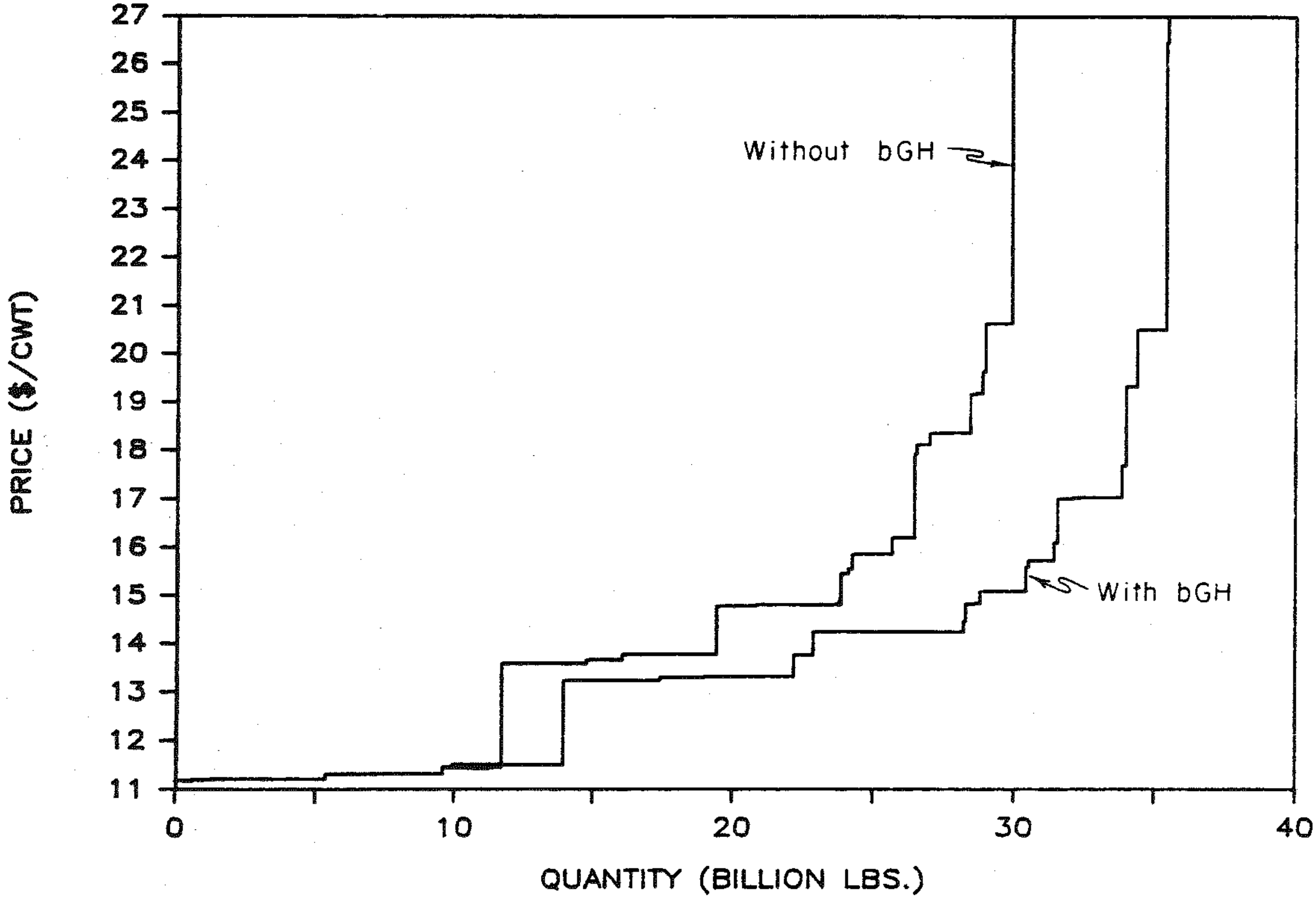
The programming model is not a complete representation of the sector for a number of reasons. Perhaps most significantly is the fact the model allows land classes to enter solution independent of each other. In fact, because land of various qualities rarely exists in isolation, it is likely that farmers would raise crops on less productive lands than is indicated by the model. Unfortunately there are no data available that would allow more detailed stratification of the land resource.

Table 2. New York Milk Supply

New York State Milk Supply Schedule (without bGH)		New York State Milk Supply Schedule (with bGH)	
Price ($/cwt.)	Quantity (million lbs)	Price ($/cwt)	Quantity (million lbs)
≤ 11.18	0	≤ 11.18	0
11.18-11.21	604.0	11.18-11.21	604.0
11.21-11.22	1,238.2	11.21-11.22	1,238.2
11.22-11.32	5,375.5	11.22-11.32	5,375.5
11.32-11.47	9,578.8	11.32-11.44	9,578.8
11.47-11.52	9,900.0	11.44-11.46[a]	11,276.9
11.52-13.61	11,700.0	11.46-11.51	11,697.8
13.61-13.68	14,766.0	11.51-13.26	13,940.2
13.68-13.79	16,048.9	13.26-13.32	17,383.6
13.79-14.79	19,433.6	13.32-13.34	18,963.3
14.79-14.82	20,852.6	13.34-13.78	22,197.1
14.82-15.47	23,855.0	13.78-14.26	22,877.6
15.47-15.57	24,123.7	14.26-14.49	28,217.3
15.57-15.87	24,268.0	14.49-14.84	28,284.3
15.87-15.88	24,338.6	14.84-14.86	28,550.2
15.88-16.22	25,657.3	14.86-15.11	28,778.1
16.22-17.94	26,459.6	15.11-15.61	30,415.3
17.94-18.14	26,532.9	15.61-15.75	30,510.1
18.14-18.37	26,992.4	15.75-16.12	31,409.3
18.37-19.18	28,426.9	16.12-17.02	31,544.7
19.18-19.20	28,625.3	17.02-17.05	32,685.4
19.20-19.64	28,859.0	17.05-17.71	33,846.0
19.64-20.65	28,972.0	17.71-19.33	33,978.7
20.65-26.44	29,902.9	19.33-20.53	34,389.8
26.44-27.00	29,931.7	20.53-26.46	35,408.2
		26.46-27.00	35,464.8

[a] Lowest price with bGH entering solution.

Figure 1. NEW YORK MILK SUPPLY



The model is also limited to 13,000 lb. producing cows. While the average production per cow in New York in 1984 was 12,250 there were significant numbers of higher producing animals. High production animals require more nutritionally concentrated rations. The 13,000 lbs assumption thus affects land use and probably biases the solution values for land in corn and corn silage downward and hay upward. The impact of falling prices can also be expected to reduce the share of production accounted for by low production animals as these animals leave the industry. This would imply that the average output per cow should increase with falling total output. Finally, falling milk price may also decrease demand and thus price for production inputs. Unfortunately, this cannot be easily accommodated for in a linear programming framework.

When bGH rations are allowed to enter solution the supply curve pivots, producing significantly larger quantities at prices exceeding $12/cwt. This is consistent with the farm level financial results reported by Kalter et al. The convergence of the without and with bGH supply curves at low milk prices, however, is not fully anticipated by their farm level studies. The reasons for the supply curve convergence in this model are the direct cost incurred for the use of bGH, and the indirect costs of using more concentrated rations to support the higher yields of bGH. At low milk prices the use of the resource intensive bGH technology does not enter solution. Sensitivity analysis, using higher bGH and corn grain prices, shows that even higher milk prices are needed to bring bGH rations into solution (see table 3). Only if bGH is provided at no cost does the entire supply curve shift downward. Milk production and bGH use then occur at milk prices as low as $10.96/cwt.

Table 3. Milk Prices ($/cwt) Needed to Bring bGH into Use

		Corn Grain Price $/bushel		
		2.75	3.00	3.25
	.00	10.96	10.96	10.96
	.20	11.44	11.66	11.73
bGH Price $/injection	.25	11.87	12.08	12.15
	.50	13.77	14.22	14.44

Market Analysis

In order to fully assess the impact of bGH it is necessary to combine the supply impacts estimated above with information about the demand for milk and government price policy. Approximately 9.3% of national dairy output has been removed from the market in recent years by federal purchase (New York Economic Handbook). By assuming a constant elasticity of demand function of the form $Q = BP^{\epsilon}$, with $\epsilon = -.3$ (Ippolito and Masson, George and King, Riley and Blakely) we were able to estimate an entire demand curve from one point. For this we used the 1984 New York average price of $13.50/cwt and 90.7% of the quantity actually supplied. This demand curve implies a market clearing price of $9.75/cwt for the quantity actually produced in 1984. In order to facilitate the calculation of consumer surplus we then estimated a straight line demand function through these two points. This yields: $Q = -2{,}832{,}861\ P + 141{,}855{,}670$, where Q = quantity demand (million lbs), and P = price in $/cwt, as our estimate of the demand for milk.

Table 4 shows the price, quantity and government purchases implications of selected combinations of technology and price policy. If government price supports are removed and the market allowed to adjust, the model predicts price falling to $11.52/cwt and quantity to 10,922.11 million lbs. The introduction of bGH would result in a further decline in price of $0.08 and an increase over the equilibrium quantity of 22.66 million lbs. The 1985 farm bill should allow New York milk price to be in the mid $11 range by 1988 (Jacobson et al). If, however, bGH had been introduced without a compensatory change in price policy, the $13.50/cwt support price would have induced production of an additional 10,497.1 million lbs. To support this, government expenditures for New York state alone would have had to increase to $1,597.85 million.

Table 4. Price and Quantity Effect of Selected Policies and Technologies

Policy and Technology	Price ($/cwt)	Quantity (million lbs.) Supplied	Demanded[a]
without bGH/with current price support	13.50	11,700.00	10,361.20
without bGH/without price support	11.52	10,922.11	10,922.11
with bGH/with current price support	13.50	22,197.10	10,361.20
with bGH/without price support	11.44	10,944.77	10,944.77
with bGH/with NY price support at $11.51/cwt.	11.51	11,697.80	10,924.94

[a]Difference between Quantity Supplied and Quantity demanded is assumed purchased at support price.

Table 5 illustrates the social welfare implications of those policy and technology changes in the New York State dairy sector. Under current technology and price policy the sector generates a net social surplus (NSS) of almost $2 billion per year. By allowing prices to equilibrate this could be increased by 5% to more than $2.1 billion. Table 5 also shows the importance of price policy in creating and distributing gains and losses from bGH. If bGH is introduced along with removal of price supports, the improved technology leads to a modest (< $1 million) increase in NSS over what could have been achieved by simply removing price supports. However, if bGH is introduced without accompanying policy reform NSS falls by 69% to $615.9 million. Consumers do not benefit from the new technology without policy reforms, producers gain $62.31 million (24%), but government expenditures skyrocket to $1.6 billion.

Table 5. Welfare Implications of bGH

Policy and Technology	Consumer Surplus	Producer Surplus	Government Expenditures	Net Social Surplus
		$ million		
without bGH/with current price support	1,894.81	256.66	-180.74	1,970.73
without bGH/without price support	2,105.51	25.00	--	2,130.51
with bGH/with current price support	1,894.81	318.97	-1,597.85	615.93
with bGH/without price support	2,114.26	17.18	--	2,131.44
with bGH/with NY price support at $11.51/cwt.	2,106.61	25.28	-88.96	2,042.93

The final row of Table 5 shows the distribution of costs that would occur if price policy was adjusted to leave NSS surplus unchanged by bGH. This would require a New York price of $11.51/cwt. Consumers gain $12 million, producers would lose $231.4 million and government expenditures would fall by $91.8 million compared to no bGH and 1984 support price.

Conclusions

In this paper we described a linear programming model that allows us to examine the implications of bovine growth hormone on price, quantities and welfare in the New York state dairy sector. The model indicates that the private profitability of bGH is largely predicated on a government price policy that induces resource intensive methods of milk production. Relaxation of this policy essentially eliminates bGH as a viable technology although it may continue to be attractive for highly productive cows.

Failure to relax price supports will not only lead farmers to pursue use of bGH but will also lead to enormous increases in government price support payments. Maintainence of current price supports would, in fact, essentially evaporate net social benefits from the sector. The 1985 farm bill should provide the mechanism to balance milk usage with production.

Aside from the immediate price support issues raised by these findings, this research also raises perhaps a more important question. While it is widely held that government intervention can severely distort incentives in agriculture, little attention has been given to the effect of distortions on the pace and direction of inventive activity. If the tools of modern biotechnology turn out to be as powerful as some expect, and if prices (including support prices) play an important role in guiding research effort (Hayami and Ruttan, Binswanger and Ruttan), then serious efforts need to be given to focusing research on commodities where social benefits are the greatest.

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