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The Impact of bovine Growth Hormone on the New York Dairy Sector: An Example using Sector Linear Programming

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I. Introduction

Rather drastic milk production increases per cow have occurred over the last 20 years. In 1964 the national average production per cow was 7,907 pounds. In 1984 it was 12,495 pounds, an increase of 58 percent. Various technological and management changes have been responsible for those increases. These include feed production, storage, and feeding practices, as well as genetic improvements through improved selection and artifical insemination.

The compound bovine Growth Hormone (Somatrophin), when it becomes commercially available, has the potential to further increase the milk output of a cow. That availability is projected to be before 1989 (Kalter). The hormone naturally occurs in the cow but has been produced by bacteria with gene-splicing techniques (Miller et al.). The control mechanism is not fully understood, but injecting supplemental hormone into the dairy cow causes her to produce additional milk. Increases of 40 percent during application have been measured experimentally (Bauman et al.). No ill effects on the cow have been observed, and the cow simply eats more feed to produce the additional milk. The milk itself is unaltered.

The purpose of this paper is to determine the potential impact of bGH on New York's dairy sector by the use of a dairy sector linear programming model. The primary activities in the model are representative dairy farms that were constructed from farm level linear programming models. Since bGH

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can drastically increase the milk output of the state, milk price is determined endogenously in the model by approximating a downward sloping demand curve for milk using separable programming.

In the next section the structure of the sector linear programming model is presented and discussed. In the third section the empirical coefficients are derived. The fourth section presents the results of the model. The final section presents suggestions for additional research.

II. The Sector Model

As McCarl has summarized, sector models may be constructed using two fundamentally different approaches. First, there are the cost-minimizing models which divide a country into regions, each region containing aggregate activities and constraints (Heady and Srivastava). Since this procedure does not model individual farm behavior, results may not represent true aggregate equilibrium. Second, there are modeling systems which use a large number of representative farms which are used to arrive at equilibrium conditions, often through an iterative process (Walker and Dillon).

Duloy and Norton suggest a linear programming model where farm activities are represented, along with a set of national market clearing relationships. Because the size of the model becomes hopelessly large, they suggest a decomposition algorithm such as the Dantzig-Wolfe algorithm for solutions. As McCarl has observed, however, another approach that this procedure suggests is to utilize activities representing whole farm plans in the linear program rather than attempt to generate entire representative farms in the linear model. That is the approach used in this paper.

Optimal farm plans are generated using farm linear models which maximize profits. Those farm plans for different technologies and resources are then used in the sector model as individual activities. The sector model includes fixed resources, such as various types of land, that are available. Sector income is then maximized given the various types of farms that are possible and the resources available to the sector. Income maximization at the sector level implies that farms will compete for limited resources and only the most profitable farms will survive. This assumption is generally accepted in modeling long-run equilibrium.

At the sector level prices are endogenous and must be allowed to change as output changes. This is accomplished by incorporating a downward sloping demand curve into the linear program by separable programming. For example, assume the aggregate demand curve for a product is linear, $p = a - Bq$, and that cost is a function of output, $c(q)$. Then maximizing $Z = q\ (a-.5\ Bq) - c(q)$ or $qa - .5\ Bq^2 - c(q)$, fulfills the first order condition of profit maximization for each farm because $dZ/dq = a - Bq - c'(q)$, or $p = MC$. In a linear programming sector model MC is simply the cost of an additional farm brought into solution. This MC will be linear or an increasing step function. Unfortunately, the remainder of the function Z, or $W = q\ (a - .5\ Bq)$ is nonlinear. However, it is a concave function of q so that approximate solutions are possible with separable programming (Duloy and Norton). Also, revenue to the sector is $p \cdot q$ or $q\ a - B\ q^2$. Since separation is based upon different amounts of q being produced, the revenue function can be added as an accounting row to measure revenue or income to the sector.

III. The Empirical Model

A relatively small dairy sector model of approximately 150 dairy farms was constructed rather than a national or state model. These results could be easily compared to results obtained by Magrath and Tauer who used a beginning sector of 147 dairy farms. Results derived here can also be scaled up to the state level if the small model is representative of the state's dairy sector.

As an approximation of reality the sector model cannot be expected to provide completely accurate results. That should be clear with linear programming after more than a decade of discussion of aggregation of representative farms (Day; Buckwell and Hazell). In fact, this model with only a few representative farm types cannot be expected to exactly duplicate the changes that will occur in New York's dairy industry. However, the model should provide relative changes in key characteristics in the sector, such as income, prices, and farm numbers, as bGH is adopted. More accurate results should be obtainable if the model is extended to include more detail.

The linear programming matrix consists of 28 columns and 10 rows and is shown in Figure 1. The first 6 columns are dairy farm activities with no use of bGH, consisting of three feeding/crop production systems each at two production levels. The first system is a 65-cow farm feeding primarily hay (mixed mainly grass) and corn silage. The second system is a 100-cow farm feeding hay (mixed mostly legume) and corn silage and producing some of its corn requirement. The third system also is 100 cows, feeding hay (mixed mostly legume), corn silage, and corn, but also producing excess corn for sale. Each representative farm is evaluated at 13,000 and 16,000 pounds of milk sold per cow. These activities were generated from farm linear programming models reported in Kalter et al. as their normal feed intake farm results. Reflected in the objective function is fixed and variable cost minus the sale of any livestock crops and other non-milk income. These objective values reflect the marginal cost of an additional dairy farm. Milk income is incorporated by a separate set of milk sale activities via a milk transfer row.

The next 12 activities are dairy farms that have adopted bGH. They are the same 6 representative farms with the impact of bGH reflected in their cost of production and milk output. The land resources for each farm, however, have not been altered. The coefficients are from Kalter et al. and were also generated from farm linear programming models. Experimentally, the greatest response on an annual basis has been a milk increase of 25.6 percent so that response level and half that amount, 12.8 percent, were used on each of the 6 farm types.

The next set of 10 columns are the milk selling activities. A constant elasticity (E=-.3) demand function from Magrath and Tauer was used, $q = 3{,}247{,}255\ p^{-.3}$, where p is price in cwt. and q is quantity in cwt. This function had been derived for the market share of 147 dairy farms with government price supports removed. Table 1 shows the 10 price and quantity combinations used to represent the demand curve, as well as the revenue at each price and the area under the demand curve for each milk quantity. The area under the demand curve and the cost of producing milk are components of the objective function. Since the area under the demand curve is an increasing but concave function of milk quantity and the objective function is maximized, then at most two milk sale activities will come into solution at any time. With the addition of a milk balance constraint in the matrix

Table 1. The Demand Curve for Milk (E = -.3)

Price	Quantity (cwt.)	Revenue	Area Under Demand Function
14.00	1,471,221	20,597,094	20,597,094
13.50	1,487,361	20,079,374	20,814,984
13.00	1,504,296	19,555,848	21,035,139
12.50	1,522,101	19,026,263	21,257,702
12.00	1,540,856	18,490,272	21,482,762
11.50	1,560,656	17,947,544	21,710,462
11.00	1,581,601	17,397,677	21,940,857
10.50	1,603,835	16,840,268	22,174,314
10.00	1,627,483	16,274,830	22,410,794
9.50	1,652,720	15,700,841	22,650,545

constraining the level of sale activities to sum to 1, linear segments of price and quantity between any 2 price nodes are possible. Included as an accounting row is the income to the dairy sector. This consists of the milk revenue at the solution prices minus the variable and fixed farm costs of producing that quantity of milk.

The rows of the matrix include, besides the dairy income accounting row and a milk transfer row, the 3 land types, a constraint on the number of 13,000 and 16,000 producing cows, and the maximium number of 12.8 milk increasing and 25.6 milk increasing bGH adopting farms. Since the demand function was constructed for 147 dairy farms, 37,000 acres of land, or about 252 acres per farm, were provided to the sector. Based upon a survey of estimated cropland by soil group in 21 New York counties (Boisvert and Bills), 14,544 acres were allocated as Land 1, 13,276 acres were allocated as Land 2, and 9,180 acres were allocated to Land 3. Although average milk production per cow in New York during 1984 was 12,250 pounds, 16,000 production cows were limited to 6,000 head. This allowed 60 of the 147 farms to have 100 cow herds averaging 16,000 pounds. The constraint on the 13,000 pounds producing cows was set at 8,000 but was never binding.

Alternative non-dairy enterprises were not included in this sector model. In a declining sector it was presumed that resources would be utilized by the dairy sector until losses occur. Then those resources will exit the dairy sector and be used in the production of other commodities or set idle. The purpose of this model was not to determine those alternatives. To the extent that alternative enterprises are more profitable than dairying at some milk price that still provides a positive net income to dairying, the exclusion of these alternatives will bias the results.

IV. Results

Although this model cannot be expected to generate exact answers because of its limited scope, it was validated by removing the endogenous milk price columns and using an exogenous milk price of $13.50. This was the 1984 average New York milk price. The result was 141.6 farms and milk production of 1,711,573 cwt. This compares closely to the sample result of 147 farms and milk production of 1,711,514 cwt. (Magrath and Tauer). Of the 14,544 acres of the poorest land, 4,987 acres go unused. The farms consisted of 57.8 silage and 13,000 pounds per cow farms, 15.6 silage and 16,000 pounds per cow farms, and 68.3 hay and 16,000 pounds per cow farms. No excess corn producing farms entered solution.

The next step was to remove the government price support mechanism but not yet allow the adoption of bGH. The result was a reduction in the number of farms to 117 and milk price to $13.00. Output and dairy income also fell. These results are summarized and compared to other scenarios in Table 2.

Table 2. Impact of bovine Growth Hormone and Removing Government Price Supports

Scenario	Number of Farms	Milk Price	Milk Produced	Dairy Income a/
Government price supports	141.6	$13.50	1,711,573 cwt.	$4,793,753
No price supports	117.0	$13.00	1,504,296 cwt.	3,992,540
bGH 12.8-percent increase	100.9	$12.00	1,540,586 cwt.	3,783,651
bGH 25.6-percent increase	86.1	$11.50	1,560,656 cwt.	3,988,267

a/ Costs include a charge for farmers' labor and equity. See Kalter et al.

It is perplexing that milk price does not drop lower than $13.00. However, this model assumes instantaneous equilbrium adjustment based upon long-run profit behavior. In the short-run prices would fall much lower and farm numbers would slowly fall. This is demonstrated later when dairy farms are allowed to operate at a loss.

Two levels of bGH farm level response rates were analyzed. One rate was a 25.6 response increase, the maximum obtained to date on experimental animals. Since field response will probably not reach that level, a response of half that amount was also used. The results are also summarized in Table 2. As expected, farm numbers fall as does milk price. The introduction of bGH does increase milk production from the level with no price supports, but the aggregate milk output increase is only 2.4 percent with 12.8-percent farm increasing bGH and only 3.7 percent with 25.6-percent increasing bGH. Milk output never approaches the level of production that occurred with government price supports. Dairy aggregate income also decreases with bGH adoption, but the reduction is small with the 25.6 percent bGH response when compared to no price supports and no bGH.

Although the number of farms decreases with no price supports and bGH, the decrease primarily occurs because dairy farms producing grass hay on low quality land leave the industry (Table 3). There is little contraction in farms producing silage. The optimal cropping mixes of these farms do change, however, as reported in Kalter et al. More hay (legume) is grown on the silage producing farms at the high bGH response level. The dairy farms producing excess corn never enter solution.

Table 3. Farm Types with bovine Growth Hormone and Removing Government Price Supports

Scenario	Hay		Silage		Corn	
	13,000 lbs.	16,000 lbs.	13,000 lbs.	16,000 lbs.	13,000 lbs.	16,000 lbs.
	-- Number of farms --					
Government price supports		68.3	57.8	15.6		
No price supports		43.7	41.9	31.6		
bGH 12.8-percent increase		27.5	31.3	42.1		
bGH 25.6-percent increase	12.7		13.4	60.0		

The change in farm numbers and types is reflected in aggregate land use (Table 4). As the hay farms decline in numbers, poor land and some average land are removed from use in milk production.

Table 4. Land Use in Acres With bovine Growth Hormone Adoption and Removing Government Price Supports

Scenario	Poor Land	Average Land	Good Land
	-- Acres in crops --		
Government price supports	9,557	13,276	9,180
No price supports	6,123	11,804	9,180
bGH 12.8-percent increase	3,853	10,831	9,180
bGH 25.6-percent increase	1,787	9,946	9,180

As stated earlier these results are based upon long-run profit maximization behavior on the part of farmers. In the long-run this behavior is forced upon farmers because they cannot operate indefinitely with losses and expect to survive. However, in the short-run it is possible for a farmer to operate at a loss, and many will until they determine that the long-run income of their operation is negative. To model this short-run behavior the variable cost for each representative dairy farm was used rather than total cost of production. The results are that more farms enter solution at each scenario, milk price is lower with greater output, and dairy income is lower than when total costs of production were used. Table 5 summarizes these results, which can be compared to the summarized results in Table 2. With government support prices and farmers covering only variable costs, there are 160.2 farms in solution, an increase of about 19 compared to the solution based on total costs. The decrease in farm numbers is not as great when using variable costs as price supports are removed and bGH is introduced. With variable costs milk price falls as low as $9.55 with 25.6-percent bGH farm increasing production whereas the price fell only to $11.50 using total costs. These differences between total and variable costs indicate the necessity to design policy to encourage the orderly exodus of resources, including farmers, from dairying.

Table 5. Impact of bovine Growth Hormone if Farmers Cover Only Variable Costs of Production

Scenario	Number of Farms	Milk Price	Milk Produced	Dairy Income a/
Government price supports	160.2	$13.50	1,790,291 cwt.	$4,283,487
No price supports	144.6	$10.87	1,587,367 cwt.	1,548
bGH 12.8-percent increase	129.6	$10.05	1,624,111 cwt.	- 14,019
bGH 25.6-percent increase	118.9	$ 9.55	1,650,038 cwt.	- 3,982

a/ Costs include a charge for farmers' labor and equity. See Kalter et al.

The type of dairy farm that enters solution is not much different using variable or total costs with government support of milk price. This is not too surprising since the resource constraints using either cost measure strongly influence results. What is interesting is the difference in the types of farms that enter solution between variable and total costs when price supports are removed and bGH is introduced. With variable costs the shift is to hay and corn farms (Table 6) where previously with total costs the shift was to silage farms (Table 3). These differences are also reflected in land use patterns summarized in Table 7. With variable costs

Table 6. Farm Types With bovine Growth Hormone if Farmers Cover only Variable Costs of Production

Scenario	Hay		Silage		Corn	
	13,000 lbs.	16,000 lbs.	13,000 lbs.	16,000 lbs.	13,000 lbs.	16,000 lbs.
	-- Number of farms --					
Government price supports	11.6	92.3	56.3			
No price supports	61.9	42.0	8.0			32.7
bGH 12.8-percent increase	57.0	35.8				36.7
bGH 25.6-percent increase	46.4	35.8				36.7

Table 7. Land Use in Acres With bovine Growth Hormone if Farmers Cover Only Variable Costs of Production

Scenario	Poor Land	Average Land	Good Land
	-- Acres in crops --		
Government price supports	14,544	13,276	7,042
No price supports	14,544	12,142	9,180
bGH 12.8-percent increase	12,997	11,078	9,180
bGH 25.6-percent increase	11,511	10,441	9,180

more of the poor and average land stays in production. This is probably due to the relatively greater fixed costs of owning good land as compared to poor land.

As stated earlier these results can be scaled to the state level. This was accomplished by calculating the percentage changes in the total cost and then the variable cost scenario results from their base of government price supports. These percentage changes were then applied to the number of farms, milk price, and milk produced in New York for 1984. The range of results are in Table 8. Given the small scope of the model and its limitations, these projections should be viewed as rough approximations. Also listed is a projection from Magrath and Tauer based upon a 20-percent bGH induced milk production increase. That projection is slightly more pessimistic in regard to farm numbers and milk price than the results from this study.

Table 8. Potential Impact of bovine Growth Hormone on New York Dairy Production a/

Scenario	Number of Farms	Milk Price	Milk Produced
Currently (1984)	17,500	$13.50	11,405 mil. lbs.
Removing price supports	15,015-15,803	$10.87-$12.00	10,150-10,265 mil. lbs.
and 12.8-percent bGH farm level increase	13,003-14,158	$10.05-$11.00	10,345-10,538 mil. lbs.
or 25.6-percent bGH farm level increase	11,165-12,985	$ 9.55-$10.50	10,515-10,686 mil. lbs.
Magrath and Tauer (20-percent bGH)	12,600	$9.42	10,522 mil. lbs.

a/ Results derived from a small sector linear programming model with farmers covering variable costs or total costs.

V. Model Extensions

An obvious model extension is to expand the model to encompass the whole state of New York. As stated previously, however, expanding the resource endowments and adjusting the milk demand curve accordingly would not alter the results obtained here except for a scalar multiple. An extension, however, would be to model additional representative farms to encompass additional technologies and land usage. Also a possibility would be to divide resources by region within the state to determine intrastate regional impacts.

A more ambitious effort would be to include other states in the sector model. Inclusions could be Wisconsin and California. This would tell us whether any regional adjustments could be expected. Given the fixed milk processing plants in some locations, regional demand functions could be utilized.

Finally, the whole farm budgets utilized in this study were generated from fixed milk and feed prices. Allowing milk price to change endogenously when a fixed milk price is reflected in the farm activity is inconsistent. However, Kalter et al. ran their farm models for lower milk prices. Their results indicate that there was usually no change in farming activities until the milk price fell below $9.50.

Kalter et al. did not run their models for various feed prices since the adoption of bGH was thought to have less impact on those prices than milk prices. The results of this study imply that a significant increase in hay production from former dairy farms might occur. With production increases of that magnitude and adjustments in the dairy sector, it would be appropriate to extend the model by modeling hay production and consumption.

All of these extensions would enlarge the model and require additional efforts in model construction and data collection. The extensions would allow the analysis of more detailed and subtle changes and concerns, while the current analysis permitted only the more rudimentary questions of price, income, production, farm numbers, and resource usage.

Figure 1

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            ************ TRANCOL OF LP MATRIX ************

LP PROBLEM FILE NAME: BGH
PROBLEM TYPE: MAX

                                                                                                                          PAGE 1
ROW            HAY13000   SIL13000   COR13000   HAY16000   SIL16000   COR16000    H13B13     H13B26     H16B13     H16B26     S13B13
OBJ FCN    %-108938.0000%-134688.0000%-122118.0000%-118581.0000%-150065.0000%-136059.0000%-114142.0000%-119471.0000%-125478.0000%-133
808.0000%-142832.0000
DAIRY-IN G%-108938.0000%-134688.0000%-122118.0000%-118581.0000%-150065.0000%-136059.0000%-114142.0000%-119471.0000%-125478.0000%-133
808.0000%-142832.0000
MILK-TR  G  8450.0000 13000.0000 13000.0000 10400.0000 16000.0000 16000.0000  9531.5996 10613.2002 11715.5996 13062.4004 14664.0000
MILK-BAL L      .          .          .          .          .          .          .          .          .          .          .
LAND1    L   140.0000      .          .       140.0000      .          .       140.0000   140.0000   140.0000   140.0000      .
LAND2    L    60.0000   125.0000   150.0000    60.0000   125.0000   150.0000    60.0000    60.0000    60.0000    60.0000   125.0000
LAND3    L      .       125.0000   250.0000      .       125.0000   250.0000      .          .          .          .       125.0000
COW16000 L      .          .          .        65.0000   100.0000   100.0000      .          .        65.0000    65.0000      .
COW13000 L    65.0000   100.0000   100.0000      .          .          .        65.0000    65.0000      .          .       100.0000
ADOPT13  L      .          .          .          .          .          .         1.0000      .         1.0000      .         1.0000
ADOPT26  L      .          .          .          .          .          .          .         1.0000      .         1.0000      .



                                                                                                                          PAGE 2
ROW             S13B26     S16B13     S16B26     C13B13     C13B26     C16B13     C16B26     MILK1      MILK2      MILK3      MILK4
OBJ FCN    %-151445.0000%-160965.0000%-173319.0000%-129605.0000%-137483.0000%-145266.0000%-155873.0000%20597090.0000%20814980.0000%21
035140.0000%21257700.0000
DAIRY-IN G%-151445.0000%-160965.0000%-173319.0000%-129605.0000%-137483.0000%-145266.0000%-155873.0000%20597090.0000%20079370.0000%19
555850.0000%19026260.0000
MILK-TR  G 16328.0000 18024.0000 20096.0000 14664.0000 16328.0000 18024.0000 20096.0000%-1471221.0000%-1487361.0000%-1504296.0000%-1
522101.0000
MILK-BAL L      .          .          .          .          .          .          .         1.0000     1.0000     1.0000     1.0000
LAND1    L      .          .          .          .          .          .          .          .          .          .          .
LAND2    L   125.0000   125.0000   125.0000   150.0000   150.0000   150.0000   150.0000      .          .          .          .
LAND3    L   125.0000   125.0000   125.0000   250.0000   250.0000   250.0000   250.0000      .          .          .          .
COW16000 L      .       100.0000   100.0000      .          .       100.0000   100.0000      .          .          .          .
COW13000 L   100.0000      .          .       100.0000   100.0000      .          .          .          .          .          .
ADOPT13  L      .         1.0000      .         1.0000      .         1.0000      .          .          .          .          .
ADOPT26  L     1.0000      .         1.0000      .         1.0000      .         1.0000      .          .          .          .



                                                                                                                          PAGE 3
ROW             MILK5      MILK6      MILK7      MILK8      MILK9      MILK10     R H S
OBJ FCN    %21482760.0000%21710460.0000%21940860.0000%22174310.0000%22410790.0000%22650540.0000    ********
DAIRY-IN G%18490270.0000%17947540.0000%17397680.0000%16840270.0000%16274830.0000%15700840.0000        .
MILK-TR  G%-1540856.0000%-1560656.0000%-1581601.0000%-1603835.0000%-1627483.0000%-1652720.0000        .
MILK-BAL L     1.0000     1.0000     1.0000     1.0000     1.0000     1.0000     1.0000
LAND1    L      .          .          .          .          .          .     14544.0000
LAND2    L      .          .          .          .          .          .     13276.0000
LAND3    L      .          .          .          .          .          .      9180.0000
COW16000 L      .          .          .          .          .          .      6000.0000
COW13000 L      .          .          .          .          .          .      8000.0000
ADOPT13  L      .          .          .          .          .          .          .
ADOPT26  L      .          .          .          .          .          .          .
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