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OPTIMAL PRODUCTION SCHEDULES FOR A REPRESENTATIVE FARM UNDER ALTERNATIVE SEASONAL MILK PRICING PATTERNS OF THE BASE-EXCESS PLAN

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ABSTRACT

Production of milk under various pricing policies were examined for a representative dairy farm operating under the base-excess plan. Three pricing scenarios were examined to determine calving schedule, milk production, and shadow prices. The period May-July was most profitable, and December-January the least profitable months for calving, under the base-excess program in the Mid-Atlantic Order. The representative producer responded to the pricing policies by shifting production in response to changes in the seasonal patterns of the base and excess prices.

INTRODUCTION

Legislation establishing the Federal Milk Marketing Orders had as one of its goals to "provide in the interests of producers and consumers an orderly flow of the supply thereof through its normal marketing season and avoid unreasonable fluctuations in supplies and prices" (U.S.D.A., 1971, p2). To respond to this objective, several marketing orders have established seasonal incentive plans, including the base-excess plan and the Louisville plan, to provide milk producers with economic (price) incentives to shift some of their production to be more in line with seasonal milk consumption.

The dairy industry in the Northeast and throughout the U.S. faces seasonal supply-demand imbalances. Supplies which are not consumed as fluid products must be processed into other products. Processing facilities must be available to handle all supplies. Smith, et al. found a wide variation in seasonal reserves in the Northeast, with the largest daily amount in June and smallest in November. Since milk is perishable and bulky, these reserves must be processed in a timely way, which requires large processing capacities to meet the seasonal requirements. Then, because of the seasonal supply-demand imbalances, excess processing capacity is available for the remainder of the year.

Costs of handling and managing seasonal milk reserves must be absorbed by the industry. This may include the costs of transportation, storage, and processing, but may also include the costs of underutilized equipment and personnel during several months of the year. On a national basis, Lasley and Sleight found that manufacturing capacity is underutilized most of the year with operation at less than 90 percent for 9 or 10 months of the year and below 80 percent for 7 or 8 months. Christensen, et al. also examined seasonal supply-demand imbalances and indicated the premium which could be paid if supply patterns followed consumption patterns.

OBJECTIVE

The purpose of the research reported in this article was to examine representative producer response to seasonal price incentives of the base-excess plan and to predict how profit-maximizing producers should respond to changes in the seasonal pattern of milk prices. A linear programming model was developed for a representative farm operation with 100 milk cows. The objective function was to maximize annual profit, subject to the monthly changes in base and excess milk prices, a standardized lactation curve with adjustments for month of calving, and monthly feed and labor costs and requirements.

Profit-maximizing dairy producers are expected to plan their production to respond to price patterns within the year. If feed and other input prices were held constant throughout the year and milk prices followed a seasonal pattern, milk production would generally be expected to follow the same pattern. If, however, milk prices were constant throughout the year, and feed and other input prices followed a seasonal pattern, then milk production would be expected to move counter to the feed price patterns. In both cases a seasonal production pattern is expected to result in response to the seasonal movement of prices.

Historically, milk prices in the Middle-Atlantic market have exhibited seasonal price cycles, with prices lowest in the period April-June and highest in the period October-January. This cycle results from the seasonal pattern exhibited in the basic formula (Minnesota-Wisconsin) price and month-to-month adjustments in Class II prices of the Mid-Atlantic Marketing Order (Shaw and Levine). The seasonal price pattern of the basic formula price responds to supply and demand conditions for milk and dairy products. Additional price adjustments are contained in the Mid-Atlantic Milk Marketing Order to encourage milk pro-

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ducers to plan their production to be more in line with milk consumption.

Producers subject to the Mid-Atlantic Marketing Order are paid a higher "base" price for milk produced within the farm's established base (defined as the average daily production for the period August-December). They are paid a lower "excess" price during the period March-February for production which exceeds their established base during the previous August-December (U.S.D.A., 1975). The program was therefore designed to encourage producers to increase their production during the base-forming period of August-December by paying them a higher average price for their milk throughout the year.

Milk producers may respond to seasonal price variations by scheduling production for the months of the year which are most profitable by planning calving, culling, or replacement decisions to increase their profitability. Producers may also adjust feeding patterns to respond to seasonal changes in feed or milk prices. Labor availability for the peak production period may be a constraint on some farms and may determine the production scheduling choices of those producers.

THE REPRESENTATIVE FARM MODEL

A linear programming model was developed for a representative farm operation with 100 milk cows. The output of the model indicated the number of cows to freshen in each month, monthly milk production, monthly utilization of inputs, and other information.

The objective function for the model was to maximize annual profit and may be written as:

$$\text{Max } \Pi = \sum_{t=1}^{12} \left(P_t^b Q_t^b + P_t^e Q_t^e - \Sigma\, p_t^i q_t^i \right) - FC \quad [1]$$

where Π = annual profit,

P_t^b = base milk price in month t,

Q_t^e = excess milk price in month t within the established base,

P_t^e = excess milk price in month t,

Q_t^e = quantity of excess milk produced in month t,

p_t^i = price of input i in month t,

q_t^i = quantity of input i in month t,

F = fixed costs per cow per year, and

C = number of cows (=100 for representative farm)

Base and excess milk prices incorporated in the model were from 1978 in the Mid-Atlantic Milk Marketing Order. Other prices, including feed and labor costs, were also based on 1978 to provide internal consistency within the model.

The operation of the base-excess plan, the standardized lactation curves with adjustments for month of calving, feed and labor utilization, and other relationships were incorporated into the equations of the model (Livezey). The remainder of this section is used to describe these relationships.

The standardized lactation curve with adjustments for month of calving may be specified by the following formula:

$$Q_{\ell,m} = L + M \quad [2]$$

where $Q_{\ell,m}$ = daily milk production in month of the lactation for a cow freshening in month m,

L = daily milk production in month of the cow's lactation (the standard lactation curve), and

M = adjustment in daily milk production due to month of calving.

Specific coefficients for L and M are shown in Table 1. The largest adjustment is for May and June calving. Based on equation 2, milk production per lactation ranged from 13,920 pounds for a May freshening cow to 12,420 pounds for a November calving. By comparison, average milk production per cow in Maryland for 1978 was 11,943 pounds (Maryland Department of Agriculture). Monthly milk production was calculated for cows freshening in each month, and the model calculated monthly production for the herd.

One important assumption of the model is a 12-month calving interval for the herd. This is possible for individual animals, but probably not realistic for an entire herd due to illnesses, breeding problems, heat detection, or other reasons.

The model incorporated the full-time hired man example of labor input. In this specification, the same amount of labor was hired each month, and this was equal to the amount required in the peak production month. Excess labor was therefore present in months when cows were dry. Carley estimated the labor requirement per cow per year for a 100 cow herd to be 58 hours. He also determined that 60-70 percent of the labor used per cow was for milking. Based on these relationships, labor utilization was allocated between milking and non-milking uses in the model.

The model for the representative 100-cow dairy farm implemented the assumption that the forage and most of the feed for the herd was produced on the farm. The cost of supplying such feed was incorporated into the fixed costs per cow in the objective function. Additional feed was purchased, based on National Academy of Sciences energy requirements data, for cows with production per lactation over 13,000 pounds (Livezey). The additional feed was purchased at the average price for 16 percent protein dairy feed concentrate paid by Maryland farmers in 1978.

Table 1: Standardized lactation curve with adjustments for month of calving

Daily Milk Production During Month of Lactation		Adjustments for Month of Calving	
Month	(Pounds per day)	Month	(Pounds per day)
1	54.33	Jan	0.67
2	52.92	Feb	1.59
3	49.30	Mar	2.05
4	45.89	Apr	2.95
5	43.04	May	4.41
6	40.14	Jun	4.19
7	37.16	Jul	2.89
8	33.52	Aug	1.32
9	29.86	Sep	0.78
10	26.50	Oct	0.14
11	Dry	Nov	-0.35
12	Dry	Dec	0.0

Source: Wiggins

Table 2: Optimal Production Schedule Based on 1978 Prices

Month	Base Price	Excess Price	Cows Freshening	Milk Production		Value of Increasing Total Production	Reduced Profit From Freshening a Cow in Month
				Base	Excess		
	($/cwt)	($/cwt)	(Number)	(cwt)	(cwt)	($/cwt)	(Dollars)
Jan	10.65	8.89	0	1103.63	0.0	10.65	151.76
Feb	10.75	8.97	0	899.06	0.0	10.75	104.57
Mar	10.71	8.99	0	237.69	0.0	10.71	66.35
Apr	10.71	9.10	0	170.13	0.0	10.71	39.18
May	10.71	9.08	76	1389.60	0.0	10.59	0.0
Jun	10.75	9.10	5	1389.60	0.0	9.15	0.0
Jul	10.75	9.31	19	1389.60	301.04	9.31	0.0
Aug	11.00	9.73	0	1389.60	207.01	11.16	14.68
Sep	11.25	9.91	0	1389.60	64.81	11.34	52.42
Oct	11.56	10.19	0	1389.60	20.41	11.62	87.88
Nov	11.85	10.45	0	1275.98	0.0	13.28	116.81
Dec	12.03	10.61	0	1210.99	0.0	13.46	142.56
Total			100	13,235.08	593.27		

Equations of the model describe the operation of the base-excess plan, as operated in the Mid-Atlantic Milk Marketing Order, for the representative farm. Under this seasonal incentive plan, the base for the farm is calculated as the average monthly production for August-December. Milk produced within the base is sold at the higher "base" price and milk produced exceeding the base is sold at the lower "excess" price. The "excess" price declined from January-May and increased for the period June-December. The "base" price was at its lowest price in July, generally declined from February-July, and increased from July to December. This price pattern is common in the Mid-Atlantic Order.

RESULTS

Results of the linear programming model described above are presented in this section. First, the results are presented given the actual 1978 base and excess prices. Then, the results of two alternative pricing patterns are presented for comparison and producer response to these pricing patterns are analyzed.

PRICING PATTERN OF 1978

The solution from the linear programming model indicated the optimal calving schedule, monthly milk production, and other output for the profit-maximizing producer on the representative farm. Data in Table 2 indicate the most profitable schedule for calving was to freshen 76 cows in May, 5 in June, and 19 in July. By following that schedule, a monthly base of 1389.60 cwt was established. Some milk was sold at the lower excess price during the months July-October.

The data in Table 2 indicate that July is the only month with milk production above the farm's base which does not add to the farm's base. Excess milk produced in August-October was averaged with the November-December production to establish the farm's base.

The appropriate number of cows are freshened in May and June to exactly produce the farm's base. The producer is able to sell this milk at the higher base price. The model indicated that the representative producer should calve the remaining cows in July and sell at the lower excess price, as opposed to waiting till the base-forming period of August-December. It is interesting to note that although the base-forming period is August-December, the recommendation of the model is to calve in May-July, given the price pattern of 1978.

Output of the linear programming model also indicated the value of increasing the farm's total milk production by one hundred pounds, as shown in Table 2. Base and excess prices for the Mid-Atlantic Order in 1978 are shown for comparison. Additional production during the months January-April has a shadow price equal to the base price. Production during these non-base-forming months was less than the farm's established base. Therefore additional production during this period could be sold within the base at the higher base price.

Additional output during the period May and June, had a shadow price between the base price and the lower excess price. This period is not in the base-forming period, although production was at the level of or above the farm's established base. No excess milk was sold in the optimal solution during these months.

The value of additional output during July was equal to the lower excess price. This month is not in the base-forming period. Excess milk was produced and sold, therefore additional milk produced would necessarily be sold at the lower excess price.

The value of additional production in the base-forming months of August-December is higher than the base price. This results since additional production in a month would increase the farm's established base and allow the farm to sell additional milk at the higher base price during the entire year.

It is interesting to note that in this example the shadow price for additional milk production was at or above the higher base price in nine months of the year. In only one month was the shadow price as low as the excess price.

Data in the last column of Table 2 indicate the value to the farm's profit of scheduling the calving to be during the optimal months, as opposed to other months of the year, as indicated by the linear programming model. This data may also be referred to as the cost of making the wrong decision with respect to scheduling calving. Relative values of the data in this column indicate that the most costly (least profitable) month of calving was January. As already indicated in Table 2, the most profitable months for calving were May-July.

Milk producers operating in an order with a base-excess plan should make management decisions related to calving, culling, replacement, feeding, health care, etc in an effort to increase profits. They may be influenced by more complete knowledge of the value of production in various months, following seasonal changes in prices and the operation of the base-excess plan.

ALTERNATIVE PRICING PATTERNS

Various marketing orders have different base-forming periods or base-paying periods. Within an individual order, such as the Mid-Atlantic Marketing Order, one possible policy choice available to those operating the order is to increase the base prices in the base-forming period. Such a decision would be based on the expectation that higher production would result in those months, resulting in higher average annual utilization of processing capacity or other objectives. The first alternate pricing pattern investigated was one in which the base prices for

Table 3: Optimal Production Schedule Based on 1978 Prices with a 10 Percent Increase in Base Prices During Base-Forming Months.

Month	Base Price	Excess Price	Cows Freshening	Milk Production		Value of Increasing Total Production	Reduced Profit From Freshening Cow in Month
				Base	Excess		
	($/cwt)	($/cwt)	(Number)	(cwt)	(cwt)	($/cwt)	(Dollars)
Jan	10.65	8.89	0	1181.35	0.0	10.65	191.14
Feb	10.75	8.97	0	964.64	0.0	10.75	134.99
Mar	10.71	8.99	0	962.25	0.0	10.71	74.42
Apr	10.71	9.10	0	145.00	0.0	10.71	43.41
May	10.71	9.08	0	0.0	0.0	10.71	0.0
Jun	10.75	9.10	83	1456.93	0.0	9.23	0.0
Jul	10.75	9.31	17	1456.93	314.06	9.31	0.0
Aug	12.10	9.73	0	1456.93	213.49	11.46	0.35
Sep	12.37	9.91	0	1456.93	56.23	11.64	40.67
Oct	12.72	10.19	0	1456.93	15.37	11.92	91.33
Nov	13.03	10.45	0	1338.07	0.0	14.17	121.54
Dec	13.23	10.61	0	1290.71	0.0	14.36	158.23
Total			100	13,266.67	599.15		

Table 4: Optimal Production Schedule Based on 1972 Prices Adjusted to 1978 Price Level.

Month	Base Price	Excess Price	Cows Freshening	Milk Production		Value of Increasing Total Production	Reduced Profit From Freshening a Cow in Month
				Base	Excess		
	($/cwt)	($/cwt)	(Number)	(cwt)	(cwt)	($/cwt)	(Dollars)
Jan	11.06	9.47	0	1088.24	0.0	11.06	137.83
Feb	11.15	9.47	0	886.81	0.0	11.15	100.60
Mar	11.05	9.40	0	230.81	0.0	11.05	62.25
Apr	10.85	9.31	0	0.0	0.0	10.85	38.91
May	10.91	9.28	76	1379.18	0.0	10.74	0.0
Jun	10.87	9.29	24	1379.18	349.39	9.29	0.0
Jul	10.83	9.44	0	1379.18	311.41	9.44	1.28
Aug	10.95	9.60	0	1379.18	204.12	11.11	17.05
Sep	11.15	9.60	0	1379.18	63.47	11.11	40.89
Oct	11.23	9.70	0	1379.18	22.03	11.21	71.41
Nov	11.35	9.82	0	1267.18	0.0	12.86	105.27
Dec	11.35	9.93	0	1201.55	0.0	12.86	124.60
Total			100	12,949.67	950.42		

the base-forming months of August-December were increased by 10 percent. All other prices in the model were left unchanged.

Results of the model with a 10 percent increase in base prices during the base-forming months are shown in Table 3. The optimal solution is 83 cows freshening in June and 17 in July. The farm's "base" was increased to 1456.93 cwt per month, about 4.8 percent higher than the original model. Total production increased less than 0.3 percent with increases in both base and excess production. No production was forthcoming in May, since all cows were assumed to have 10-month lactations with two dry months.

The base and excess prices used by the model are shown in Table 3. Shadow prices, indicating the value of additional milk production in the various months, are also shown. The shadow price is higher than or equal to the base price in seven months. Additional milk produced in the months August-October increased the farm's base, but must be sold at the lower excess price. The relative size and ranking of the data in the last column are essentially the same as the original model, as expected. The least profitable month to schedule calving was January.

The second alternative pricing pattern examined was one in which the seasonal price differences were reduced, i.e., there was less month-to-month variation in prices. The actual price pattern for 1972, adjusted to 1978 prices, was used for the base and excess prices. This pattern is shown in Table 4.

The optimal production schedule for this alternative pricing pattern is to freshen 76 cows in May and 24 cows in June, as shown in Table 4. With this calving schedule, the representative farm's base is 1379.18 cwt per month. This is about 10 cwt per month lower than the results shown in Table 2 for the 1978 pricing pattern. The total amount of milk produced increased, compared to the results shown in Table 2. It is notable that the amount of excess milk production increased from 4.3% for the earlier model to 6.8% for the model results shown in Table 4.

The more level pricing pattern provided less incentives for the producer to plan production for the base-forming period. The value of increased production in a month is equal to or greater than the base price in seven months. However, compared to the data in Table 3, one different month is included.

The cost of calving a cow in a non-optimal month is reduced under the pricing pattern described in Table 4. Again, January is the least profitable month for calving.

SUMMARY AND CONCLUSIONS

Dairy producers have been encouraged to shift some of their production to other seasons through seasonal incentive plans, such as the base-excess plan which operates in the Middle-Atlantic Milk Marketing Order. The model described in this article incorporates the basic operation of the base-excess plan as it affects the representative producer's decisions related to scheduling calving and milk production.

The results of the model described indicate the producer should schedule calving for the months May-July. This result is forthcoming in spite of the fact that the base-forming period is August-December. Excess milk is produced both prior to and during the base-forming period. The value of additional production is equal to or greater than the base price in a majority of the months of the year, and in only one or two months is the value as low as the excess price.

Producers should benefit from the results shown in this article by planning calving, culling, and replacement activities. The cost of making the wrong decisions is indicated in the tables presented.

Policymakers and those administering an order with a base-excess plan may be interested in examining the results of this research since the results suggest the optimal response by representative producers to alternative pricing patterns. Alternative pricing patterns may be expected to encourage changes in milk production resulting in savings to the industry. Additional research may indicate a pricing pattern which would be expected to encourage a production pattern more similar to the seasonal consumption pattern.

The pricing pattern examined in this research, exists, in part because of the seasonal supply-demand imbalance. If many or all producers shifted their production from current patterns, the seasonal pricing pattern would subsequently change. This would require additional runs of the model to accommodate the new pricing pattern.

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