A SUPPLY RESPONSE ANALYSIS OF INDUSTRIAL BULK MILK PRODUCERS IN SOUTHWESTERN ONTARIO

by H.C. Driver, H.Q. Tran and S.H. Lane

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by

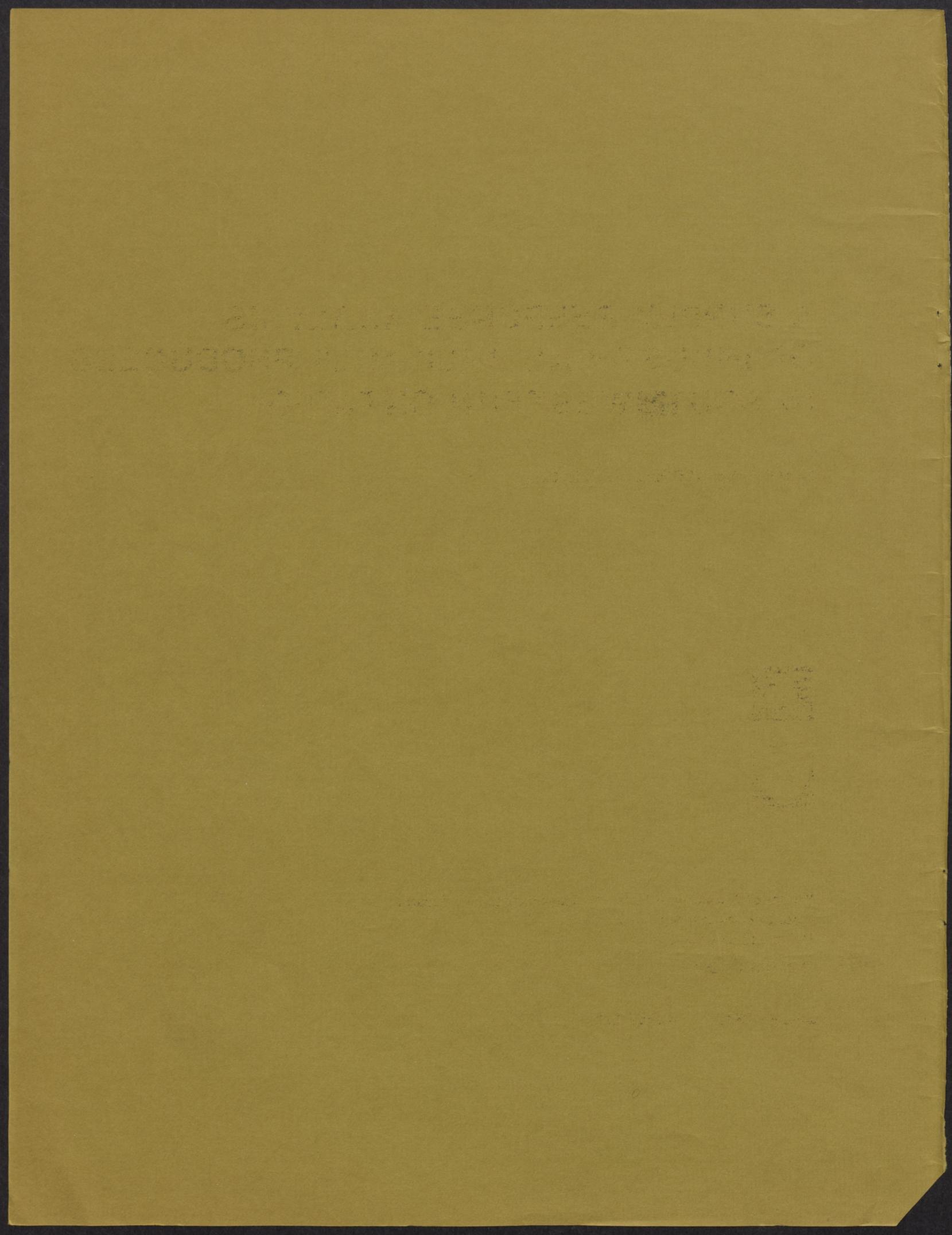H. C. Driver, H. Q. Tran and S. H. Lane

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H. C. Driver, H. Q. Tran and S. H. Lane

SUMMARY AND IMPLICATIONS

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*   The findings reported in this study are based on a pilot project   *
* conducted in 1976 in the Counties of Brant, Oxford, Waterloo, Perth   *
* and Huron in Southwestern Ontario. The research was directed toward   *
* developing a technique for supply response analysis of industrial bulk   *
* milk producers. It investigated two problem areas in determining   *
* aggregate supply responses of industrial bulk milk producers; first,   *
* the problem of selecting farms that are representative of the population;   *
* and second, the problem of modelling these farms in such a manner that   *
* the effects of dairy policy instruments on producer supply responses   *
* and costs could be estimated at the farm and regional level.   *
*   *
*   Using the single representative farm technique estimates were   *
* obtained for (a) the number of dairy farms which employ different types   *
* of technology and production costs associated with each type, and (b) the *
* supply response and costs of production that could be anticipated from   *
* (i) technological improvements and redistribution of farm types, (ii) an   *
* increase in average milk production per cow, and (iii) adjustments in   *
* delivery quotas.   *

* *

The major conclusions and implications which can be drawn from the study are:-

1. The technology of an industrial bulk milk farm had a significant effect on the producer's supply response and cost of production.

2. Other important variables which affected supply response and cost of production were average milk production per cow, the relationship between the amount of land and labour available and utilized in the farm enterprises, and the incidence and importance of competitive nondairy enterprises in the utilization of resources.

3. The cost of milk production was found to be inversely related to the level of technology. As the level of physical technology

increased, labour efficiency improved, land tended to be used more intensively in terms of crop production, and the unit cost of milk production declined.

4. The average cost of milk production within the region would be reduced if the distribution of low versus high technology farms shifted toward the higher technology groupings.

5. The average milk production per cow in the region was slightly under 10,000 lbs. An increase in this variable of 2,000 lbs. (one standard deviation) would significantly reduce the unit cost of production. This reduction in unit cost was attributed to fewer cows being required to fill M.S.Q. which, in turn, reduced labour inputs and lowered feed requirements. Although the cows remaining in the herd would be fed at higher levels this would be more than offset by the smaller amount of feed required for maintenance of the reduced herd.

6. All representative farms produced up to their M.S.Q. limits in 1976 implying that dairying had a comparative advantage over other enterprises such as beef, hogs and cash crops under prevailing price and cost relationships. If the restrictions on M.S.Q. had been lifted the model indicated that milk output would have increased approximately one-fifth with no changes in production methods or practices. With minor improvements in production practices milk production would have increased by slightly over one-quarter.

7. Associated with this potential to increase production were positive shadow values for M.S.Q. These estimated shadow values for M.S.Q. (the maximum amount producers could pay for quota) were relatively high due to the favourable cost and price relationships for milk production compared to competing enterprises. They also increased directly in relation to the level of technology, being about four times greater on the highest technology farms compared to the lowest technology farms. Based on 1976 cost price relationships the shadow value of M.S.Q. on the former type of farm was estimated to be 8.57 cents per pound if the quota value were capitalized over 5 years at 10 per cent. Quota price was fixed at 2 cents a pound during most of the 1976/77 fiscal year. To the extent that dairying is made more attractive relative to competing enterprises, the shadow values increase.

8. By improving their technology the lower technology farms had the greatest potential to reduce costs and improve their net incomes. However, the possibilities of them doing so are limited without additional M.S.Q. It follows that policies designed to increase the demand for milk products, coupled with corresponding increases in M.S.Q., would provide a positive stimulus to upgrading technology on the low technology farms. If there is

little prospect of expansion of the demand for industrial milk
products and hence, little likelihood of an increase in M.S.Q.,
serious consideration should be given to policies which would
facilitate the adjustment of lower technology farms out of the
dairy industry. Given appropriate incentives, adjustments
toward nondairy enterprises are feasible for a majority of these
farms because they can shift to other enterprises without major
structural changes in their farm businesses.

These findings suggest that the methodology of using the single
representative farm to make inferences about a group of farms is worthy
of consideration in the development of an operational framework for
periodic evaluation of dairy policy instruments used in the supply
management program. However, two major limitations should be recognized
and investigated before extending the methodology to the provincial and
national setting.

1. The variability of average milk production per cow was not
   effectively reduced after the classification by technology.
   Further, there was not adequate information from the survey
   to allow thorough investigation of the nature of variability
   resulting from the relationship between the amount of land
   and labour available and rates at which they are utilized.
   Additionally, the variability resulting from the presence of
   nondairy enterprises was not investigated. Because of the
   high degree of observed variability within the farm groups
   in some factors affecting supply response, the classification
   system should be further developed and tested.

2. Considerable time was required to apply the linear programming
   technique on individual farms. Given familiarity with the
   technique it was possible to process and analyze about 30
   farms per man year. If the same technique were applied to an
   adequate sample of representative farms at the national level
   it would require a substantial amount of time just to operate
   the supply response model. However, these procedures could be
   mechanized and the operating time requirements reduced by
   about 70 percent.

Once these two limitations have been resolved the use of this
technique for periodic evaluation of alternative dairy policy instruments
would be feasible.

BACKGROUND

Supply Management Developments

The Interim Comprehensive Milk Marketing Plan for industrial milk came into existence in December 1970 when Ontario and Quebec became signatories to the agreement. Since that time all provinces in Canada with the exception of Newfoundland joined the plan. The national agreement was intended as a means of achieving a closer balance between production and market requirements in an orderly and equitable manner, thereby improving farmers' returns. Within the framework of this national agreement, provincial governments accepted responsibility for administering the terms of the agreement in their respective jurisdictions. In most cases this responsibility was delegated to producer marketing boards.

The Ontario Milk Marketing Board (O.M.M.B.) has broad powers delegated to it under the Milk Act with respect to the marketing of milk in Ontario. Two of the major policy instruments which it uses for management of the supply of industrial milk are prices and delivery quotas, neither of which are entirely within the control of the Board. The producer prices which the Board establishes for milk used for industrial purposes are determined to a large extent by the target price established by the Canadian Dairy Commission and simultaneously, the amount of subsidy which the federal government is prepared to pay. Similarly, the amount of Market Share Quota (M.S.Q.) available for distribution in Ontario is strongly influenced by decisions made at the national level. Also, from time to time the provincial government may introduce programs which affect the supply of industrial milk such as the Industrial Milk Production Incentive Program (IMPIP) which provided partially forgivable loans to industrial milk producers who expanded their milk production.

The Problem

Management of these dairy policy instruments (prices, quotas and subsidies) and provincial programs is dependent upon a capability to anticipate changes in supply and demand conditions, to adjust policy

instruments and to implement programs which embody the incentives or disincentives which are appropriate for bringing about the desired response in milk supply. The difficulties in managing these programs are highlighted by (a) imbalances between milk production and market requirements, and (b) failure to increase or reduce production in an orderly and equitable manner.

Shortly after the national supply management program was introduced, the world demand for industrial milk products strengthened and prices rose. Concurrently, the prices of livestock and grains rose relative to milk prices at the farm level making dairying a less attractive enterprise. Consequently milk production dropped. For example, in 1972, 1973 and 1974 Ontario farmers utilized only 70, 61 and 69 percent respectively of the M.S.Q. that was allotted to Ontario.

By April 1975, the relationship between milk prices and those of products from competing enterprises had changed to such an extent that dairying was once more an attractive enterprise. About the same time large surpluses of skim milk powder and butter began to accumulate on the world market and by the year's end, world prices were severely depressed. This development did not deter Ontario dairy farmers' plans for expansion because additional quota was available free of charge, the price to producers (including subsidy) was only slightly affected by the depressed world market and many were already committed to expanding because of investment in additional physical facilities, some of which were financed by IMPIP. For the 1975/76 dairy year, Ontario utilized 97 percent of its M.S.Q. allotment which had been reduced by 14 percent compared to the previous year.

In April 1976, milk prices were maintained at attractive levels by a price increase but Ontario producers were faced with a further 15 percent reduction in their M.S.Q. holdings and for a short period thereafter, M.S.Q. was negotiable between producers. Owing to the attractiveness of the dairy enterprise relative to other competing enterprises and the subsequent willingness of producers to bid for quota, such transfers were soon (end of May) prohibited by the O.M.M.B.

and any quota relinquished by the producers was purchased by the Board at a fixed price. Quota was subsequently allocated to producers at a fixed price according to their "need" as determined by the Board. Toward the end of the year the Ontario allocation of M.S.Q. was increased by 4 percent.

The adverse effects of the 15 percent reduction in M.S.Q. holdings were felt by most milk producers but were particularly severe for new producers who were expanding their dairy operations and were caught in the position of being unable to acquire additional quota. The Board attempted to remedy inequities in quota distribution by allocating the limited amount available on the basis of certain selected criteria. However, this procedure generated considerable opposition from a significant number of producers who felt they were being treated unfairly.

In April 1977, M.S.Q. was once again permitted to be negotiable and subsequently, quota prices rose from a fixed price of 2 cents per pound to the current price of somewhere between 10 and 15 cents per pound. This brief description of market and policy developments which affected industrial milk producers in Ontario serves to highlight some of the problems inherent in operating a supply management program which was intended to bring more order to the market while providing producers with fair and equitable returns. It also raises questions concerning the mix and appropriateness of the various dairy policy instruments which were used. It is apparent that the successful management of such programs is dependent upon a capability to anticipate changes in supply and demand conditions and to implement programs which will bring about the appropriate adjustments. This study was concerned with developing a technique which would provide insights into the factors affecting industrial milk supply responses and costs of production.

Objectives of the Study

The central purpose of this study was to develop and test a methodology for analyzing and evaluating the effects of certain dairy policy instruments on milk supply responses at both the farm and regional level.

The study was confined to industrial bulk milk producers in one region of Southern Ontario but the technique lends itself to application in the total dairy production sector.

The specific objectives of the study were:

1. To identify representative groups of industrial bulk milk producers.

2. To develop procedures for selecting a representative farm from each of the identified groups.

3. To determine the comparative advantages held by each representative farm in terms of costs and efficiency in milk production.

4. To generate short-run milk supply responses for each representative farm, and the region as a whole.

5. To analyze and evaluate at both the farm and regional levels the effects of prices, quotas and potential technological improvements on milk supply responses and producers' costs.

FRAMEWORK FOR ANALYSIS

The Region and Data Base

The region chosen for this study of industrial milk supply response is situated in Southwestern Ontario. It consists of five counties: Brant, Huron, Oxford, Perth and Waterloo known as Region 2 (Figure 1). According to O.M.M.B. statistics, this region has been the leading producer of both fluid and industrial milk. In May 1976, there were 1066 industrial bulk milk producers in these five counties. Together they shipped 22 percent of the total provincial Group II Pool milk during 1975.

Since up-to-date information on physical resources and other characteristics of all the industrial milk farms in the region was considered necessary for the purpose of farm classification, a mail questionnaire was designed in co-operation with the O.M.M.B. and sent to every industrial bulk milk producer in the region in the spring of 1976. The information obtained was coded and entered into the Statistical Package for the Social Sciences (SPSS) computer file. Additional information from the O.M.M.B. tape such as total milk shipped and M.S.Q. were merged with the above to create a more complete file of the characteristics of the industrial bulk milk farms in the region.

The Representativeness of the Sample

The 456 producers who returned completed questionnaires represented 43 percent of the total number of industrial bulk milk producers. To ascertain how representative this sample was of industrial bulk milk farms in the region the sample means annual milk shipments and the number of milk cows were compared with the known values of these variables for the entire population. The number of milk cows was considered to be the most significant indicator of these two variables, as it was directly related to a number of other important variables such as level of technology, the amount of land and labour utilized and the existence of competing enterprises. Table 1 presents the sample and population means of the two variables selected and,
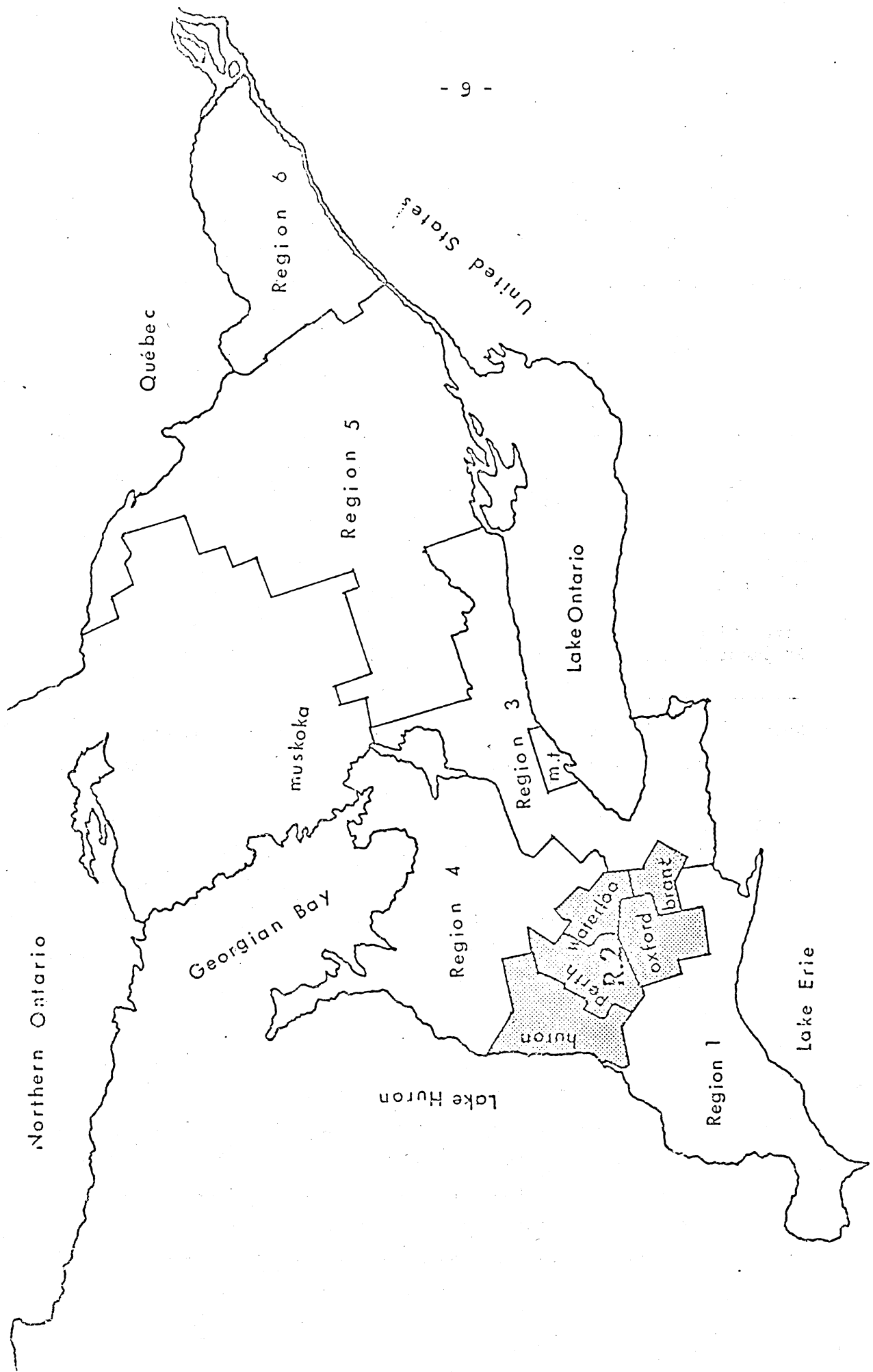
Figure 1. DAIRY REGIONS IN SOUTHERN ONTARIO

as indicated, there were relatively small differences between them.
Hence, it was concluded that the mean characteristics of the respondent
farms closely resembled the mean characteristics of the entire
population of industrial bulk milk producers in the region.

Table 1. Comparison of Population and Sample Means of
the Number of Milk Cows and Milk Shipments
Per Farm in Region 2, 1976

Variable	Population Mean	Sample Mean	Absolute Difference	Percent
Number of Milk Cows	32.19[1]	31.4	.79	2%
Total Milk Shipment (lbs.)	312164[2]	313704	1540	0.5%

Source: (1) Economics Branch, OMAF, Unpublished Statistics.

(2) Ontario Milk Marketing Board, Statistics 1975-1976.

The Classification System

On the basis of previous research by Cairns and Campbell, physical
dairy technology was considered to be the most significant variable for
classifying farms for the purpose of analyzing milk supply responses and
production efficiency. The level of technology in this study was measured
by a combination of technological levels of the milking, cleaning and feed
handling systems on the dairy farms. The labour input for these operations
made up most of the labour requirement for the dairy enterprises.

A schematic illustration of the classification system and the number
of farms in each class is given in Figure 2. According to this classi-
fication there were 24 different possible classes of dairy farms which
could be identified. As shown in Figure 2, the distribution of dairy
farms in the region was such that over 90 percent fell into 12 of the
technology classes. These 12 classes were consolidated into five tech-
nology groups resulting in the following distribution:

Figure 2.   Dairy Farm Classification System

Feeding System Code: H : Hand feeding
                       P : Partly mechanized
                       M : Mechanized

Group	Number of Farms	Percent
Tech A1	93	20.4
Tech A2	151	33.1
Tech A3	68	14.9
Tech B	74	16.2
Tech C	27	6.0
Other	43	9.4
Total	456	100.0

A general description of each is given below.

1. Tech A1 Group: This group of dairy farms had the lowest
    level of technology in the classification system. The group
    used the conventional bucket milker system and had neither
    a stable cleaner nor mechanized feeding system. Hand-feeding
    was most common. This group had the smallest dairy herd, the
    least dairy space, the smallest amount of land and the lowest
    M.S.Q. of the five farm groups. The group accounted for 20.4
    percent of the dairy farm sample.

2. Tech A2 Group: These farms were similar to the Tech A1 group
    but had certain improvements in technology, the most dis-
    tinguishing being the existence of a stable cleaner. Moreover,
    the number of milk cows, total land area, dairy space and M.S.Q.
    were also slightly greater than those of the Tech A1 farms.
    Tech A2 was the largest group, accounting for slightly over
    33 percent of the dairy farms, and it had the lowest average
    milk production per cow, 9526 pounds.

3. Tech A3 Group: In comparison to Tech A1 farms, this group was
    significantly different in technology and resource levels.
    These farms had step-savers and stable cleaners for the
    milking and cleaning operations and partly or fully mechanized
    feeding systems. The number of milk cows, herd size, dairy
    space, land base, M.S.Q. and average milk production per cow
    were higher than the regional average and significantly higher
    than either the Tech A1 or Tech A2 groups. This group accounted
    for almost 15 percent of the dairy farms.

4. Tech B Group: In terms of technology and labour efficiency
    this group was still more advanced than Tech A3. The most
    significant improvement consisted of a pipeline milking system.
    However, in terms of resource levels, these farms had only a
    slightly larger number of milk cows, herd size and dairy space.
    Average milk production per cow was the highest among the five
    groups but the land base was slightly smaller than the Tech A3
    farm group. About 16 percent of the farms were in this group.

5. Tech C Group: This group had the most up-to-date technology. Milking parlors, stable cleaners and partial or fully mechanized feeding systems were common. These farms were the largest in terms of number of milk cows, herd size, dairy space, land and M.S.Q. The group average milk production per cow, however, was slightly lower than that of the Tech B group. Six percent of the respondent farms belonged to this group.

A summary of the major features of each of the technology groups is presented in Table 2.

Selection of the Representative Farms

The selection of a single representative farm for each technology group involved three steps. First, a simple random sampling procedure was used to select ten farms from each group. The second step involved selecting from these ten farms those that fell within the 95 percent confidence limit based on the average number of milk cows per farm in each group. The final step involved a selection by a committee of a single farm that was considered to be representative of each group in terms of number of milk cows, tillable land and man equivalents per farm and average milk production per cow.

In-depth interviews were then conducted on these farms to obtain more detailed physical and financial information on their general business setting, enterprise structure and management practices. This detailed information was used in modelling each farm. The models were then operated to simulate the effects of policy instruments (variables) on milk supply responses and costs of production. The results for each individual farm were used to draw inferences about the corresponding technology grouping. It was possible to aggregate results and to draw inferences at the regional level through weighting each technology grouping in accordance with its corresponding population frequency.

Table 2. Major Features of Industrial Bulk Milk Farms by Technology Group, Region 2, 1976

Major Features	Tech A1 Group	Tech A2 Group	Tech A3 Group	Tech B Group	Tech C Group	Total Farms
Number of farms	93	151	68	74	27	415
Milk cows per farm	23	29	35	36	53	31.4
Annual choretime per cow* (hrs.)	114	89	76	56	50	83.6
Land (tillable acres per farm)	102	136	161	158	247	145
Labour (man equivalents)	1.6	1.6	1.7	1.7	2.0	1.67
Milk production per cow (lbs.)	9637	9526	10269	10513	10349	9896
Other Related Factors						
Maximum dairy space (number of cows)	27	34	40	44	67	38
Total herd size	43	53	63	68	86	57
MSQ (lbs.)	184036	231192	307873	334294	495808	266897

*Does not include choretime for herd replacements.

Source: Dairy Survey 1976.

RESULTS

Methods of Conducting the Analysis

The individual farms selected to represent each of the five different levels of technology (A1, A2, A3, B and C) on which this analysis was based were analyzed by means of the linear programming (LP) technique. Application of the technique involved:

1. Translation of methods and practices of crop and milk production, raising dairy herd replacements and other livestock such as hogs and beef into activities constrained by the availability of land, labour, physical facilities, M.S.Q., and weather determined field time.

2. Testing the accuracy of this translation into constrained activities through determination of realistic activity levels and combinations for each representative farm.

3. Simulation of the anticipated effects of changes in milk prices, M.S.Q. holdings, milk production per cow and technology on milk supply responses and costs of production at the farm level. Analysis at the regional level was conducted through aggregation procedures based on the distribution of farms by level of technology in the total population.

Relationship Between Technology and Cost

Milk price (net of marketing costs) was allowed to vary from a level which would just cover the variable cost of milk production up to those levels which would cover the additional costs of production, i.e. fixed costs, and imputed opportunity costs for the operator's labour. The results of this analysis on each representative farm are reported below.

Supply responses resulting from the parametric pricing are shown in Figure 3 and are represented by steps in the supply function.[1] Each step is based on enterprise (activity) levels and combinations which utilize the designated resources in such a manner that the returns to these resources are maximized. Increasing the milk price brings about short-run adjustments in the size of enterprises and correspondingly, the mix and amount of resources allocated to each of them. This new

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[1] These supply responses are based on zero return for operator's labour. The effects of alternative levels of labour return on supply responses are illustrated in Appendix A for each representative farm.

Figure 3.   Supply Functions of the Five Representative Farms
            Based on Zero Return for the Operator's Labour
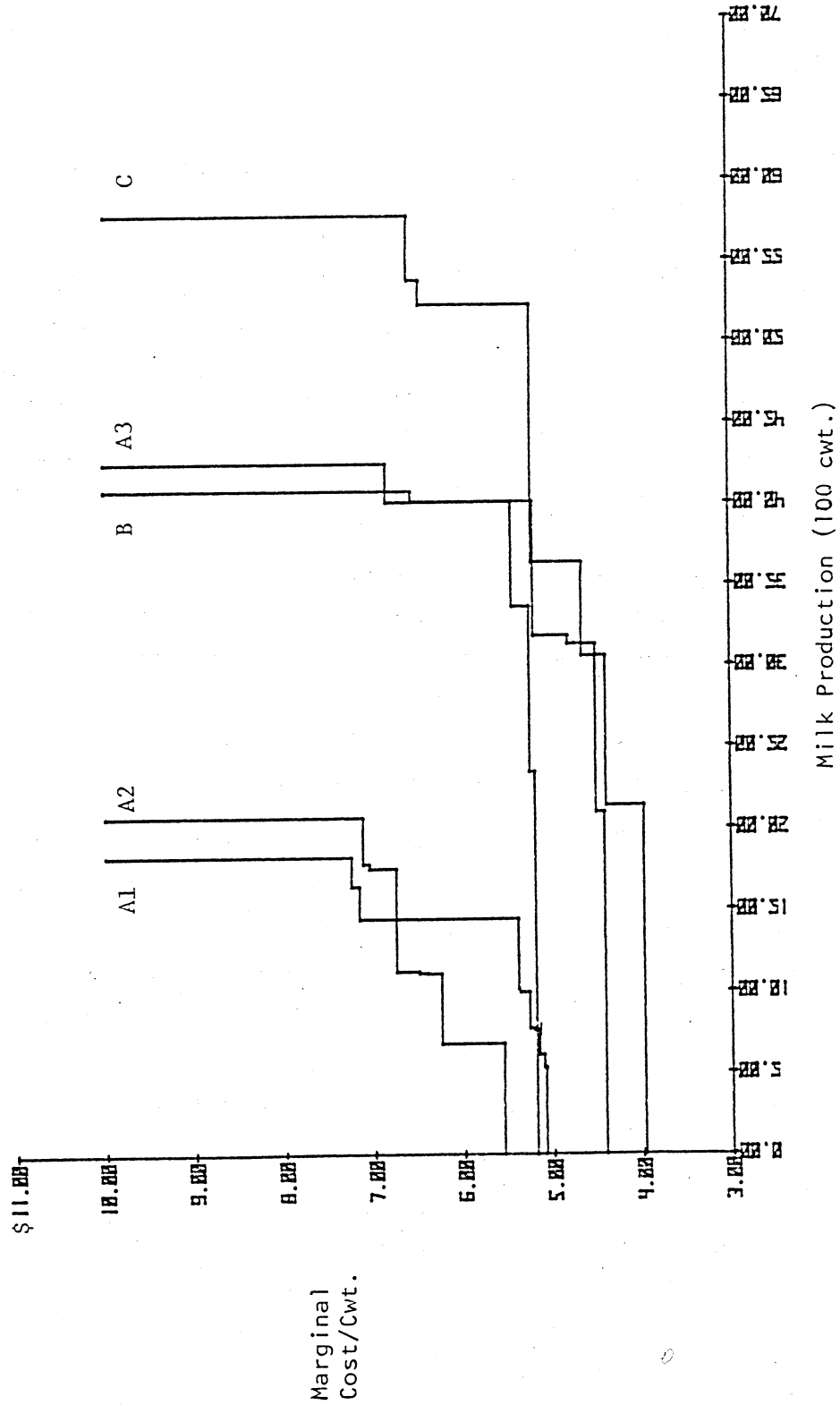
combination of resources is depicted as the subsequent step in the supply function. When a resource becomes limiting (as for instance, M.S.Q. holdings), no further adjustments are possible without increasing the availability of that resource.

The marginal cost of producing milk (i.e. the additional cost of the last unit of production) is indicated by these stepped supply functions. For example, when milk production reached M.S.Q. limits, the lowest marginal costs per hundredweight (cwt.) of milk produced on Tech A1, A2, A3, B and C representative farms were $7.25, $7.12, $6.84, $6.56 and $6.59/cwt. respectively.

It can be observed in Table 3 that marginal and average variable cost per hundredweight of milk decreased as the level of dairy technology increased with the exception of the Tech C farm where the marginal cost was slightly higher in comparison to the Tech B farm. The relationship between technology and allocated unit fixed cost and cost of equity was not as clear. The Tech A3 farm had the highest allocated unit fixed cost and the lowest allocated unit cost of equity. However, when average variable cost, allocated fixed cost and the cost of equity were combined to calculate the unit total cost, the relationship between technology and cost became more distinct. The unit total costs were estimated to be $8.04, $8.39, $7.52, $7.66 and $7.54/cwt. for Tech A1, A2, A3, B and C representative farms, respectively.

In the above analysis, the cost of the operator's labour was assumed to be zero. To determine the effect of the rate of return for the operator's labour three different rates ($1.85, $2.65 and $3.43 per hour) were imputed. These wage rates represented low, medium and high labour earnings based on data obtained from a recent dairy labour management study.[2]

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[2]Source: Funk, T. F. and W. A. Okyere, An Economic Analysis of Full-Time Hired Labor on Ontario Dairy Farms, Research Bulletin AEEE/76/7, School of Agricultural Economics and Extension Education, University of Guelph, July 1976.

Table 3.   Costs of Milk Production on Five
Representative Farms Based on Zero
Return for Operator's Labour

	Marginal Cost	Average Variable Cost	Allocated Fixed Cost	Allocated Cost of Equity	Total Unit Cost
		- per cwt. -			
Tech A1	$7.25	$3.48	$1.35	$3.21	$8.04
Tech A2	7.12	3.04	1.70	3.65	8.39
Tech A3	6.84	2.85	2.57	2.10	7.52
Tech B	6.56	2.55	2.12	2.99	7.66
Tech C	6.59	2.50	1.88	3.16	7.54
Weighted Mean	6.96	2.98	1.86	3.14	7.98

The parametric programming of these wage rates generated new supply functions for each representative farm (Appendix A). As would be expected, the higher the rate of return allowed for the operator's labour, the higher the minimum price of milk required to maintain the short-run supply of milk at a constant level (as depicted by the heavy vertical lines in the figures of Appendix A). Increases in the imputed rate return for the operator's labour had the effect of "flattening" the supply response functions, and this effect was more pronounced in the lower technology farms as compared to the higher ones. This would imply that if the operator wished to obtain a higher return for his labour the possibilities of doing so are much greater by shifting to an improved technology. However, the results of the survey indicated that the mean values of average milk production per cow (Table 1) were relatively low in all technology groupings. Accordingly, there exists room for considerable improvement in milk output within any given technological group. Improvements in both the technological setting as well as milk output per cow would provide the operator with many options (steps) to earn at least $3.43 per hour. Indeed, the stepped supply functions would flatten out for Tech C farms only when that labour rate was increased 3-fold.

In Table 4, the marginal cost associated with these four supply functions when milk production was at its M.S.Q. limit level are shown for each representative farm. It is apparent that the inverse relationship between cost and technology becomes more distinct when labour is considered as part of the production cost. When full unit costs were included (Table 5) this inverse relationship still held. Moreover, as the wage rate was increased, the cost differentials between Tech Al and Tech C farms widened. These differences were $0.50, $1.49, $1.91, and $2.31/cwt. when operator's wages were $0.00, $1.85, $2.65 and $3.43 per hour, respectively.

The above analysis indicated that costs and technology are closely related. The lower technology farms appeared to have slightly higher

Table 4.   Comparison of Marginal Cost of Five Representative
Farms Under Various Imputed Operator Wage Rates

	Zero Wage	$1.85/hr.	$2.65/hr.	$3.43/hr.
		- per cwt. -		
Tech A1	$7.25	$8.87	$9.56	$10.20
Tech A2	7.12	8.36	8.91	9.44
Tech A3	6.84	7.67	8.03	8.38
Tech B	6.56	7.28	7.58	7.88
Tech C	6.59	7.24	7.49	7.73
Weighted Mean	6.96	8.08	8.56	9.02

Table 5.   Comparison of Full Unit Cost[1] of Five
Representative Farms Under Various Imputed
Operator Wage Rates

	Zero Wage	$1.85/hr.	$2.65/hr.	$3.43/hr.
		- per cwt. -		
Tech A1	$8.04	$9.66	$10.35	$10.99
Tech A2	8.39	9.63	10.18	10.71
Tech A3	7.52	8.35	8.71	9.06
Tech B	7.68	8.40	8.70	9.00
Tech C	7.54	8.19	8.44	8.68
Weighted Mean	7.98	9.10	9.57	10.05

[1]Full unit cost = direct variable cost + fixed cost + opportunity cost
of capital and labour. Marketing costs are not included in these
estimates of full unit costs.

marginal and average variable costs than the higher technology farms. This characteristic is mainly attributable to higher productivity of resources and more efficient use of resources on the higher technology farms as reflected in higher crop yields and greater milk production per cow. Fixed costs per unit of milk production were somewhat lower on low technology as compared to high technology farms due to the relatively low depreciation cost and interest expenses of the low technology farms. Although the allocated unit cost of equity exhibited no perceptible relationship to technology, the inclusion of wage rates into full unit costs brought about a very evident inverse relationship between cost and technology. This finding is not surprising when one observes the annual choretime requirements per cow as shown in Table 2. It follows that as the level of technology rises, labour requirements decrease and labour productivity rises.

Effects of Technological Improvement

The effect of technological improvements at the farm level on the regional milk supply response and the associated costs of production was analyzed by assuming that there was a shift from the low to higher levels of technology. Specifically, it was assumed that the frequency distribution of Tech A1 and A2 farms decreased by 15 percent and 9 percent respectively, while the frequency distribution of Tech A3, B and C farms increased by 10 percent, 11 percent and 37 percent respectively. The regional milk supply functions before and after this adjustment in level of technology are shown in Figure 4.

According to the model, this amount of improvement in farm technology would cause the regional milk supply to increase by about 5 percent assuming there was sufficient M.S.Q. available to cover the additional output. On the other hand, if the regional production were limited to the M.S.Q. available in 1976, the technological improvement outlined above would result in a reduction of about $0.35 per cwt. in the weighted marginal cost of milk production for the region.

The lower technology farms comprised about 53 percent of the industrial bulk milk farms in Region 2. Obviously, these farms had the

Figure 4. Effect of Technological Change on Aggregate Milk Supply Functions

Marginal Cost/Cwt.

Milk Production (10,000 cwt.)
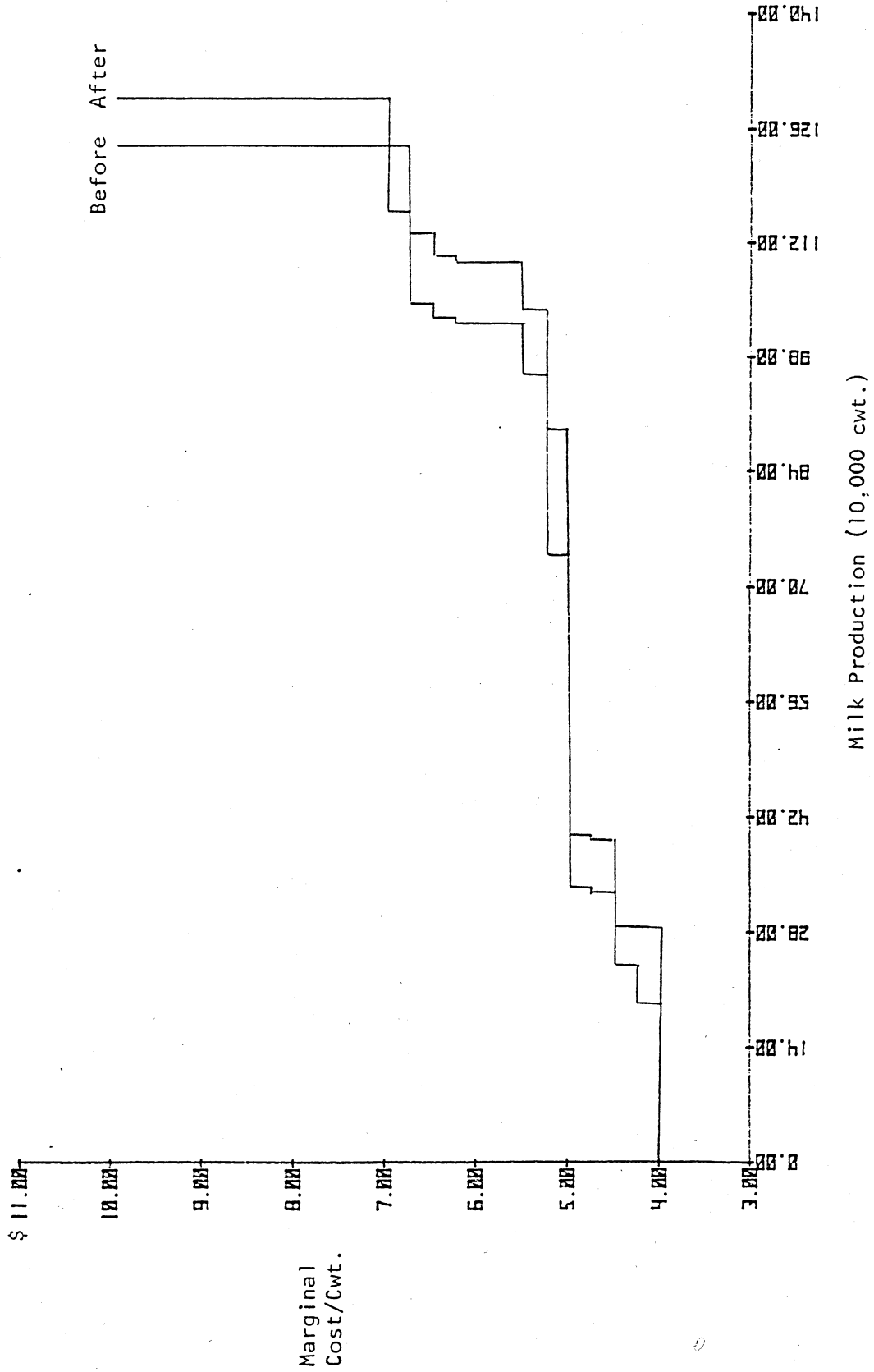
greatest potential (given the necessary resources) for reducing costs and improving net incomes. However, unless these farms cou'd obtain additional M.S.Q., an improvement in technology, by itself, would be of little benefit to them unless the labour released from the dairy enterprise could be used more profitably in competing enterprises either on or off the farm.

## Effects of An Increase in Average Milk Production per Cow

Previous studies indicated that average milk production per cow was an important variable affecting both the cost and level of milk production. Thus, programs to encourage improvements in herd management and feeding practices should significantly improve the income situation of dairy farmers.

To evaluate the effect of an increase in the average milk production per cow on the cost of production, two sets of programming analysis were carried on for each representative farm. In the first set the average milk production per cow for each representative farm was adjusted to its corresponding group average. The second set involved upward adjustment of each group's average milk production per cow by one standard deviation (approximately 2000 lbs. of milk). Thus, the second set of farms had identical characteristics to the first, except for having a higher average milk production per cow.

Again parametric programming on milk prices was performed on each representative farm at these two different levels of milk production per cow. The supply functions generated for these farms were weighted to obtain two separate aggregate supply functions, one with the group average milk production per cow and the other with milk production per cow one standard deviation higher than the group average.

An increase in the average milk production per cow resulted in an increase in the supply response and a lower marginal cost per unit of milk production (Figure 5). The weighted average marginal cost of the first and second supply functions were estimated to be $7.10 and $6.00 per cwt., respectively. According to these findings, if milk production per cow were increased by 2000 lbs. of milk annually, marginal cost of producing milk is reduced by $1.10 per cwt.

Figure 5. Effect of an Increase of 2000 lbs. in Average Milk Production Per Cow on Aggregate Milk Supply Functions
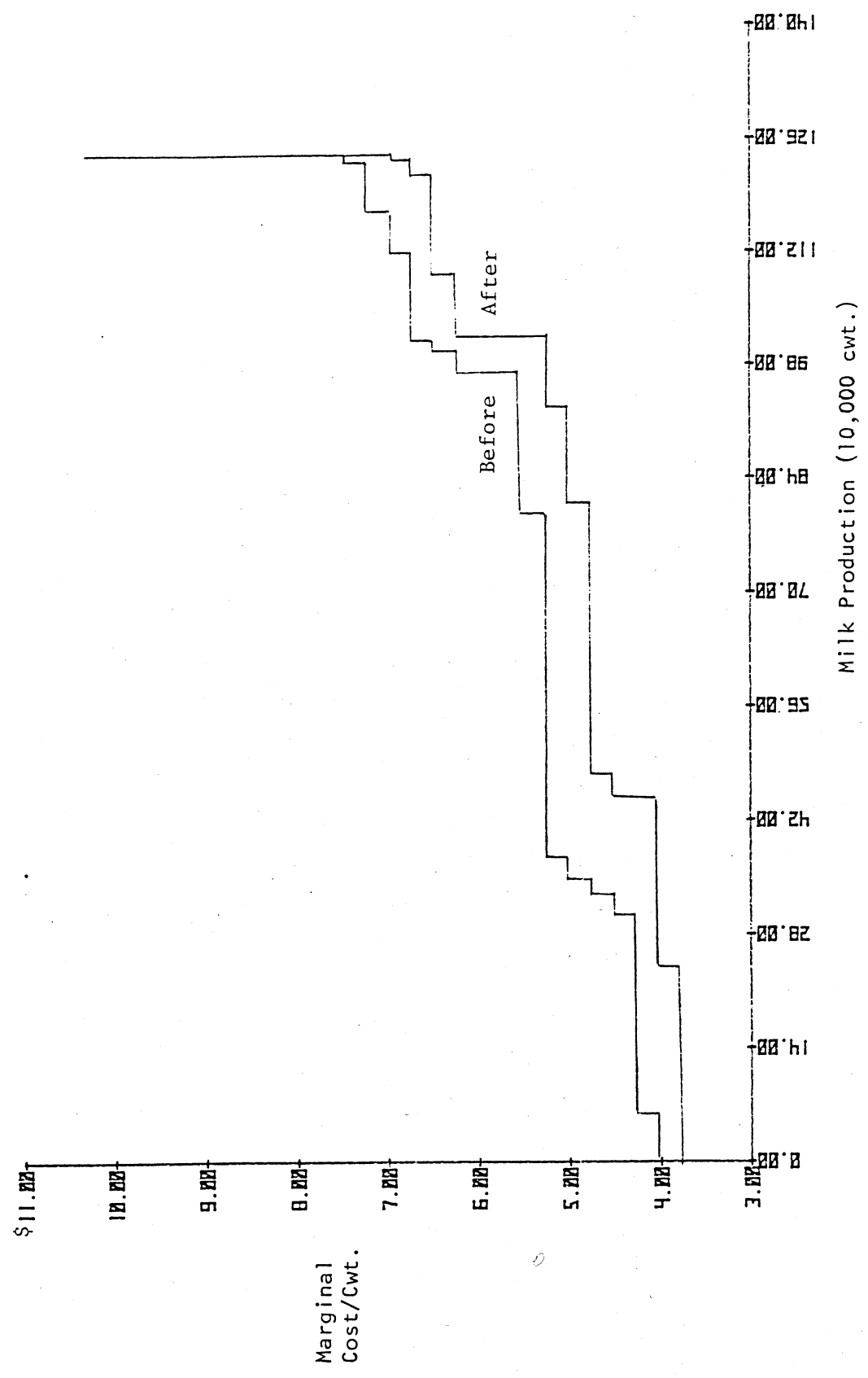
This decrease in marginal cost can be explained on the grounds that fewer milk cows would be required to fill the M.S.Q. levels. The decrease in feed nutrients for maintenance purposes for the larger herd tended to offset the increase in the nutrient requirements for higher production.[3] At the same time labour inputs for milk production would be reduced thus lowering labour costs. Accordingly, it was strongly implied that improvement in output per milk cow can be an effective means of trimming the costs of milk production and thus improving net farm income for all of the representative farms.

M.S.Q. Values

During most of the 1976-77 dairy year, M.S.Q. was not freely negotiable and whatever transfers did take place were regulated by the O.M.M.B. at prices established by them. Since the dairy enterprise had favourable cost-price relationships relative to most alternative farm enterprises during this period, there was a marked tendency for industrial milk producers to produce up to the limit of their M.S.Q. holdings. This was the case for the 5 representative farms selected in Region 2. The production (and M.S.Q. holdings) of the Tech A1, A2, A3, B and C representative farms were 1922, 2062, 4367, 4067 and 5768 cwt. respectively.

Given the prevailing returns from industrial milk production relative to alternative enterprises and the availability of M.S.Q., milk production was restricted below the level which would have occurred had more M.S.Q. been available. This meant that milk producers could improve their net returns position by purchasing additional quota. The maximum amount which any producer would be justified in paying for an additional unit of quota would be the difference between the extra revenue he would receive by virtue of acquiring it less the additional costs incurred in producing the milk to fill the quota. In other words, it would be the difference between the marginal revenue and marginal cost.

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[3]The majority of herds were already on full feed. Hence, increasing the nutrients for the higher level of production involved ration balancing. By implication the higher level of production was only possible when the acreages and the mix of crops grown as well as the kinds of supplements purchased were allowed to change. The necessary adjustments were all possible within the business settings of the representative farms.

of producing an additional unit of milk. For purposes of this study, this difference is referred to as the "shadow value" of the quota.

On the assumption that the operator's labour had zero value, the shadow values of M.S.Q. were estimated to be $2.74, $2.88, $3.15, $3.43 and $3.40 per cwt. of milk for the Tech A1, A2, A3, B and C farms respectively. These shadow values were, of course, reduced as higher wage rates for the operator's labour were assumed. The M.S.Q. shadow values for each representative farm under different assumptions with respect to the value of the operator's labour are summarized in Table 6.

As the operator's wage rate was increased, the shadow value of M.S.Q. decreased much more drastically for the low technology farms than for those with a higher level of technology. Furthermore, the shadow values increased as the level of technology increased. These results indicate that if M.S.Q. were freely negotiable the higher technology farms would be at a considerable advantage in outbidding the lower technology farms for the available quota. The figures shown in Table 6 are based on the assumption that the purchaser of the quota would recover the cost of the quota within one year. Should he decide to amortize the cost of quota over a period of time this would have the effect of increasing the amount he is prepared to pay for it.

In Table 7 estimates are given of the shadow values of M.S.Q. for each of the representative farms based on the assumptions that the investment in quota is written off over a five year period at a discount rate of 10 percent. Under these assumptions the spread between the shadow values of the representative farms becomes greater.

These results raise some interesting questions with respect to quota policy. Does a policy which permits freely negotiable transfer of quota provide a mechanism which stimulates improvements in efficiency of the industry? Conversely, in periods when the demand for quota is strong relative to its availability what is the effect of restrictions on quota transfers on adjustments in the industry? Is there justification for developing programs which would enhance the ability of the

Table 6.   Effect of Variations in Rate of Earnings of
Operator's Labour on M.S.Q. Shadow Values
Based on Amortization over One Year

	Zero	$1.85	$2.65	$3.43
Tech A1	2.74	1.13	.43	0
Tech A2	2.88	1.62	1.08	.55
Tech A3	3.15	2.32	1.96	1.62
Tech B	3.43	2.72	2.41	2.21
Tech C	3.40	2.75	2.50	2.26
Weighted Mean	3.04	1.90	1.42	1.03

Table 7.   Effect of Variations in Rate of Earnings of
Operator's Labour on M.S.Q. Shadow Values
Based on Amortization over Five Years at
Ten Percent Discount Rate

	Zero	$1.85	$2.65	$3.43
Tech A1	10.38	4.28	1.63	0
Tech A2	10.92	6.14	4.09	2.08
Tech A3	11.94	8.79	7.43	6.14
Tech B	13.00	10.31	9.41	8.38
Tech C	12.89	10.42	9.48	8.57

lower technology farms to improve their efficiency as milk producers or should efforts be directed toward policies and programs which would assist these farmers in shifting to alternative activities, either within farming or outside of it? The answers to these broad questions involve considerations beyond the scope of this study.

Effects of Lifting M.S.Q. Limits

As previously indicated, the five representative farms produced up to their M.S.Q. holdings because of favourable cost-price relationships with respect to the dairy enterprise. Under such favourable conditions, it was anticipated that if M.S.Q. limits could be adjusted upward, milk production would increase up to the new limits bringing about lower costs of production. Accordingly, two additional sets of analyses were conducted. The first involved simulation of how and to what extent each of the representative farms would respond if their M.S.Q. holdings were increased by 18 percent over the existing level for the group.

The second set involved removal of M.S.Q. limits on each farm to simulate a policy of imposing no M.S.Q. restrictions on milk production. Parametric programming of milk prices was performed on these representative farm models to obtain individual farm supply functions. These individual supply functions were then aggregated into total supply functions for the region and compared to the regional supply function which existed prior to these changes. These aggregate milk supply functions are presented in Figures 6 and 7.

It will be noted that when M.S.Q. was increased by 18 percent, the aggregate milk supply also increased by 18 percent at the prevailing milk price. With no restrictions on M.S.Q. the aggregate milk supply function also increased, giving an increase of 26 percent in milk output (Figure 7). Since both of these changes indicated an increase in supply (i.e. a shift of the supply function downward and to the right) it follows that the average total cost functions of producing milk decreased implying lower unit costs of production and more efficient use of resources.

Figure 6.   Effect of an Eighteen Percent Increase in MSQ on
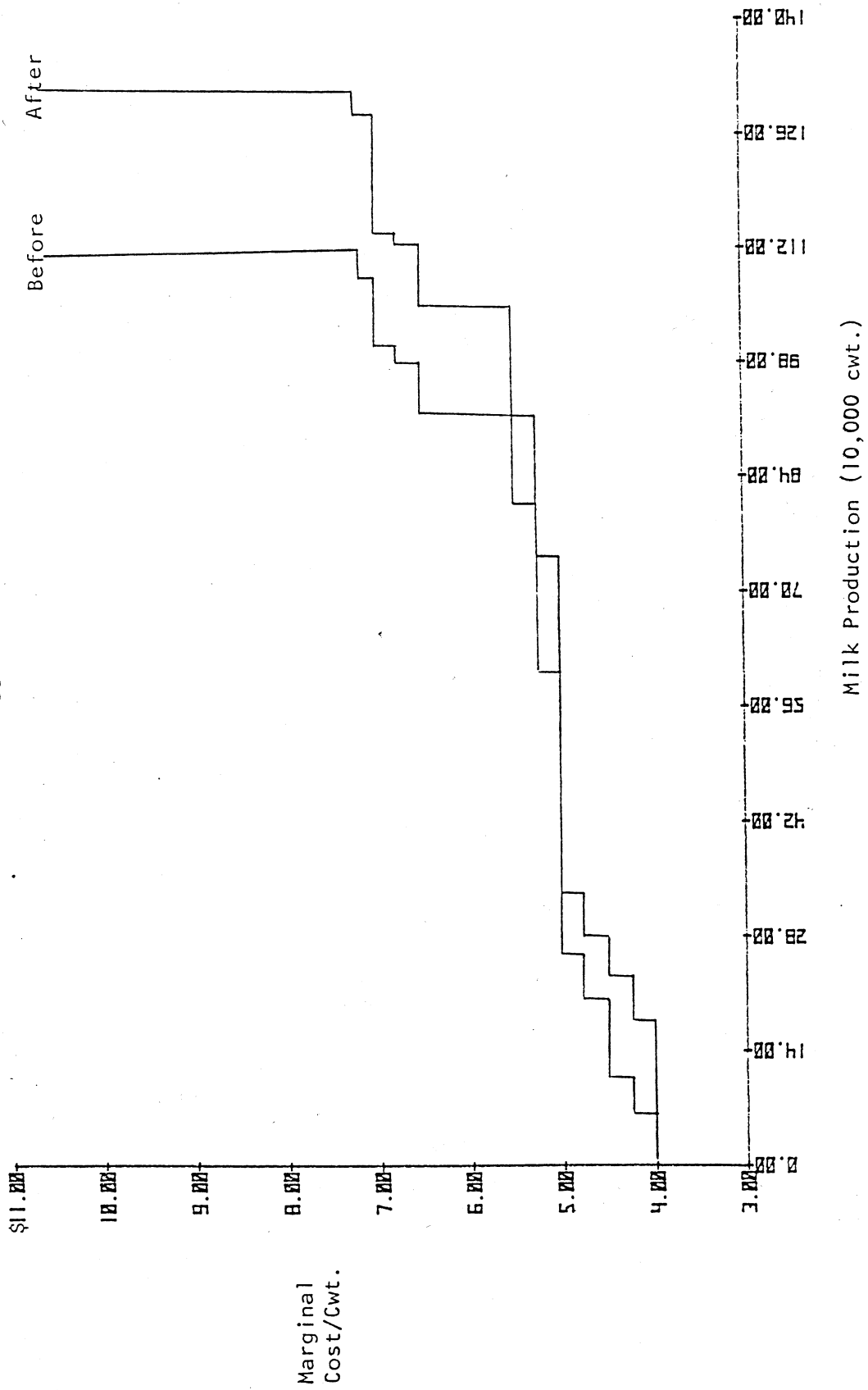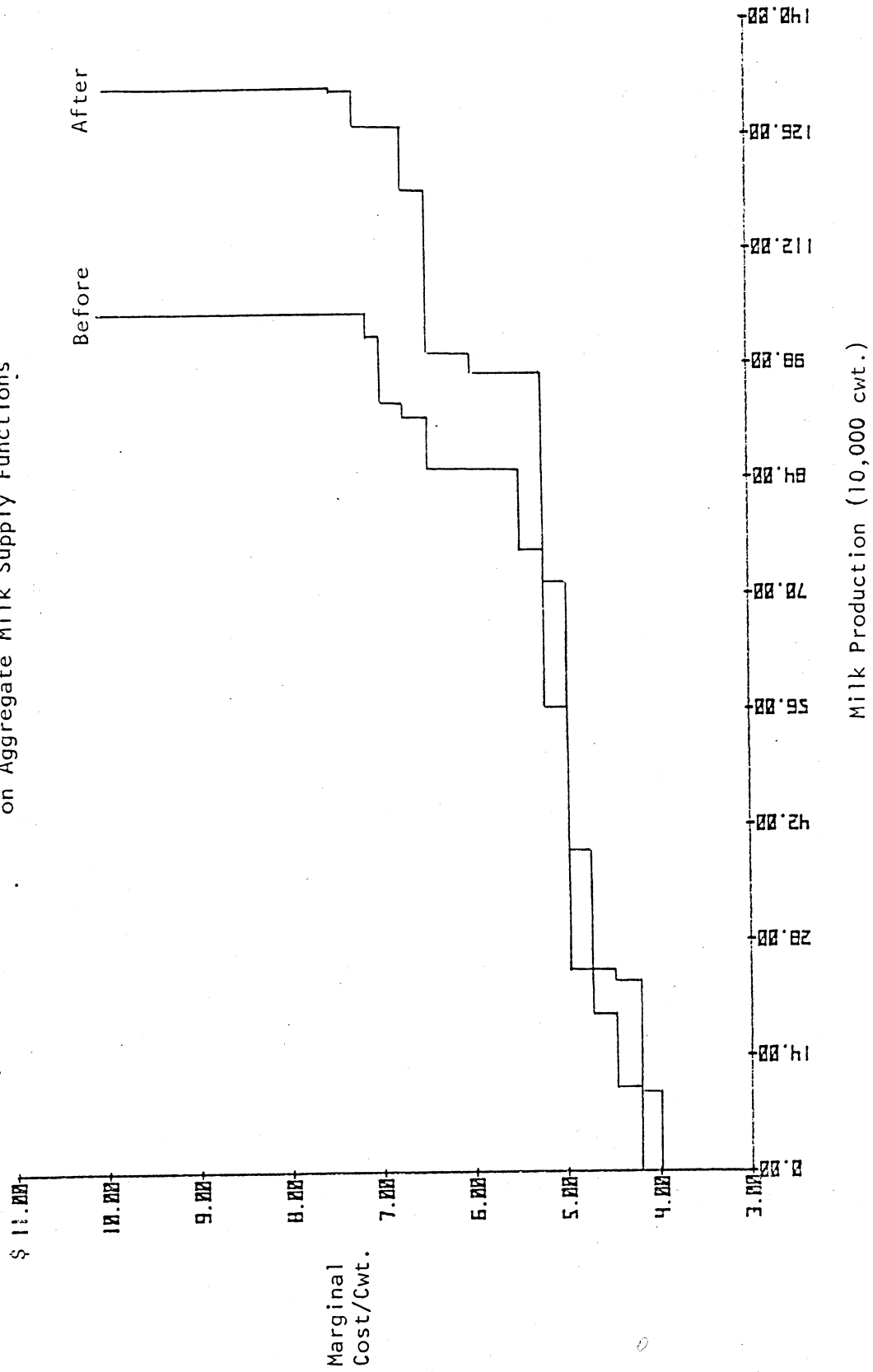   Aggregate Milk Supply Functions

Figure 7. Effect of Removal of MSQ Restrictions on Aggregate Milk Supply Functions

Marginal Cost/Cwt.

Milk Production (10,000 cwt.)

According to the information collected in the survey of the region, the average number of milk cows was 31.4 while the maximum number that could have been handled with the existing dairy facilities was 37.6. As a result, 20 percent of the potential dairy capacity was available to increase milk production. The farm models indicated that favourable milk prices would induce better feeding practices. As a result, the anticipated short-run potential to increase output was at least 20 percent but not over 26 percent. However, these lower and upper limits on potential capacity to increase production would not be fully realized unless the demand for milk products could be increased sufficiently to maintain price at its present level. If expansion in supply occurred faster than demand, milk price would decline and thereby reduce the incentive to fully utilize potential capacity.

Relevancy of the Technique at the Regional Level

The single representative farm technique was used to estimate the aggregate milk supply of industrial bulk milk producers in Region 2, during the 1975-76 dairy year, so that this estimate could be compared to the actual amount supplied by these producers. The purpose of doing this was to examine the reliability of the technique for aggregating supply response for a region.

Before simulation of producer responses for 1975-76, M.S.Q. holdings of the five representative farms were adjusted to the quota held prior to the 15 percent cutback which occurred early in the 1976-77 dairy year. Again, the models were operated to generate farm-level results which were aggregated to the regional level. The results corresponding to the particular net price received in 1975-76 are shown in Table 8.

The difference between the actual and estimated milk output was quite small, the estimated milk output being 1 percent greater than the actual milk production. The close approximation of the actual milk supply through aggregation of the supply responses of the five representative farms was likely due to:

1. Profit incentives in the dairy enterprise which encouraged all producers to produce at the limit of their quotas.

Table 8.   Comparison of Actual and Simulated
Milk Output in Region 2 in 1975-76

Technology Group	No. of Farms In Each Group	Actual Milk Output	Simulated Milk Output
		- cwt. -	
Tech A1	93	205097	201345
Tech A2	151	412880	410720
Tech A3	70	249337	253540
Tech B	74	281404	291042
Tech C	27	149103	157491
Total milk output		1297824	1314138
Percent difference between Actual and Simulated Output			1%

2. The extent to which the representative farm models accurately reflected group perceptions of productive activities and resource constraints.

However, the analytical model itself is a normative tool which is intended only for estimating the underlying supply response pressures as they existed at the farm, group and regional levels. These normative responses are based on the assumption that the producers would make those adjustments in their farm operations which would maximize their net incomes. However, producers might react differently from time to time for a variety of reasons. Some of these would be associated with their behavioral characteristics and their attitudes toward expanding (or contracting) their enterprises or making major changes in their technology. Others could be associated with biological production factors, some of which might be beyond their control. However, if the farm operators were shown the simulated results of specific adjustments in their farm businesses and the corresponding potential net income, their behavioral reactions could be included in additional runs of the model and the process continued until the modelling results coincided with the farmers' actual activities at any point in time.

IMPLICATIONS OF RESULTS

On the basis of these results, it is apparent that the methodology of using the single representative farm to make inferences about a group of farms is worthy of consideration in the development of an operational framework for periodic evaluation of dairy policy instruments used in the supply management program. However, two major limitations should be recognized and investigated before extending the methodology to the provincial and national setting.

1. The variability of average milk production per cow was not effectively reduced after the classification by technology. Further, there was not adequate information from the survey to allow thorough investigation of the nature of variability resulting from the relationship between the amount of land and labour available and rates at which they are utilized. Additionally, the variability resulting from the incidence and importance of nondairy enterprises in the utilization of resources was not investigated. Because of the high degree of observed variability (in some factors affecting supply response) within the farm groups, it is suggested that the classification system should be further developed and tested.

2. Considerable time was required to apply the linear programming technique on individual farms. Given familiarity with (a) the technique itself, (b) the data requirements, and (c) the translation of results, it would be possible to analyze about 30 farms per man-year. If the same technique were applied to an adequate sample of representative farms at the national level it would require a substantial amount of time just to operate the supply response model. However, these procedures could be mechanized and the operating time requirements reduced by about 70 percent.

The construction of an operational framework for periodic dairy policy analysis at the provincial and national setting is a plausible venture once these two limitations have been satisfactorily resolved. The analysis of each representative farm (selected from the classification system) should provide an indication of:

1. The numbers of dairy farms by region which employ different types of technology and the production costs associated with each type.

2. The levels of efficiency and productivity on various typical dairy farms and the costs and benefits of programs to improve efficiency.

3. The supply response that could be anticipated by adjusting various dairy policy instruments such as quotas, prices and subsidies.

The specific benefits for dairy farmers would lie in using the models to decide whether to remain in the dairy industry, and if so, whether and how to expand milk production, and how to cut milk production costs.

The potential exists for using the framework to indicate how production efficiency can be increased and how efficient allocation of present dairy farm resources can be achieved. Subsequently, it could be used as a basis for development of dairy policy incentives for improving production efficiency and resource allocation, as well as for evaluation of the effects of present policy instruments at the dairy farm level.
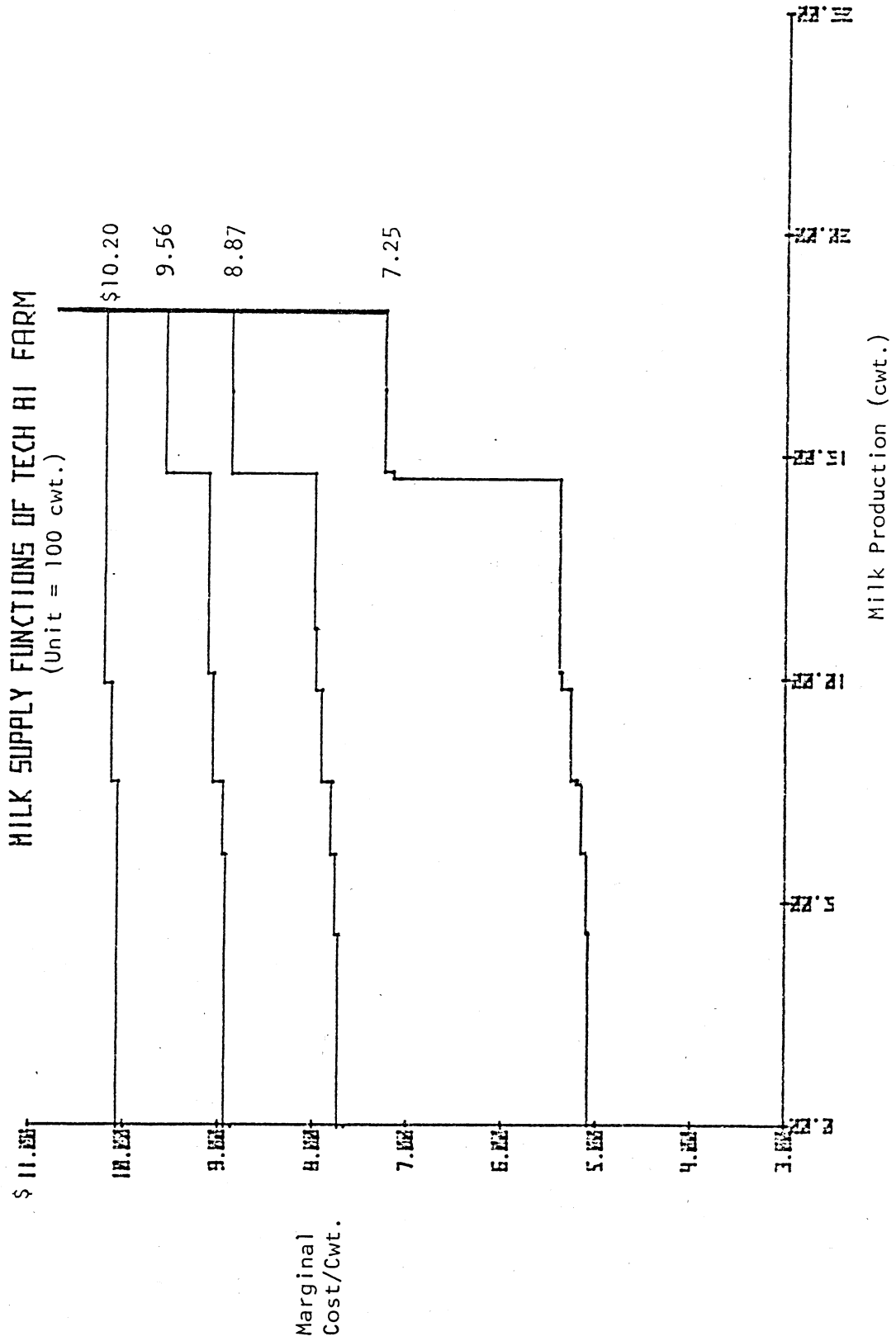
When the framework becomes a reality, it could also be used in rationalizing a national dairy farm accounts system, developing data banks and determining the appropriateness of on-going research and extension programs in relation to different but typical dairy farm business and behavioral settings.
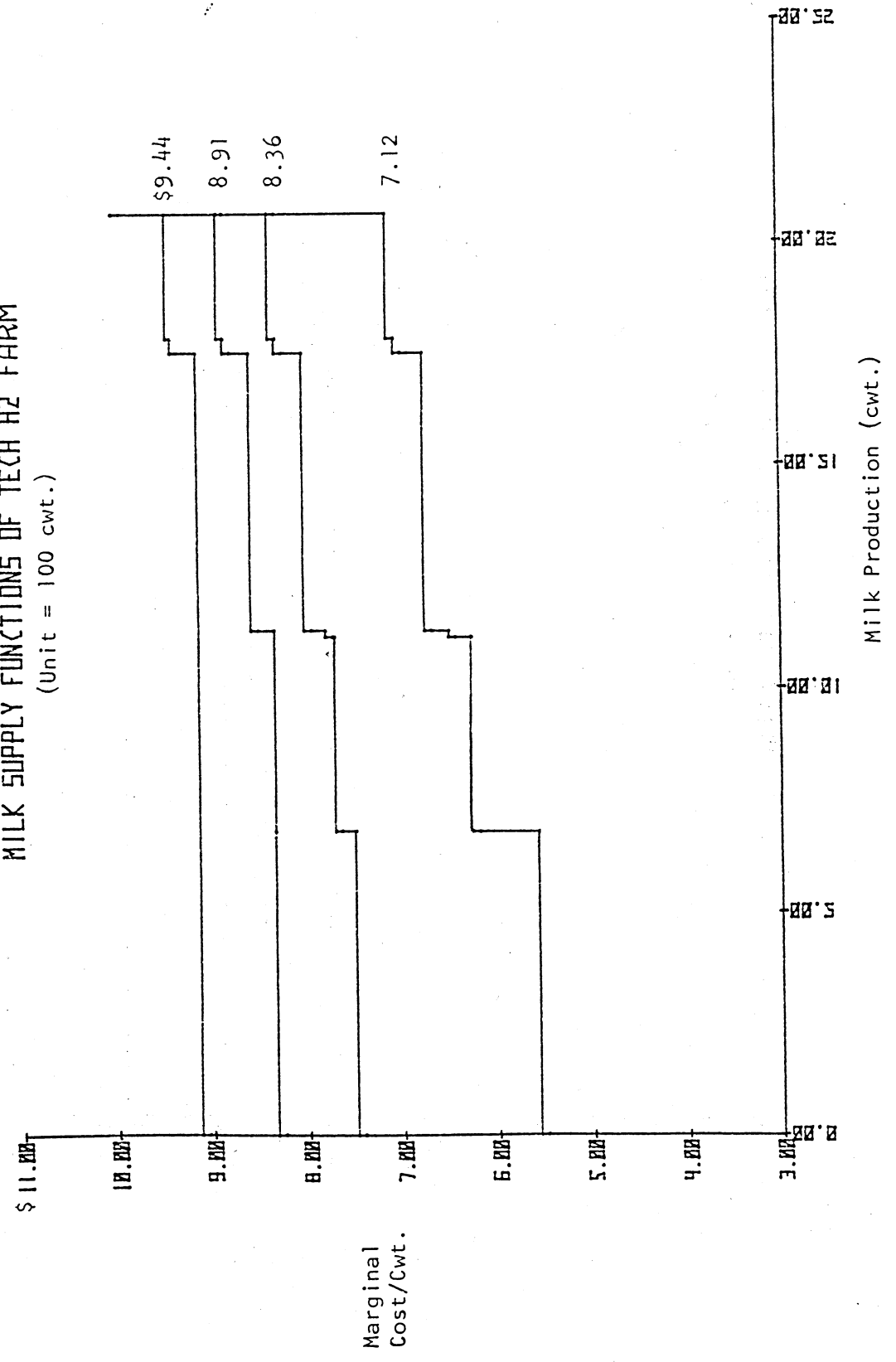
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APPENDIX A

Representative Farm Milk Supply Functions at
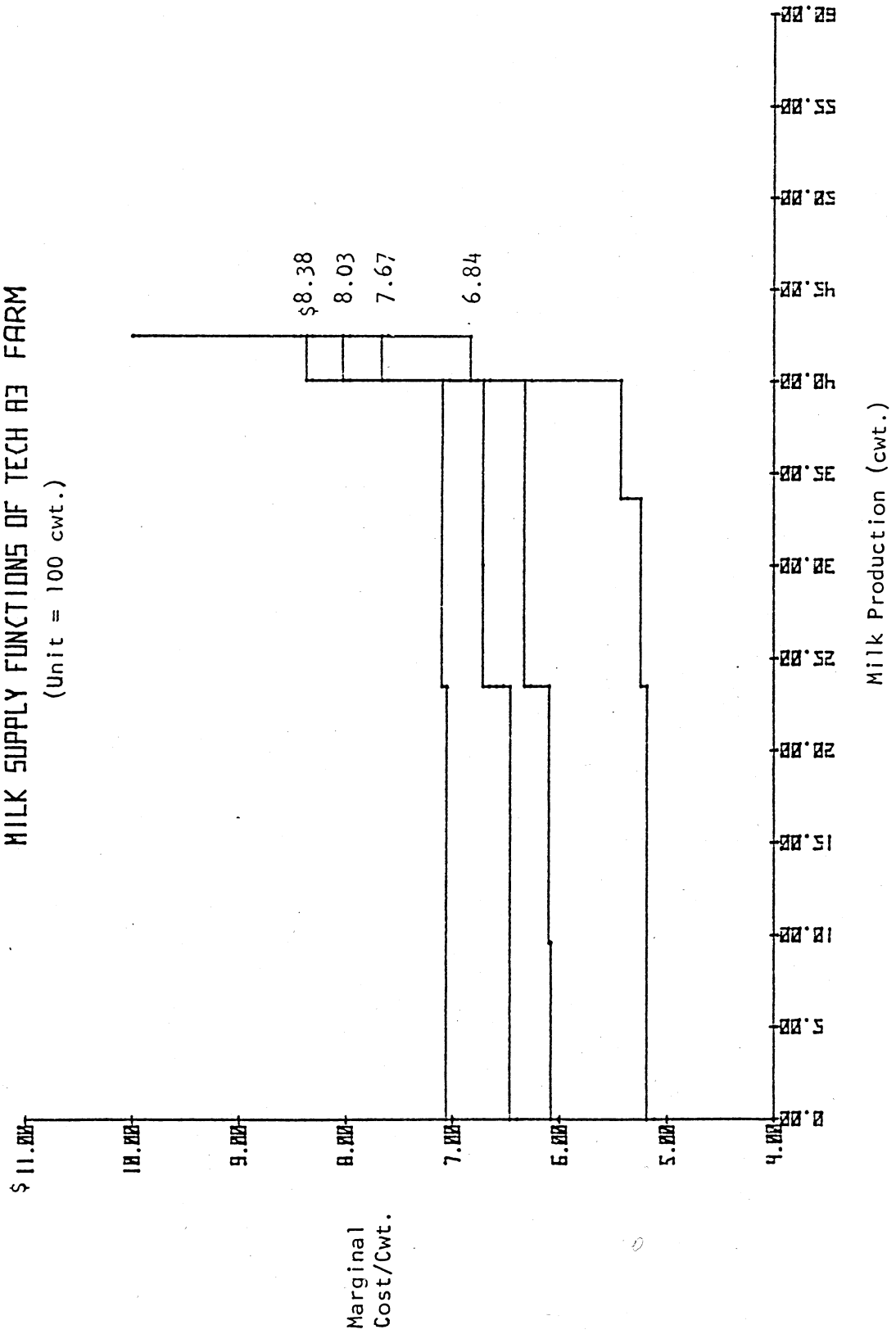Alternative Wage Rates for Operator Labour

MILK SUPPLY FUNCTIONS OF TECH AI FARM
(Unit = 100 cwt.)

$10.20

9.56

8.87

7.25

Marginal
Cost/Cwt.

Milk Production (cwt.)

MILK SUPPLY FUNCTIONS OF TECH A2 FARM
(Unit = 100 cwt.)

$9.44

8.91

8.36

7.12

Marginal
Cost/Cwt.

$ 11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00

0.00   5.00   10.00   15.00   20.00   25.00

Milk Production (cwt.)

MILK SUPPLY FUNCTIONS OF TECH B FARM

(Unit = 100 cwt.)

$7.88
7.58
7.28

6.56

Marginal
Cost/Cwt.

$11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00

0.0   5.00   10.00   15.00   20.00   25.00   30.00   35.00   40.00   45.00   50.00   55.00   60.00

Milk Production (cwt.)

MILK SUPPLY FUNCTIONS OF TECH ⊂ FARM

(Unit = 100 cwt.)

Marginal
Cost/Cwt.

$7.73
7.49
7.24

6.59

Milk Production (cwt.)