REGIONAL PRICE ELASTICITIES OF SUPPLY OF GRADE A MILK IN THE UNITED STATES

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1976

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1982

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PREFACE

This study is concerned with estimating regional supply response for milk in four regions and two states in the United States. Specific objectives include estimating own and cross price elasticities by region. The obtained elasticities are compared between regions.

I wish to extend my warm appreciation to Dr. Leo Blakley, my committee chairman, for his limitless patience and guiding hand during this study. His ability to keep me on the right path through the maze of problems encountered while conducting this study will not soon be forgotten. I will always remember the pleasant atmosphere he provided which helped make the problems seem much easier to cope with.

I would also like to thank the other members of my committee for their contributions; these are Dr. Ronald Krenz, Dr. Tom Tice, and Dr. Alan Baquet. Special thanks go to Dr. Ronald Krenz, who, as my USDA supervisor, gave me the flexibility to conduct this research while performing my duties for the USDA.

I would like to thank Dr. James Osborn, who, as head of the Agricultural Economics department, provided the computer programming expertise and funding necessary to complete this study.

Many thanks go to Meg Kletke and Roberta Helberg for their willingness to drop whatever they were doing to help me with an urgent computing problem. I cannot thank Meg enough for her willingness to interrupt her own research to help when I was desperate.

Most of the data used in this report were provided by the United States Department of Agriculture. I would like to thank Dr. Robert Olsen for the use of this data, for without it, this study would not have been possible.

Thanks are in order for my USDA co-workers, Dr. Ronald Krenz, Dave Fawcett, Gail Garst, Charles Micheels, and Tim Ulrich, for their acceptance of me even though I am from the Northeast. Special mention goes to Tim Ulrich for his late night company at the office and in the coffee room, and most of all, his ability to sit in the same office with me and still maintain his sanity.

To Deborah, my wife, goes my unending gratitude for her understanding, encouragement, and willingness to spend two years in Oklahoma.

Finally, I wish to dedicate this study to George E. Frick, without whom I would be just another dairy farmer without a master's degree.

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CHAPTER I

INTRODUCTION

The performance of the milk producing sector of the United States agricultural economy is subject to a wide variety of exogenous forces. These forces emanate from both the market place and governmental policies. Market forces that affect the dairy producing sector include regional population shifts, changes in the composition of dairy products demanded by consumers, foreign trade, wage rates, competition for land from both agricultural and non-agricultural sectors, and increasing energy costs.

The shifting of population away from the northern to the southern areas of the United States has shifted the regional demand for dairy products in the same direction. The fluid milk market is most affected by these shifts, since fluid milk is perishable and expensive to transport. Consumer preferences have moved away from dairy products with high "visible" milk-fat content such as butter and whole milk to products such as yogurt, skim milk, and cheeses. This change has precipitated the component method of pricing milk in some regions. Increased foreign trade in recent years has resulted in increased demand for feed grains used by dairy farmers. This increased demand has resulted in higher feed prices which especially affect production costs in those regions of the United States which rely heavily on purchased grains for feeding dairy cattle. In addition, U.S. dairy farms tend to be located very close to centers of population. Increasing wage rates have made it more and more difficult for dairy farms located near these urban centers or rural industrial centers to compete for labor, and they are also, as witnessed in the Northeastern region, subjected to increasing pressures to sell their land to developers.

The dairy sector of the agricultural economy in the United States is especially affected by government policies. The federal government, through the milk price support program and the Federal Milk Marketing Orders, is directly involved in determining the level of milk prices. Additional decisions that alter the existing prices and costs for dairy producers include policies concerning importation of foreign dairy products and Environmental Protection Agency regulations concerning animal wastes.

The Problem

The exogenous forces discussed in the previous paragraphs have the potential to create large changes in the economics of milk production. Because of this potential, it is useful to assess the regional and aggregate impacts of these forces on the supply of milk. If the responsiveness of milk production to changes in the price received by farmers for milk is known, it is then much easier to formulate both agricultural policy decisions and to adjust these policies to changing economic conditions in the market place.

In the past 20 years, there have been numerous supply response studies concerning milk production. Many of these studies, however, were conducted for the Northeast and Lake States regions in the 1960's. The estimates made before the 1970's probably have little relevance today because the technology of dairy farming has changed so drastically.

Some studies of supply response have been undertaken since 1970; however, the only recent comprehensive study of regional supply response for the entire United States that this author could find was written in 1974.

In the spring of 1980, the United States Department of Agriculture conducted a survey of 2,095 dairy farms as part of an ongoing project to estimate the annual costs of producing milk in the United States. This survey provided data on the crop-mix, number of cows, and the types of buildings and equipment used in dairy production for each farm surveyed. The availability of these data, along with data from other USDA cost of production surveys, provide an excellent opportunity to estimate regional supply response for milk production using the representative farm approach. The regional estimates of supply response will be extremely useful in updating results from previous studies.

Objectives and Procedures

The overall objectives of this study are to estimate regional supply response for milk production and to assess the impact of changes in the price of milk and alternative production possibilities on the size of dairy farms. The specific regions included in this analysis are the Northeast, Lake States, Corn Belt, Appalachian, Texas, and California regions. The representative farm method of estimating supply response is used to obtain estimates of supply elasticities for each of the above regions.

The specific objectives of this study are then:

1. The estimation of regional supply response of milk production by region.

    a. estimating the own price elasticities

    b. estimating the cross price elasticities

2. The comparison of the estimated elasticities among regions.

Chapter II describes the dairy producing sector of the agricultural economy. Here the historical transition of milk production is traced and the regionality of milk production is discussed. Chapter III discusses the concept of supply response and theoretical considerations of estimating supply response. Chapter IV is a description of the data and models used to estimate supply response for each of the six regions involved in the study. The results of this analysis are contained in Chapter V. Finally, Chapter VI contains the summary and conclusions.

CHAPTER II

UNITED STATES MILK INDUSTRY IN TRANSITION

Since the 1940's, agriculture in the United States has undergone dramatic change. The dairy sector is no exception. In the 38 years from 1940 through 1978, the structure of dairy farming has evolved from a situation with a great many farms, each with a few dairy cattle that produced milk, to one where milk is produced by relatively few highly specialized farms, each with a large number of dairy cattle. Table I shows how the number of farms with milk cows has changed since 1940. There were 6,102,417 farms in the United States in 1940, and by 1978, the total number of farms had decreased by 3,617,816 farms, or 59 percent. The number of farms that had milk cows in 1940 was 4,663,413. By 1978, the number of farms with milk cows had decreased to 33,567, a change of 92.8 percent.

The data in Table II further emphasize the changes that have taken place in the structure of the dairy sector since 1940. These data document the movement towards fewer and larger farms. In 1978, the number of cows per farm was over five times greater than in 1940.

From the data contained in Tables I and II, it is evident that the trend in dairying has been towards fewer and larger farms. The majority of dairy farms in 1940 were farms with under five milk cows which sold milk as a sideline to other agricultural enterprises. In 1978, the greater percentage of milk sold came from farms that were highly specialized in the production of milk. The data in Table III

TABLE I

TOTAL NUMBER OF FARMS AND NUMBER OF FARMS WITH MILK COWS, UNITED STATES, 1940-78

Year	Total No. of Farms, United States	No. of Farms With Milk Cows	% of All Farms With Milk Cows
1940	6,102,417	4,663,413	76.4
1945	5,859,169	4,481,384	76.5
1950	5,388,437	3,648,253	67.7
1954	4,782,416	2,956,000	61.8
1959	3,710,503	1,791,729	48.3
1964	3,157,857	1,133,589	35.9
1969	2,730,250	568,052	20.8
1974	2,310,581	403,629	17.5
1978	2,484,581	333,567	13.4

Source: Jacobson, 1980, p. 128.

TABLE II

NUMBER OF FARMS WITH MILK COWS, TOTAL MILK COWS, AND AVERAGE NUMBER OF MILK COWS PER FARM, UNITED STATES, 1940-74

Year	No. of Farms With Milk Cows	Total Milk Cows in United States	Average No. of Cows Per Farm
1940	4,663,413	23,671,000	5.1
1945	4,481,384	25,033,000	5.6
1950	3,648,253	21,944,000	6.0
1954	2,956,900	21,581,000	7.3
1959	1,791,729	17,901,000	10.0
1964	1,133,589	15,677,000	13.8
1969	568,052	12,693,000	22.3
1974	403,624	11,230,000	27.8
1978	333,567	10,374,408	31.1

Source: Jacobson, 1980, p. 128.

TABLE III

NUMBERS OF OPERATIONS WITH MILK COWS AND PERCENT OF OPERATIONS AND COW NUMBERS BY HERD SIZE, UNITED STATES, 1977-79

Year	No. of Operations	1-29 Cows		30-49 Cows		50 or More Cows	
		Operations	Inventory	Operations	Inventory	Operations	Inventory
		(Percent)		(Percent)		(Percent)	
1977	401,910	66.9	18.2	17.4	24.2	15.7	57.6
1978	379,530	65.2	16.0	17.9	24.0	16.9	60.0
1979	351,970	63.2	14.8	18.2	23.2	18.6	62.0

Source: U.S. Department of Agriculture, 1980c.

are presented in an effort to show that this is an ongoing trend. Since 1977, the Crop Reporting Service of the USDA's Economic and Statistics Service (ESS) has collected data on the number of operations with milk cows and the distribution of these operations by herd sizes. It is important to note that, while the majority of farms in the United States have between 1 and 29 cows per farm, the majority of the milk producing cattle are on farms with 50 or more cows per farm (see Table III). Also, the number of operations with dairy cattle decreased from 401,910 farms in 1977 to 351,970 farms in 1979. This is a decrease of 49,940 farms, or 12 percent, since 1977. The decrease in the total number of farms between 1966 and 1979 was accompanied by a change in the distribution of the number of farms and the number of milk cows by herd size. Since 1977, both the percentage of operations and the percentage of the total milk cows in the 50 or more classification increased. The percentage of operations and the percentage of total milk cows both decreased in the 1-29 cow category. In the 30-49 cow category, the percentage of operations increased while the percentage of total milk cows is still declining and the movement from smaller to larger farms is also continuing.

Causes of Change

The changes in the structure of dairy farming described in the previous section have come about as the result of two factors: the changing socioeconomic environment in the United States and the increase in technology available to agriculture that has taken place since the 1940's. Although these two factors are often treated separately, it must be recognized that the changes that have occurred in the structure of dairy farming are not the result of technology alone, nor could the socioeconomic forces have changed the nature of milk production without the technological advances.

The technological advancements associated with the changing structure of dairy farming in the United States are of two basic types. The first may be labeled mechanical technology and the second management technology. The dairy farm of the 1930's and 1940's was an extremely labor intensive organization. Most of the operations performed on the farm, such as barn cleaning, feeding, milking, etc., were done by hand. The introduction of new labor saving machinery and equipment has changed all that. Gutter cleaners, automatic conveyor systems, and mechanical silo unloaders, to name a few, have dramatically reduced the amount of labor necessary to operate a dairy farm. Chores that were once performed by hand, such as barn cleaning and feeding, are now performed with the push of a button or, in some cases, are completely automated with timed switches. Perhaps the most revolutionary change in dairy technology has occurred in milking equipment. Where milking was once performed by hand and in the stable, it is now done in milking parlors where, with the aid of microcomputers and flow sensors, the milking process is almost entirely automated. Where one man could milk about five cows per hour by hand in the 1940's, he can milk in excess of 60 cows per hour with modern milking equipment.

The technological advancements in the dairy sector of United States agriculture are not at all in the area of mechanical technology. Many of the changes that have occurred in the structure of dairying can be attributed to an increased knowledge of the factors associated with producing milk. Through public (land-grant universities) and private research, a great deal more is known today about the intricacies of milk production in cattle than was known in the 1940's. This research has centered around feeding practices, feed handling and storage, and the physiology of milk production and reproduction in dairy cattle. Advances in the area of genetics have had a tremendous impact on dairy farming. The perfection of methods of collecting and storing semen and artificial insemination techniques has put a huge genetic pool at the disposal of virtually every dairyman in the United States. With the use of records provided by the Dairy Herd Improvement Association, bulls from the best cows in the nation may be selected for use by dairymen around the country. Genetic improvement in dairy cattle seems likely to increase, especially with the new advancements being made in the use of embryo transplants.

The technological advancements in machinery and equipment and the research and development of improved management techniques, coupled with the information dissemination performed by the Cooperative Extension Service, have had a profound effect on the structure of dairy farming in the United States. Perhaps the greatest single effect of the combination of these factors on dairy farming can be seen in the data presented in Table IV. In 1940, the milk produced per cow averaged 4,622 pounds per year. By 1979, the average production per cow per year was 11,471, or 6,849 pounds per cow more than in 1940. This increase in milk output per cow has resulted in 14.1 billion more pounds of milk being produced by 12,894 million fewer cows in 1979 than in 1940.

While research and technological developments have enabled changes in the structure of dairy farming to occur, the impetus for change has come from other areas. One cause for change in the agricultural sector since the 1940's has been the movement of population from the farm to urban areas. In 1950, there were 23 million people living on farms. By 1978, there were only eight million people left living on farms, a 65 percent decrease in the farm population since 1950. The movement of people off the farm has resulted in dairying and agriculture in general to become more capital intensive and less labor intensive as farmers replace labor with machinery.

TABLE IV

NUMBER OF MILK COWS, PRODUCTION PER COW, AND TOTAL MILK PRODUCTION, UNITED STATES, 1940-79

Year	No. of Milk Cows	Production Per Cow (Pounds)	Total Milk Production (Billion Pounds)
1940	23,671,000	4,622	109.5
1945	25,033,000	4,787	119.8
1950	21,944,000	5,314	116.6
1955	21,044,000	5,842	122.9
1960	17,515,000	7,029	123.1
1965	14,954,000	8,304	124.2
1970	12,000,000	9,747	117.0
1975	11,143,000	10,350	115.3
1979	10,777,000	11,471	123.6

Source: Jacobson, 1980, p. 143.

Changing market forces have also changed the structure of dairy farms in the last 30 to 40 years. Perhaps the largest structural change to come about from marketing forces is the conversion from grade B milk to grade A. In 1950, approximately 61 percent of all milk marketed was grade A; by 1979, this proportion had increased to 83 percent. Among the several reasons for this shift are the conversion of milk processing plants from can to bulk tank assembly, forcing farms to follow suit; processing plants discontinuing the handling of grade B milk; and increasing sanitary requirements, forcing more and more processed dairy products to be made with grade A milk.

Regional Nature of Milk Production

The level of milk production in the United States varies a great deal from one geographic region to another. The data presented in Table V indicate the regional nature of milk production. The data in this table also show that while milk production is indeed regional, patterns have been changing over time. The Lake States region has increased its share of the total milk output of the United States from 23.8 percent in 1940 to 29.1 percent in 1979 (see Table V). The Pacific region (mainly California) has increased its share of the total milk production from 7.5 percent in 1940 to 13.3 percent in 1979. The Northeast region also increased its share of the total milk production during this time period from 16.8 percent to 20.5 percent, which is a lower rate of increase than that in the Lake States and Pacific regions. While the Lake States, Pacific, and Northeast regions have posted significant gains in their share of the total milk production in the United States, there are two regions that have shown dramatic decreases. The most notable decrease occurred in the Corn Belt. Here, the percentage of total milk produced dropped from 21.0 percent in 1940 to 12.6 percent in 1979, a decrease of 8.4 percentage points. The Northern Plains had the second largest decrease, 4.4 percentage points, between 1940 and 1979. The only other region to lose a significant percentage of the total milk production between 1940 and 1979 was the Southern Plains. In this region, the percentage of the total milk produced dropped from 6.0 to 3.6. In all of the remaining regions, the percent of total milk produced in the United States moved by less than one percentage point between 1940 and 1979.

TABLE V

MILK PRODUCTION BY REGIONS AND PROPORTION THAT EACH REGION IS OF TOTAL MILK PRODUCTION, 1940, 1960, AND 1979 (in Millions of Pounds)

Region	1940 Pounds	1940 %	1960[a] Pounds	1960[a] %	1979[a] Pounds	1979[a] %
Northeast	18,417	16.8	24,566	20.0	25,283	20.5
Lake States	26,019	23.8	33,225	27.0	35,925	29.1
Corn Belt	23,004	21.0	22,157	18.0	15,527	12.6
Northern Plains	9,276	8.5	7,124	5.8	5,982	4.1
Appalachian	7,257	6.6	8,883	7.2	8,186	6.6
Southeast	3,078	2.8	3,806	3.1	4,397	3.5
Delta States	3,139	2.9	3,022	2.5	2,555	2.1
Southern Plains	6,572	6.0	9,353	3.5	4,507	3.6
Mountain	4,399	4.0	4,750	3.9	5,535	4.5
Pacific	8,251	7.5	11,101	9.0	16,463	13.3
United States	109,412	100.0	123,109	100.0	123,623	100.0

Source: Jacobson, 1980, p. 137.

In order to fully understand and anticipate regional changes and variations in milk production, it is necessary to have an understanding of the underlying causes for these differences. The regionality of milk production of the United States is due to the interaction of several factors. These factors include: The availability and quality of inputs necessary to produce milk, the competition from other agricultural and non-agricultural alternatives for these inputs, comparative advantage, and shifts in population.

The extent to which any region produces milk depends a great deal on its comparative advantage for milk production over other possible agricultural production alternatives. Resources available for agricultural production vary by quantity and quality between geographical locations in the United States. In some regions the resources for producing agricultural commodities exist in sufficient quantity and quality to be used over a wide range of alternatives. In areas such as these, one would expect that production of milk would depend a great deal upon the prices of competitive products. In these areas, the own price and cross price elasticities for milk production would be high. On the other hand, a region with restricted production possibilities due to limitations in the quantity or availability of resources may limit itself to the production of a single product. Here the production of a commodity may not be as responsive to a change in its price. For example, the income from dairying in a particular region may exceed the income possibilities from other agricultural production to such an extent that the price of the alternative products will elicit little or no response in the production of milk. Competition for resources used in agriculture may originate from the non-agricultural sector as well. Land and labor are inputs to both the agricultural and non-agricultural sector. In a region such as the Northeast, the comparative advantage may be in the non-agricultural uses of these resources.

Perhaps the best example of how the concept of comparative advantage has worked on the regional patterns of milk production can be found in the Corn Belt. In 1940, the Corn Belt produced 21 percent of the total milk produced in the United States (see Table V). By 1979, the Corn Belt was producing only 12.6 percent of the total milk produced. This drop in the share of the total production can be attributed to the increased returns from corn, soybeans, and meat animals. The data presented in Table VI show that, while the number of milk cows have decreased annually since 1975, the agricultural alternatives to dairying have been increasing. The number of cattle and calves on feed has increased over six percent since 1975, and the number of hogs and pigs raised in the Corn Belt has increased by 28 percent since 1975 (see Table VI). The Corn Belt's comparative advantage appears to be in the production of non-dairy agricultural commodities.

Regional variation in milk production may also be affected by demand for milk and dairy products. Demand for fluid milk varies by region and thus may dictate the nature of the milk producing sector within a region. The high demand areas for fluid milk are naturally in the densely populated regions. For example, the Northeast typically has a higher Class I utilization for milk than does the Lake States region. In recent years, there have been some significant shifts in the regional population distribution in the United States. In general, population has been shifting away from the Northern areas of the United

TABLE VI

NUMBERS OF CATTLE ON FEED, HOGS AND PIGS, ACRES OF SOYBEANS, ACRES OF CORN, AND DAIRY CATTLE FOR THE CORN BELT, 1975-79

Year	No. of Cattle and Calves on Feed (Thousand Head)	No. of Hogs and Pigs (Thousand Head)	No. of Acres of Soybeans (Thousand Head)	No. of Acres of Corn (Thousand Head)	No. of Dairy Cattle (Thousand Head)
1975	8,605	26,975	26,570	34,900	1,573
1976	9,940	30,350	24,570	37,460	1,548
1977	10,040	30,150	28,060	36,260	1,526
1978		32,050	30,500	36,130	1,472
1979	9,195	34,670	32,500	36,140	1,453

Source: U.S. Department of Agriculture, 1980a, pp. 32, 131, 306, 314, and 365.

States to the "Sun Belt." The data in Table VII show that while each region has experienced some increase in population, the regions with warmer climates (Southern Mountain, Southern Plains, Southeast) have had the largest increases in population since 1965. These shifts in population have the potential to change milk production patterns regionally through increased demand for fluid milk.

TABLE VII

UNITED STATES POPULATION BY GEOGRAPHIC REGION, 1965-80

Region	1965 Population	1980 Population	% Change 1965-80
Northeast	51,557	53,794	4.3
Lake States	16,181	18,002	11.2
Corn Belt	33,025	35,403	7.2
Northern Plains	5,017	5,261	4.86
Appalachian	17,998	21,291	18.29
Southeast	10,269	12,334	20.21
Delta States	7,636	8,989	17.72
Southern Plains	12,818	17,175	33.99
Mountain	7,740	11,352	46.67
Pacific	23,489	30,278	28.9

Source: Beale, 1981.

CHAPTER III

CONCEPTS OF SUPPLY, COSTS, AND SUPPLY RESPONSE FUNCTIONS

The supply function of a commodity is traditionally defined as the various quantities of the commodity that sellers or producers will place on the market at all possible alternative prices, other things being equal. The supply curve shows the maximum quantities per unit of time that sellers will place on the market at various prices. Cochrane states that this concept of supply has two implicit conditions associated with it (p. 1162). These are: (1) that one or more factors of production may be varied in the production process, and (2) that these factors of production are substitutable among enterprises, firms, and industries. Cochrane also points out that the concept of all other things being held constant is explicit to the concept of supply. The concept of supply is timeless and reversible.

The Production Function

The production function describes the technical relationship, at a given point of time, between resource inputs and product outputs. The production function may be expressed as:

$$Y = f(X_1, X_2, X_3, \ldots X_k | X_{k+1}, \ldots X_n) \qquad (3.1)$$

It is assumed that the function described in equation (3.1) is a single valued continuous function with continuous first and second derivatives with respect to the variable inputs $X_1, X_2, \ldots X_k$. Technical efficiency is implicit to the production function. Thus, Y is the maximum output attainable for the specified levels of the inputs $X_1, X_2, \ldots X_n$.

As stated in the above paragraph the production function is defined for a given unit of time. Economists have historically used the two concepts of the short run and long run to describe the time dimension of the production function. Henderson and Quandt state that the short run production function is defined by three general restrictions (p. 55). These restrictions are: (1) the time period is sufficiently short so that the firm is unable to alter the levels of its fixed inputs, (2) the time period is sufficiently short so that technological improvements cannot alter the shape of the production function, and (3) the time period is sufficiently long enough that the necessary technical processes are completed. The long run is obtained by relaxing the first condition. In the long run the fixed inputs $X_{k+1}, \ldots X_n$ would become variable inputs.

Heady (1952, pp. 54-56) states that the maximization of returns to a given cost outlay or the minimization of costs for a given return cannot be estimated without knowledge of the production possibilities gained from the technical relationships expressed by the production function. If the firm is assumed to be a profit maximizer, then it must produce any given level of output at the minimum possible cost. For any given output, total revenue is assumed fixed. The difference between total revenue and total costs is maximum only if the total costs are minimized. The total costs of production for a firm in the short run may be expressed as:

$$TC = b + \sum_{i=1}^{k} P_i X_i \quad (3.2)$$

In equation (3.2), b is the fixed costs to the firm which cannot be varied in the short run and P_i is the cost of the X_ith variable factor of production. Since a cost function gives the minimum costs of production at a specified level of output, equation (3.3), a constrained cost minimization equation, will give the firm's cost function in terms of its production function.

$$Z = b + \sum_{i=1}^{k} P_i X_i + \lambda(Y_o - f(X_1, X_2, \ldots X_k | X_{k+1} \ldots X_n)) \quad (3.3)$$

The first order conditions for the minimization of Z may be expressed as:

$$\frac{\partial Z}{\partial X_1} = P_1 X_1 - \lambda f_1 = 0 \quad (3.4)$$

$$\frac{\partial Z}{\partial X_2} P_2 X_2 - \lambda f_2 = 0 \quad (3.5)$$

$$\frac{\partial Z}{\partial X_k} = P_k X_k - \lambda f_k = 0 \quad (3.6)$$

$$\frac{\partial Z}{\partial \lambda} = Y_o - f(X_1, X_2, \ldots X_k | X_{k+1} \ldots X_n) = 0 \quad (3.7)$$

Solving equations (3.4) through (3.7) will give the optimal levels of variable inputs. For the cost of producing Y_o to be minimized, the first order conditions require that the rates of technical substitution or the ratio of the marginal products of X_i be equal to the ratio of the factor prices. This relationship may be expressed as:

$$\frac{f_i}{f_j} = \frac{P_i}{P_j} \qquad \begin{array}{l} i \neq j \\ i = 1, 2, \ldots, k \\ j = 1, 2, \ldots, k \end{array} \tag{3.8}$$

For a production function given its first and second order conditions the following relationships hold:

$$\frac{MPP_i}{MPP_j} = \frac{P_i}{P_j} = \frac{X_j}{X_i} \qquad \begin{array}{l} i \neq j \\ i = 1, 2, \ldots, k \\ j = 1, 2, \ldots, k \end{array} \tag{3.9}$$

and therefore,

$$P_iX_i - P_jX_j = 0 \tag{3.10}$$

Equation (3.10) may be expressed as equation (3.11), an implicit function of $X_1, X_2, \ldots X_k$.

$$G(X_1,X_2, \ldots X_k) = 0 \tag{3.11}$$

The function expressed in equation (3.11) is referred to as the expansion path and is the locus of points where isoquants and isocost lines are tangent. Since the isoquant expresses the maximum output attainable for given levels of variable inputs, the tangencies of isoquant and isocost curves or the expansion path represents the minimum costs of production for various output levels given fixed factor prices.

Cost Functions

Short Run

The short run cost functions may be derived from the production function equation (3.1), the cost equation (3.2), and the expansion path (3.11). This system of equations may be reduced to a single equation where costs are expressed as an explicit function of the level of output and fixed costs.

$$C = f(Y) + b \tag{3.12}$$

The cost function given by equation (3.12) specifies the minimum cost of producing each level of output.

Cost functions instrumental in the firm's pricing and output decisions, and thus forming the basis for the supply function derivation, are derived from equation (3.12). These functions are average total costs (ATC), average variable costs (AVC), average fixed costs (AFC), and marginal costs (MC).

$$ATC = \frac{f(Y) + b}{Y} \tag{3.13a}$$

$$AVC = \frac{f(Y)}{Y} \tag{3.13b}$$

$$AFC = \frac{b}{Y} \tag{3.13c}$$

$$MC = \frac{df(Y)}{dY} \tag{3.13d}$$

The shapes of the above cost functions given the law of diminishing returns are given in Figures 1 and 2. The law of diminishing returns states that if a producing unit holds quantities of all resources except one, equal increments in the variable resource eventually will yield decreasing movements in output. In other words, successive increments of variable inputs will result in smaller and smaller increments of output.

Total cost is a function of output plus the cost of fixed inputs. Total fixed cost is constant in the short run and is depicted as a horizontal line at some positive level in Figure 1. Total variable

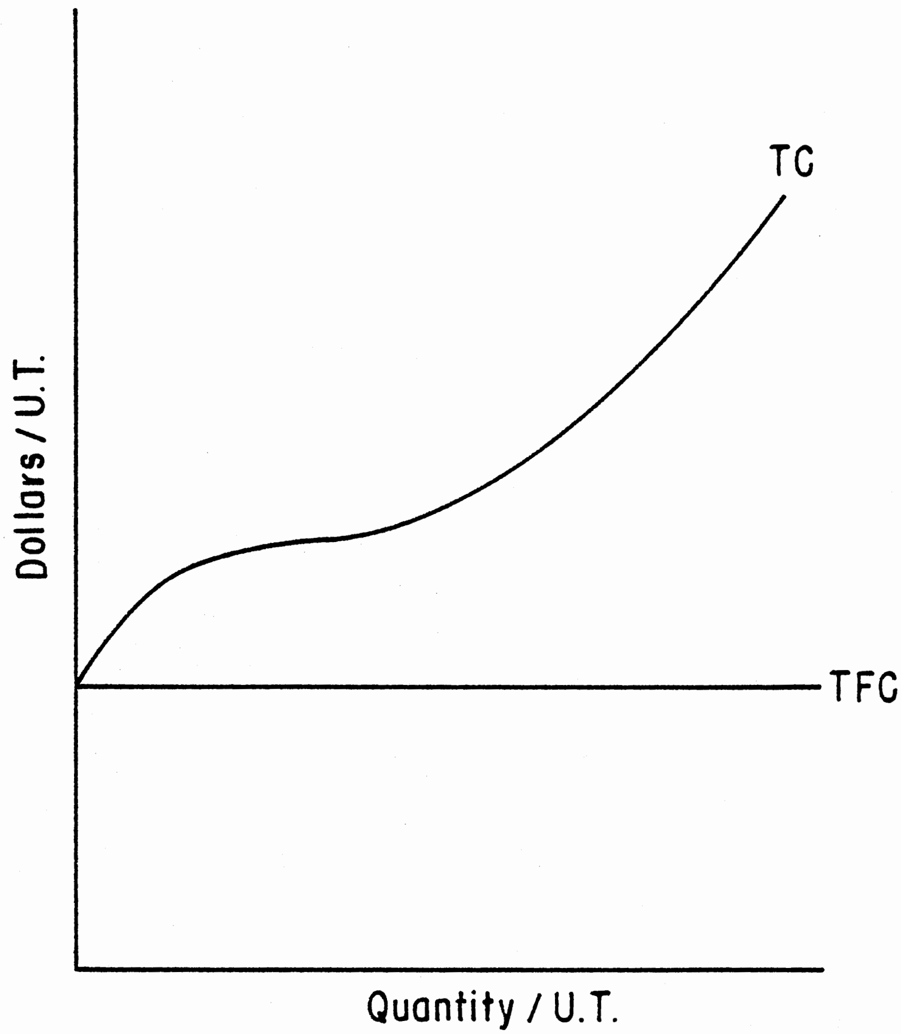

Figure 1. Relation of Total Cost (TC) and Total Fixed Cost (TFC) Curves

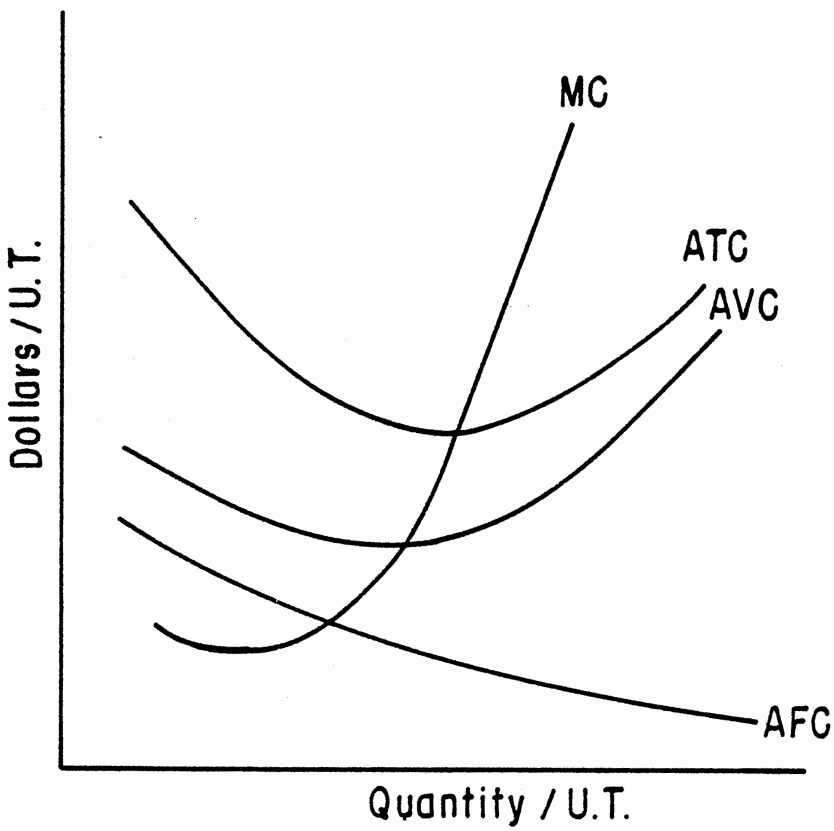

Figure 2. Relation of Average Variable Cost (AVC), Average Total Cost (ATC), Marginal Cost (MC), and Average Fixed Cost (AFC) Curves

costs is a function of output only. Under the conditions stated by the law of diminishing returns the total variable cost curve first increases at a decreasing rate and then increases at an increasing rate.

The inverse relationships between average variable cost and average physical product and between marginal cost and marginal physical product, along with the nature of the total cost function, determine the U-shape of the average variable and marginal cost curves. Given the law of diminishing returns, average physical product rises to some maximum and decreases; average variable cost decreases to some minimum and then increases. Marginal physical product increases to a maximum and then decreases, intersecting the average physical product curve at its maximum point. After the point of intersection with the average physical product curve, the marginal cost curve decreases at a faster rate than the total physical product curve. The marginal cost curve decreases until it reaches a minimum and then increases at a faster rate than the average cost curve. The marginal cost curve intersects the average cost curve at the average cost curve's minimum point.

The average fixed cost curve is a rectangular hyperbola, declining monotonically, since the fixed cost is spread over an increasing number of units of output. The average total cost curve is the result of the vertical summation of the average variable and average fixed cost curves.

A firm's revenue is a function of the level of output, given fixed prices for the output. The firm's profit function may be expressed as:

$$\pi = PY - f(Y) - b \qquad (3.14)$$

The point of maximum profit is, then, found by taking the first derivative of equation (3.14) with respect to Y and setting it equal to zero.

$$\frac{d\pi}{dY} = P - f'(Y) = 0 \qquad (3.15)$$

Moving marginal cost (f'(Y)) to the right gives:

$$P = f'(Y) \qquad (3.16)$$

The profit maximizing firm, then, must equate its marginal cost with marginal revenue. Since a perfectly competitive world is assumed, marginal revenue is equal to a constant price. The profit maximizing firm will not produce at any point where MC is less than price, since an additional unit of output will result in returns being greater than costs at the margin.

The second order condition for profit maximization is expressed in equation (3.17):

$$\frac{d^2\pi}{dY^2} = - \frac{d^2f(Y)}{dY^2} < 0 \qquad (3.17)$$

or, multiplying by -1,

$$\frac{d^2f(Y)}{dY^2} > 0 \qquad (3.18)$$

This condition specifies that the firm's marginal cost curve must be increasing at the profit maximizing output.

In the short run, fixed costs do not affect the profit maximizing level of output. These costs are paid regardless of the quantity produced. If the market price is less than the minimum average variable costs, the firm, in order to minimize its losses, will discontinue production. The maximum loss at this point will equal the firm's total fixed costs. If the market price for output is greater than the average variable costs but less than the average cost, the firm will continue to produce, since production at this point results in losses that are less than the total fixed costs.

Long Run

The long run differs from the short run in that, with the long run, there are no fixed inputs. Thus, the firm's long run production function becomes:

$$Y = f(X_1, X_2, \ldots, X_k, b) \tag{3.19}$$

In the short run, the problem was to maximize profits, given the size of plant. In the long run, plant size may vary; thus, the problem or goal becomes one of selecting optimum plant size.

The minimum costs of production in the long run are expressed by the firm's long run cost functions. The long run cost function is derived from the long run production function, the long run cost equation, and the long run expansion path. The long run cost equation and expansion path are expressed in equations (3.20a) and (3.20b), respectively.

$$TC = f(b) + \sum_{i=1}^{n} P_i X_i \tag{3.20a}$$

$$G(X_1, X_2, \ldots X_n) = 0 \tag{3.20b}$$

The variable b, or what was the fixed cost in the short run, is now an increasing function of plant size ($f'(b) > 0$). Equations (3.19), (3.20a), and (3.20b) may be manipulated so that the variable inputs are eliminated. Long run total costs may now be expressed as:

$$C = f(Y,b) + g(b) \qquad (3.20c)$$

From equation (3.20c) it is clear that when specific plant size is chosen (e.g., $b = b_o$), the cost function becomes that of the short run relationship. Thus, by varying the value of b, a whole family of short run cost functions may be generated. The long run total cost curve is an envelope of the short run curves generated by varying the value of b and is defined as the locus of the minimum cost points for each level of output.

Equation (3.20c) may be expressed as an implicit function of C and Y.

$$C - f(Y,b) - b = G(Y, X_i, b) = 0 \qquad (3.21)$$

The long run total cost function is derived by first setting the partial derivative of (3.21) with respect to be equal to zero:

$$\frac{\alpha c}{\alpha b} = G(Y, X_i, b) = 0 \qquad (3.22)$$

and then eliminating b from equations (3.21) and (3.22) and solving for C.

$$C = k(Y) \qquad (3.23)$$

The long run average and marginal cost curves may be derived from equation (3.23). While the long run average cost curve may be constructed by dividing long run total costs by quantity produced or by constructing the envelope of the short run average cost curves, the long run marginal cost curve is not the envelope of the short run marginal cost curves. Since short run marginal cost is the rate of change of the short run variable cost with respect to changes in output and long run marginal cost is the rate of change of all costs (no fixed costs) with respect to changes in output, the two curves will intersect. The points where the long run marginal cost and the short run marginal cost intersect correspond to the tangency points of the short run average cost and long run average cost curves.

The concept of maximum profit in the long run is identical to the maximum profit in the short run. However, in the long run, the firm may adjust the size of plant in order to obtain the minimum cost. The profit function for the long run is the difference between revenue and cost with plant size variable and may be expressed as:

$$\pi = PY - f(Y) \tag{3.24}$$

Taking the derivative of the profit equation and setting it equal to zero gives the following:

$$P = f'(Y) \tag{3.25}$$

Thus, long run profits are maximized at the point where marginal revenue is equal to long run marginal cost, given the second order conditions that:

$$\frac{d^2\pi}{dY^2} < 0 \tag{3.26}$$

Supply Functions

Cost functions were defined in terms of short run and long run. Conceptually, there are three lengths-of-run categories for supply.

Henderson and Quandt describe these as: (1) the very short run, (2) the short run, and (3) the long run (p. 108). Plaxico describes a fourth category, termed the intermediate run. These categories are discussed below.

The very short period describes a period so short that no adjustment can be made in response by changing conditions. Marshall first described this as the "very short" or "market" period. Here, output is considered fixed at some quantity q^o. At any quantity less than q^o the marginal cost is zero. With output fixed, the marginal cost of any output higher than q^o can be considered to be infinite. Since the profit maximizing condition MC = P cannot be met, the firm will sell its output until price no longer exceeds MC. The concept of supply states that the aggregate quantity supplied by all producers is a function of price. With the output of each firm fixed at a certain level, the supply is no longer a function of price. The supply curve would in this case be a vertical line with the distance from the price axis, or aggregate supply, being the sum of all individual firm's outputs.

Any time period between that in which no resources may be varied and that in which all resources are variables may be referred to as the short run (Marshall, p. 383). However, the short run, as used here, is defined as that period in which there is a certain set of variable resources and another set of resources that cannot be changed (fixed resources). In terms of agricultural production the fixed resources may be land, buildings, technology, and management skills. Variable resources in the short run might include fertilizer, feeds, fuels, labor, etc. The period of time in which this short run concept is applicable may vary from enterprise to enterprise and from industry to industry. For example, in agriculture the short run period for a crop such as wheat may only be one year. However, in the case of milk production, the short run may be considered to span over two years, the time it takes to bring a calf into production. In the short run, the quantity of fixed resources determines the maximum output of the firm. The firm may produce at or below this level by varying the quantities of variable resources, e.g., a wheat grower is limited in total output possible by the number of acres of land which he controls. He may, however, vary his wheat output by varying the amount of fertilizer used on his crop.

The short run supply function of a firm is identical with that portion of its marginal cost curve (MC) which lies above its average cost curve (AVC). The supply function is not defined for any point below the intersection of the AVC and MC curves. Short run MC for the jth firm can be expressed as a function of output:

$$MC_j = f(Y_j) \tag{3.27}$$

The supply function for this firm may be obtained from the first order conditions for profit maximization by letting P = MC and solving for $Y_j = S_j$:

$$S_j = S_j(P) \text{ for } P \geq \text{Min AVC} \tag{3.28}$$

$$S_j = 0 \qquad \text{for } P < \text{Min AVC} \tag{3.29}$$

The aggregate supply function is obtained by summing the supply functions from the n individual firms. Thus, the aggregate supply may be expressed as:

$$S = \sum_{j=1}^{n} S_j(P) = S(P) \tag{3.30}$$

The second order conditions for profit maximization require that the MC curve must be rising. The individual firm's supply function is, therefore, monotonically increasing for prices above the minimum AVC (the intersection of the MC and AVC curves). Since the summation of monotonically increasing functions is a monotonically increasing function, the aggregate supply curve will have a positive slope.

Plaxico describes a third length of run termed the intermediate run. The intermediate run is a short run concept but differs from the short run concept discussed above in that the time period perceived by producers is more than one production period. In this situation, the size of the firm is limited by the size of plant (acres of land) only. Resources such as machinery, considered to be fixed in the short run, become variable in the intermediate run. In the case of milk production, the intermediate run variable resources that are fixed resources in the short run could be cow numbers and buildings. Here all factors of production, with the exception of land, would be variable and therefore would be determinants of the firm's marginal cost curves.

The fourth category of length of run is the long run. The long run may be defined as a period sufficient in length to allow all variables to change. The firm, in this case, has time to vary the size of its plant to any size it deems appropriate. Since the long run average cost curve is an envelope to all of the short run cost curves, each point on the long run supply curve is related to a short run supply curve.

The long run optimal output of a firm is determined by the intersection of price and the long run marginal cost in a competitive model. Again, as with the short run supply curve, zero quantity is produced at prices less than the long run average cost. The firm's long run supply curve consists of that portion of the long run marginal cost curve which lies above its intersection with the long run average cost curve. The marginal cost function (MC) of the jth firm may be expressed as:

$$MC_j = f'_j \ (Y_j) \ j = 1, \ldots, n \qquad (3.31)$$

and setting $P = MC_j$ and solving for $q_j = S_j$, the supply function becomes:

$$S_j = S_j \ (P) \ j = 1, \ldots, n \qquad (3.32)$$

The aggregate long run supply function is obtained from the summation of the n firm's long run supply functions and is positively sloped for the same reasons as the short run supply function.

One important factor that affects quantities supplied in the long run is n, affected by the entry and exit of firms. A price increase in the long run not only results in increasing quantities derived from the adjustment of existing firms, but also from the entry of new firms into the industry. A long run price decrease will, on the other hand, result in quantity decreases due to the exit of firms from the industry. The short run response to price changes is smaller than the long run response, since the size of plant and the number of firms in the industry is fixed in the short run.

Estimation of Aggregate Supply Functions

Supply Versus Response

The concept of supply, as discussed previously in this chapter, may be defined as the response of quantities of output to a set of given prices with all other factors held constant. The existence of the ceteris paribus conditions imposed on the concept of supply is what separates the concept of supply from the concept of supply response. Cochrane views supply response as how the quantity of a good offer varies with changes in the price of the good without the restrictive ceteris paribus conditions (p. 1162). The concept of supply response, then, is a more general concept which includes the concept of a net supply relation. Supply response measures the changes in quantity offered in response to a price change regardless of the means of the change. Whereas the concept of supply excludes the inclusion of the shifters of supply discussed by Heady, such as fixed resources, expectations and uncertainty, technological change, supply of factors; the notion of supply response includes changes in these factors, and thus incorporates a measure of the shifters of supply.

The supply concept as discussed by Cochrane is said to be timeless and reversible. The notion of supply response, however, does not include the property of reversibility. The property of reversibility is lost when technological changes are incorporated into the response relation. Thus, there will be two response relations for a commodity; one tracing out the supply response occurring with falling prices and one describing the relationship of output to increasing prices.

Methods

There are two distinct methods in which supply response functions may be estimated. These methods are econometric models utilizing time series data and budgeting analysis using cross sectional data. The former method is often referred to as the positive approach and the latter methods as the normative approach (Heady). The econometric modeling approach uses time series data to "discover" historical trends in data. These trends are then used to predict what the supply will be at some given point in time. The budgeting approach, however, uses cross sectional data to develop possible production scenarios. With the budgeting technique the emphasis is on production possibilities and likelihoods rather than on what has happened in the past.

In using time series data, it is possible to account for technological shifts through the use of dummy regressors. However, it is extremely difficult to differentiate the various lengths of run inherent in the data. With budgeting analysis it is easy to hold any number of production factors constant or to let them vary. Thus, budgeting analysis allows some advantage in estimating supply response over various lengths of run.

Budget Method of Estimating Supply Response

Evolution

As a result of the Bankhead-Jones Act of 1935, several studies (Allen, Hole, and Mighell; Christensen and Mighell; Baumann and Hill; Stand and Hole; and Fowler) of supply response for milk were conducted in the United States. The first of these studies, the classic

Cabbot-Marshfield study (Allen, Hole, and Mighell) utilized budgeting analysis. In this analysis, 98 percent of the existing farms in the Cabbot-Marshfield area of Vermont were surveyed and then budgeted. Several farm organizations were tested for maximum net returns under expected price and normal growing conditions. Systematic comparisons of partial and complete alternative arrangements of the fixed and variable resources available to each farm operator were made. From this analysis of the individual farms, the responses of milk output to the present milk price, a 15 percent higher than actual price, and a 15 percent lower than actual milk price were estimated.

Mighell and Black took the budgeting method of estimating milk supply response one step further. This study represents the culmination of the budgeting technique of estimating supply response. The authors were the first to employ the Marshallian concept of the representative firm to the estimation of supply response (Marshall). Mighell and Black made a survey of a sample of the farms within the area of study. They then budgeted only the sample farms to estimate the supply response. The authors concluded that the use of representative farms was sufficiently accurate to use in the estimation of supply response in milk production.

With the availability of electronic computers and the development of linear programming techniques, the estimation of supply response became faster and also more normative. Two of the earliest studies conducted to estimate supply response of milk production utilizing the linear programming technique were done at Iowa State University in 1959 and 1960 (Ladd and Easely; Krenz, Heady, and Baumann). These two studies used the same basic budgeting procedure developed by Mighell and Black in 1951. The use of linear programming, however, changed the nature of the analysis somewhat. In earlier studies of supply response the conditions placed upon the budgets were those of profit maximization and what was most likely to happen. The latter criterion utilized the authors' knowledge of the exact conditions present in the geographic region being analyzed and also knowledge of what had happened in the past. With the introduction of linear programming the majority of emphasis is on the condition of profit maximization and thus the estimates are more normative than the first budgeting analyses.

The Aggregation Problem

A new set of problems that occur when using the representative farm approach for estimating supply response was discovered with the advent of linear programming techniques. The problem, aggregation bias, is one that is inherent in the concept of representative farms. Hartley was one of the first to point out that aggregation bias occurred when using representative farms to estimate supply response. The bias, according to Hartley, occurred from incorrectly specifying homogeneous groups of farms when constructing the benchmark farms. Day (1963) offered that the solution to the aggregation problem lay in the stratification of the representative farms into smaller groups and that these groups show proportional variation in their constraint or resource vectors. Day (1965) concluded that the solution to the aggregation problem was in stratifying the representative farms by homogeneous resources. He also pointed out that the use of primary data was necessary for this type of supply response estimation, since secondary data are often impossible to stratify.

Two empirical studies were undertaken in 1965 to find an exact solution to the aggregation problem. Sheehy and McAlexander estimated the aggregation bias introduced by several methods of defining the representative farms. The criteria they used to develop representative farms were: (1) the grouping of farms according to absolute levels of certain resources, and (2) the grouping of farms on the basis of the farm's most limiting resource. When supply estimates generated by these criteria were compared, it was found that the homogeneous restriction or most limiting resource method introduced the smallest aggregation error. Frick and Andrews conducted an empirical study of 51 farms in southern New England. In this study, all 51 farms were programmed individually. Benchmark farms were also defined by the following criteria: (1) the average farm for the area developed by taking the mean of the resource levels of all 51 farms, (2) farms divided into six groupings on the basis of housing capacities for cattle, (3) the homogeneous restriction method as used by Sheehy and McAlexander, and (4) a classification using a criterion of potential size in terms of cow numbers as a basis for organizing benchmark or representative farms. The conclusion of this study also pointed to the homogeneous restriction method of defining representative farm classifications as the method that introduces the least aggregation bias. In 1979, Spreen and Takayama authored a theoretical discussion on aggregation bias introduced with the representative farm approach of estimating supply response. These authors concluded that there is no exact aggregation model for this type of supply estimation. Their conclusions, however, are similar to those of Sheehy and McAlexander in that the necessary condition for "semi-exact" aggregation is that for every price vector all firms must have the same set of activities in solution. In other words, representative farms should be classified on the basis of the most limiting resources.

Representative Farm Methodology vs. the Positive Methodology

There has been little empirical work done in recent years using the representative farm approach to estimate supply response for milk. The last studies conducted in this area were done in the mid to late 1960's (Sundquist et al., Northeast Dairy Adjustment Committee, Anderson and Heady). The emphasis in estimating supply response has shifted from the representative farm approach to the econometric modeling approach in recent years. The major weaknesses and problems still encountered with the representative farm methodology, as pointed out by Sharples, are: (1) interdependence or externalities, (2) changes in farm size, (3) unrealistic firm level assumptions, (4) the selection of representative farms, and (5) mechanical problems. The interdependence problem arises from the fact that with the representative farm technique we assume that the individual farm's input costs and transformation rates are constant for all levels of aggregate production. However, in the real world, the aggregate level of production does indeed affect the level of input prices and, in turn, the individual firm's supply function. The problem of farm size arises, since a large portion of aggregate supply response stems from the changing of farm size. The problem of farm size in the representative farm methodology is founded in estimating the impact of increasing farm size on the region. For example, there is no good or valid method to assure that sold land is equal to the amount of land purchased or rented in the aggregate model. The problem of unrealistic firm level assumptions has been recognized since the earliest use of the representative farm methodology. The linear programming models assume that the farm operator or manager is a profit maximizer and that farmers have perfect knowledge of their alternatives. As Sharples points out, these assumptions can have a large effect on the aggregate supply response.

The problem associated with selecting representative farms was discussed in the previous paragraphs. This problem partially can be overcome by using the homogeneous restriction method of selecting representative farms. The mechanical problems with the representative farm methodology that Sharples discusses refer to the amount of data that must be manipulated with this approach to estimating supply response. The increasing availabilities of high powered computers and data entry systems, however, do much to minimize this problem.

Sharples argues that the shift away from the representative farm approach stems mainly from the inability of researchers to overcome the problems discussed in the above paragraph. It is his contention that researchers have left this methodology in search of one that will yield better results.

Shumway and Chang made comparisons between supply response estimated from linear programmed representative farms and supply resource estimated by means of an econometric model. In their critique of the two methodologies they point out that, like the linear programming model, the classical linear regression model is also based upon a set of assumptions that may be violated. The assumptions that may be violated here are: errors in data measurement or aggregation, multicollinearity, omission of relevant variables, and incorrect specification of the model. If the above violations are avoided, the predictive properties of the econometric models are superior to those of the linear programming model. Linear programming's most important strength is that it can simulate the effects of exogeneous forces for which historical observations are not available. Shumway and Chang conclude that linear programming representative farms to estimate supply response still provides a feasible method for estimating both direct and cross price elasticities of supply. Using time series data to estimate cross price relationships often results in problems, since there is usually a high degree of correlation among independent variables. However, the validity of the results from the linear programming methodology are intimately associated with the accuracy of the assumptions imposed upon the model.

CHAPTER IV

A MODEL FOR ESTIMATING SUPPLY RESPONSE

Estimating supply response for any commodity requires the use of some mathematical or statistical technique for specifying quantities of output produced at various prices. This study uses the linear programming technique to estimate the supply response of milk. The simplex linear programming algorithm is used to determine the optimum quantities of milk to be produced by dairy farms for various prices of milk. A general discussion of linear programming and the nature of the supply function generated by this method is presented below.

Linear Programming

Linear programming is a mathematical technique of finding the best plan of action where there are several alternative plans available and limited resources to be used in obtaining the optimal action (Agrawal and Heady, p. 26). The use of linear programming to solve applied problems originated from the need to find optimal allocations of materials and to find the shortest shipping routes during World War II. In recent years, agricultural economists have applied linear programming to specify optimal farm resource and enterprise organizations, formulate least cost feed rations for livestock, determine optimum product mixes for agricultural marketing firms, estimate the most efficient energy uses in feeding livestock, and provide spatial equilibrium patterns in the flow of agricultural products.

The linear programming techniques optimize (minimize or maximize) a linear objective function Z, of n variables subject to m linear equalities or inequalities. The problem may be stated in compact notation as:

$$\text{Maximize } Z = \sum_{j=1}^{n} C_j X_j \qquad (4.1a)$$

subject to

$$\sum_{j=1}^{n} a_{ij} X_{ij} \lesseqgtr b_i \qquad i = 1, \ldots, m \qquad (4.1b)$$

$$X_j \geq 0 \qquad j = 1, \ldots, n \qquad (4.1c)$$

C_j is the price or variable cost associated with a particular variable or activity, X_i; a_{ij} equals the amount of the ith resource required per unit of the jth activity; and b_i is the amount of the ith resource available. Only one sign may hold for the linear constraints expressed in equation (4.1b).

There are several inherent assumptions in the linear programming technique (Agrawal and Heady, p. 31). The sum of the resources used by various activities must equal the total quantity of resources used for all of the activities. The objective function must be linear in order to use linear programming techniques. Products, powers, and combinations of variables violate this linearity assumption. Another assumption is that all resources and activities are assumed to be divisible. That is, activities may be brought into the solution at fractional levels and resources may also be used in fractions. The number of activities and resource restrictions for any given problem must be finite in order to use the linear programming technique. Finally, the linear programming model is said to be deterministic, i.e., all resource supplies (b_i), technical coefficients (a_{ij}), and prices (c_i) are single-valued and known with certainty.

A solution to a linear programming problem where the number of nonzero valued variables is equal to the number of constraints is said to be basic. A solution is feasible if it meets all of the resource restrictions and all of the activities in solution are nonnegative. An optimal solution is the solution that minimizes or maximizes the objective function.

Stepped Supply Functions

Supply functions generated using linear programming techniques are not smooth, but discontinuous. The smooth or continuous supply function is a continuous series of marginal costs over a range of output levels. Although the stepped supply function is discontinuous, it is based on the same marginality concepts as the continuous function. Linear programming is, indeed, a marginal analysis (Dorfman, Samuelson, and Solow). Kottke states:

> While the stepped and smooth supply functions have a close kinship because of their marginal analysis parentage, they are not identical twins in terms of their structure and the kind of behavior they represent. In other words, both have the same theoretical basis, but they differ in the combining nature of the relevant variables.

Figure 3 shows a hypothetical stepped supply function. The horizontal sections of this function are marginal costs. These segments indicate that marginal costs are constant over specified ranges of

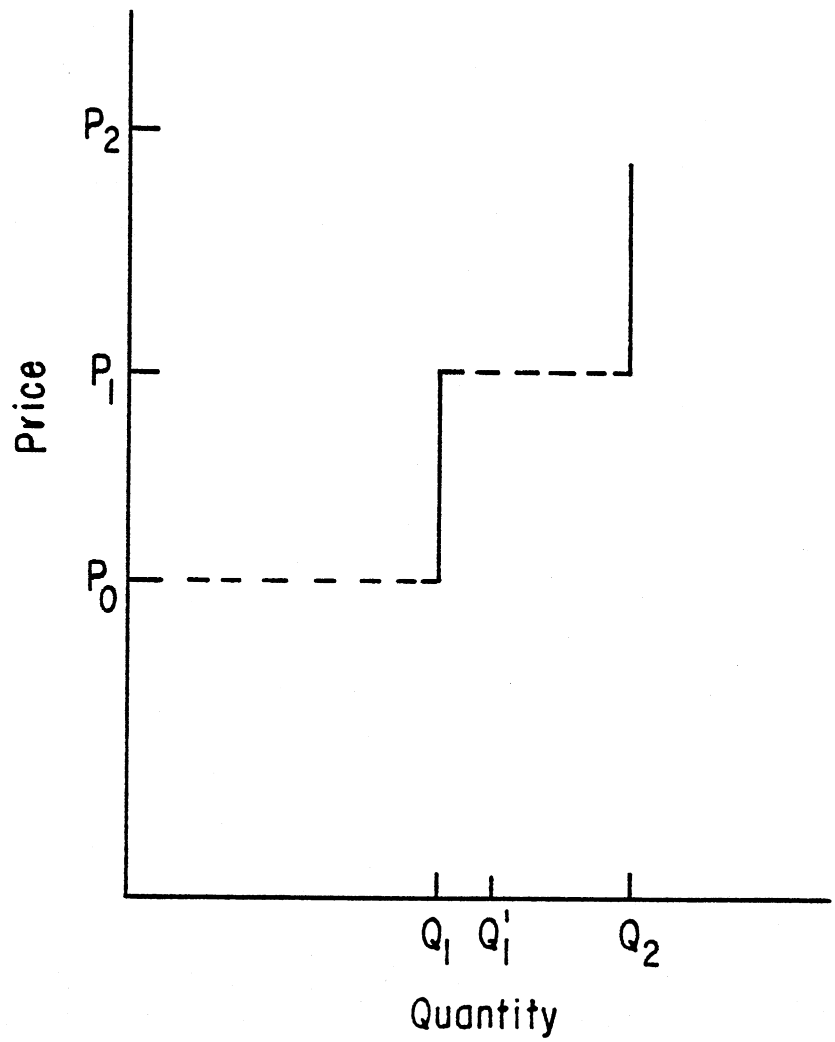

Figure 3. Theoretical Stepped Supply Function

output. Points Q_1 and Q_2 are the optimal levels of output at the given prices. The function is discontinuous at these points since the corner points of the feasible range do not have derivatives. The vertical segments of the stepped function are the optimal solutions for a range of prices. For example, Q_1 is the optimal level of output for the range of prices P_0 to P_1. The vertical segments are identified by introducing price and the profit maximizing condition of $MR \geq MC$. Given that the goal of the firm is to maximize profits, it should be willing to produce where $MR \geq MC$. The optimal solutions and ranges of prices for the steps give the following step function:

$$f(P) = 0 \text{ when } 0 \leq P < MC_a \qquad (4.2a)$$

$$f(P) = Q_1 \text{ when } MC_a \leq P \leq MC_b \qquad (4.2b)$$

$$f(P) = Q_2 \text{ when } MC_b \leq P \qquad (4.2c)$$

The horizontal segments are not included in the function described by equations (4.2a) through (4.2c) on the basis of a resource conservation concept. Up to point P_1, Q_1 assumes that MR is equal to MC. As long as MR is constant and MC is equal to MC_b, the firm will maximize profit whether it produces quantity Q_1 or Q_1'. Since nothing is gained there is no reason for the firm to use the additional resources to produce Q_1'. Thus, it will produce Q_1. If MR increases to P_1 and MC does not change, the quantity produced will increase to Q_2. Quantity Q_2 will be produced over the range of prices specified by the vertical segment at Q_2.

The supply function described by equations (4.2a-4.2c) is not continuous. Consequently, marginal revenues (MR) will not always equal marginal cost (MC) at the profit maximizing solution. Although the linear programming solution does not conform to the formal conditions of marginality, it is still a valid principle that as long as the market price is greater than the average variable cost, the firm should continue to increase its output as long as marginal revenue (MR) is more than marginal cost (MC). If net revenue is maximized at an output of n units, the marginal conditions of profit maximization are as follows:

marginal cost (MC) of n^{th} unit $\leq$ marginal revenue (MR) < marginal cost (MC) of (n + 1) unit.

This condition encompasses the second order equilibrium condition in conventional marginal analysis so linear programming is therefore within the realm of marginal analysis. The supply functions obtained in this study are obtained from linear programming solutions for small changes in product prices and are assumed to be valid approximations of supply behavior.

Procedures for Estimating Supply Response

The Lake States Region

A linear programming model is utilized to program the representative farms to obtain estimates of supply response. The procedure can be separated into five steps: data collection, stratification of farms by resource restrictions, modeling the representative farms, estimating supply response for each stratification using variable price programming, and aggregating the results into regional estimates. These steps are discussed below.

The primary data source for this study is the 1979 Dairy Cost of Production Survey, which was conducted by the USDA in the spring of 1980 (U.S. Department of Agriculture, 1980b). While this study was conducted to furnish data on the cost of producing milk, it also provided a great deal of information concerning farm organization, such as housing and milking facilities, numbers of cows, culling rates, forage feeding rates, labor use, and forage production practices. In all, 373 completed questionnaires were obtained in the Lake States region (Michigan, Minnesota, Wisconsin). Along with data obtained from the survey of dairy farms, this study utilizes information obtained from previous USDA Cost of Production surveys on crops and meat animals. Data from these surveys are summarized by region in the Firm Enterprise Data System (FEDS) budgets. These data are used to obtain coefficients for the non-dairy alternatives in the Lake States region.

In order to minimize the aggregation bias discussed in Chapter III, the data obtained from the dairy survey are stratified into homogeneous resource restrictions. Since the data utilized by this study were not collected expressly for this analysis, there are limits to the ways in which the farms can be stratified. With this limitation in force, the farms are stratified on the basis of acres of cropland per cow and the number of stalls or housing capacity per cow. Group numbers for the stratification of farms in the Lake States and other regions are shown in Table XXV in Appendix A.

The next step in this analysis is the modeling of the individual farm stratification groups into typical or representative farms. Since the Lake States sample farms are stratified into 12 sub-groups, 12 representative farm situations or organizations are modeled. Each of these 12 groups is unique in terms of the technical coefficients.

A "nested" minimization linear programming model is utilized for each of the 12 representative farms in the Lake States. The model is "nested" in that it maximizes profits while at the same time minimizing the cost of feeding the dairy cattle. This type of model enables each representative farm to feed dairy cows without locking the dairy enterprise into a specific ration. The model used for the Lake States is generated using a modification of the computerized matrix generating system developed by Smith (1981). This system utilizes dairy cow feeding equations developed at Virginia Polytechnic Institute.

The linear programming model has two types or categories of activities. One set of activities are those associated with the dairy or milk producing capabilities of the farm. The other set of activities is concerned with the non-dairy alternatives or possibilities for the Lake States. The activities associated with milk production include the cow activity which contains the coefficients related to raising dairy cows such as replacement rates, culling rates, feed requirements, etc. Other dairy activities include forage activities, building activities, and the activities associated with selling milk and its joint products. These assumptions are outlined in Tables XXVII and XXVIII in Appendix B.

The non-dairy alternatives included in the Lake States model can be further categorized into two sub-groups. These sub-groups are the non-dairy livestock activities and the cash crop activities. The non-dairy livestock alternatives for the Lake States consist of a farrow-to-finish hog operation, a cow-calf beef operation, and a beef cow feeding operation. The cash crop activities include corn, oats, soybeans, and spring wheat. For a non-dairy alternative to be included in the model, it must have been produced in the Lake States region in 1979. The data for the non-dairy alternatives were taken from FEDS budgets. A list of these budgets is contained in Table XXVI in Appendix A.

One additional activity is included in the model that is also an alternative to dairying. This activity allows the farms to exit from agriculture. The activity is set up so that the farm land base may be sold. In this activity it is assumed that: (1) a five percent real rate of return could be earned on the land investment, (2) a two percent real rate of return could be earned on the non-land investment, and (3) a farmer could earn the equivalent of the average agricultural wage rate if he discontinued farming. These returns are calculated on a per acre basis and constitute the objective function value for the sell land activity. The assumed land values and agricultural wage rates are contained in Table XXX in Appendix B. The return, in this case, is a concept of an average return to the farm's non-land investment per acre, the operator's labor, and the average value of the land.

In addition to activities such as the building activities which allow the farm operation to expand, a purchase labor activity is also included. Since there are no data explicit enough to give quantities of labor available at various wage rates, the labor supply function included in the model is based upon assumptions. The assumed minimum wage rate is that of the average wage rate for all production workers for the region. The assumed highest wage rate for the region is the minimum union hourly wage rate for building laborers for major cities within the region. The wage rates are moved at one dollar increments with 3,120 hours of labor (one man equivalent) supplied with each price increase. At the high wage rate, the supply of labor is unlimited. The minimum and maximum wage rates used in this study are presented in Table XXIX in Appendix B.

Once the representative farms for each of the 12 sub-groups of the Lake States are modeled, the supply response may be estimated for each. Each of the 12 models is run with a series of milk prices. The range of prices used in this study is \$5.00 - \$20.00 per hundredweight of milk. This procedure is referred to as variable price programming or price sensitivity analysis, and the result is the generation of 12 different supply schedules for the Lake States.

The final step in this procedure is the aggregation of the 12 supply schedules into a regional supply schedule. Each of the 12 schedules is weighted and summed into a regional schedule. The weights in this step are derived from the dairy survey and are based on the number of cows sampled and the actual number of cows in the region. The weights are converted from a per-head basis by dividing the expanded cow numbers by the average number of cows per farm calculated from the survey for each sub-group. The weighting factor is derived as follows:

$$TSCW/TACW = PS$$

$$SSCW/PS = ESTC$$

$$ESTC/ACS = WT$$

where:

TSCW is the total number of cows surveyed within a region

TACW is the actual number of cows within a region

PS is the percentage of the total cows within a region that was sampled

SSCW is the number of cow numbers in each stratification that was surveyed

ESTC is the estimated total cow numbers within each stratification

ACS is the estimated (from survey) number of cows per farm within each stratification

WT is the weighting factor

Modifications for Other Regions

Each of the other six regions in this study are examined using the same procedures described for the Lake States region. There are, however, some differences between regions in terms of the parameters used to delineate the sub-groups and in the specified non-dairy alternatives which are included in the linear programming models. The differences between regions are described below.

The non-dairy alternatives included in the linear programming models are important alternatives based on what the region actually produced in 1979. Each region, therefore, has different agricultural alternatives to milk production. A particular crop or livestock alternative, however, may have been produced in a region in 1979 and not included in the model for the region. This was the case for vegetable and fruit production in California. These alternatives were not included for California, since the geographic areas of milk production did not coincide with the areas of production for fruits and vegetables.

Table VIII gives the crop and livestock alternatives to dairying that are included in the regional models. As might be expected, the Northeast region has the smallest number of alternatives to milk production. Length of growing season and topography are major factors contributing to the lack of alternatives to milk production in this region. The Corn Belt and Lake States regions have the largest number of alternatives to dairying. These two regions have longer growing seasons and land more suited to crop production than does the Northeast. The Appalachian region has fewer alternatives than the Lake States and Corn Belt, primarily because of limited feeding of beef cattle. While there are some feedlots in the Appalachian region, there are not enough to consider it a bona-fide alternative to producing milk. The number of alternatives modeled for Texas and California obviously do not represent all of the agricultural possibilities within the two states. However, the alternatives listed in Table VIII do represent the alternatives to dairying for the areas within the two states where dairy production is concentrated.

TABLE VIII

CROP AND LIVESTOCK ALTERNATIVES TO MILK PRODUCTION BY REGION

Region	Non-Dairy Crop Alternatives	Non-Dairy Livestock Alternatives
Northeast	Corn, oats	None
Corn Belt	Corn, soybeans, oats, wi winter wheat	Hogs, cow-calf, fed cattle
Lake States	Corn, soybeans, oats, spring wheat	Hogs, cow-calf, fed cattle
Appalachia	Corn, soybeans, winter wheat	Hogs, cow-calf
Texas	Cotton, sorghum, winter wheat	Cow-calf
California	Corn, cotton, winter wheat	None

The Texas and California models also deviate from the other regional models with respect to purchasing feeds. Texas dairy farms purchase a relatively large percentage of their forage requirements. On a state average basis, Texas dairy farms purchase approximately 37 percent of the total hay fed (U.S. Department of Agriculture). The need to include activities to purchase hay is underscored by the fact that the Texas representative farms used in this analysis simply do not have the land base to feed the cattle on hand in 1979.

The problem of purchasing forage is not new to the representative farm methodology (Sharples). Based on economic theory, the quantities of hay offered for sale will vary with price. Purchasing forages within the required models used in this study presents problems associated with too many unknown factors and relationships. These unknowns include: (1) how much hay is available within a region, (2) at what price will hay move in from outside of the region, and (3) how responsive is the quantity of hay supplied to changes in the price paid for hay. Since there are few research results to answer to these unknowns, the problem was solved by using assumptions and some published price elasticity estimates.

The amount of hay that was available in 1979 to each representative farm in Texas is assumed to be that which would just satisfy the nutritional requirements of the existing cow numbers contained on those farms. The price of this quantity is assumed to be the 1979 average price received for all hay in Texas. This assumption is based on the fact that alfalfa hay production is limited in much of Texas. Since the hay price reported by the Texas Crop Reporting Service is for hay produced and sold in Texas, and since the average hay price appears to be weighted towards the price reported for non-alfalfa hay, the price of $53.50 per ton is assumed to be the base price. Shumway and Chang report the short-run supply elasticity for hay in Texas as being between .02 and .03. With these elasticities in mind, it is assumed that all of the hay grown in Texas could be purchased at the base price. Any hay from outside of the state would come in at a price higher than $53.50. The maximum price for hay is assumed to be asymptotic to the alfalfa hay price of $78.00 reported for Texas in 1979.

For example, the number of cows in the first Texas sub-group would require approximately 488 tons of hay. The 488 tons of hay required could be purchased at the $53.50 price. The average of the $53.50 non-alfalfa hay price and the $78.00 alfalfa hay price is $64.25. This is the maximum price charged for hay. Furthermore, it is assumed that a 10 percent change in price will result in a 10 percent change in quantity. The difference between the $53.50 base price and the average $64.25 price is $10.75. Ten percent of this difference is approximately $1.08 per ton. Therefore, the first increment in this supply schedule would be 537 tons of hay at $59.58 per ton. The supply schedules derived for Texas are given in Table XXXI in Appendix B.

Dairy farms in California, like those in Texas, purchase a large percentage of their forage needs. It is therefore necessary to include a hay supply function in the models used to generate the milk supply schedule for California farms. The hay supply schedules used for the California models are based on work done by Just. Just estimated the long run supply elasticity for alfalfa hay in California to be approximately .75. The starting price used in the schedules is the 1979 average price for alfalfa hay reported by the USDA. The quantity of alfalfa hay available at the base price is assumed to be the quantity that would just satisfy the nutritional requirements of the existing cow numbers on each representative California farm. The resulting supply schedules for the California models are continued in Table XXXII in Appendix B.

CHAPTER V

ANALYSIS AND RESULTS

Estimates of supply response are obtained by using linear programming to model a series of representative farms for each region. The solutions obtained for each representative farm are then aggregated to give regional estimates of supply response. The supply functions generated by this technique are stepped or discontinuous functions but are based upon the same marginal concepts as smooth supply functions. The results obtained are presented in this chapter.

Optimum Organization

In this analysis, each sub-group in a region is modeled and optimal quantities of milk at various milk price levels are found. The optimal organization of the farm changes as the prices change. Due to the nature of the aggregation procedure, it is impossible to present the regional optimal organization at price levels. However, Tables IX-XIV show the optimal farm organizations at selected prices for sub-groups in each region with the largest aggregation weights. From these tables, it is possible to see the effects of the price of milk in each region on items such as the number of dairy cows and crop mix. Two levels of milk prices presented here are: the lowest price at which milk is produced, approximately one dollar below the average 1979 milk price, the average 1979 milk price, approximately

TABLE IX

OPTIMAL FARM ORGANIZATIONS AT SPECIFIED MILK PRICE LEVELS, NORTHEAST SUB-GROUP 2

Activities	Units	Milk Price, per cwt				
		$5.15	$8.59	$12.88	$13.78	$19.39
Raise dairy replacements	head	8	17	20	28	83
Build parlor space						183
Build heifer space	stalls					2
Build hay storage	tons					22
Hired labor	hours			631	3123	18530
Sell cull calves	head	16	34	38	54	160
Sell cull cows	head	5	11	12	18	52
Number of cows	head	28	58	65	94	276
Purchase 16% concentrate	tons		114	164	343	1895
Corn silage	acres	9	18	20	49	
Corn grain	acres	69	12			
Feed corn grain	bushels	25	12			
Oat grain	acres					
Feed oat grain	bushels					
Alfalfa hay establishment	acres	5	12	14	10	17
Alfalfa hay 1-5 years	acres	31	74	83	58	100
Other hay establishment	acres	5	5	5	5	5
Other hay 1-5 years	acres	30	32	32	32	32
Sell land	acres	2				

TABLE X

OPTIMAL FARM ORGANIZATIONS AT SPECIFIED MILK PRICE LEVELS, CORN BELT SUB-GROUP 8

Activities	Units	Milk Price, per cwt				
		$8.85	$11.35	$11.95	$13.00	$19.58
Raise dairy replacements	head			20	28	96
Build cow space	stalls					86
Build parlor space						2
Build heifer space	stalls					26
Build silage storage						739
Build grain storage		9	9	77	113	464
Maximum hired labor	hours	771	771	3120	4052	11060
Sell cull calves	head			14	20	67
Sell cull cows	head			8	12	39
Number of cows				35	50	171
Purchase 16% concentrate	tons					
Corn silage	acres			50	72	234
Corn grain	acres			33	48	166
Feed corn grain	bushels			33	48	166
Soybeans		36	36	7		
Alfalfa hay establishment	acres					
Alfalfa hay 1-5 years	acres					
Other hay establishment	acres					3
Other hay 2-5 years	acres					18
Sell steer calves	head	728	728	618	561	
Buy steer calves	head	736	736	625	566	
Sell land	acres	21	21	21	21	

TABLE XI

OPTIMAL FARM ORGANIZATIONS AT SPECIFIED MILK PRICE LEVELS, LAKE STATES SUB-GROUP 11

Activities	Units	Milk Price, per cwt				
		$5.45	$10.74	$11.47	$12.93	$19.49
Raise dairy replacements	head		10	15	36	90
Build cow space	stalls					108
Build parlor space						2
Build silage storage						158
Build hay storage	tons			2	102	328
Build grain storage		78	70	112	267	201
Maximum hired labor	hours			1092	3722	12480
Sell cull calves	head		6	9	22	54
Sell cull cows	head		5	8	18	45
Number of cows	head		20	31	73	180
Purchase 16% concentrate	tons					658
Corn silage	acres				10	
Corn grain	acres		31	48	109	83
Feed corn grain	bushels		31	48	109	83
Soybeans		101				
Alfalfa hay establishment	acres		5	8	17	37
Alfalfa hay 1-5 years	acres		30	46	102	221
Fed steer calves	head	403	403	403	174	
Buy steer calves	head	407	407	407	176	
Sell land	acres		44	9	9	

TABLE XII

OPTIMAL FARM ORGANIZATIONS AT SPECIFIED MILK PRICE LEVELS, APPALACHIA SUB-GROUP 5

Activities	Units	Milk Price, per cwt				
		$5.60	$11.60	$12.20	$13.20	$18.80
Raise dairy replacements	head	8	58	58	74	429
Build cow space					31	757
Build parlor space			1	1		31
Build heifer space	stalls				2	355
Build silage storage			244	256	54	576
Build grain storage		183	127	125	89	
Maximum hired labor	hours		6240	6369	9360	69405
Sell cull calves	head	7	51	51	65	377
Sell cull cows	head	3	20	20	26	149
Number of cows	head	16	118	119	150	876
Purchase 16% concentrate	tons				5	6812
Purchase 24% concentrate			69	73	166	
Corn silage	acres	11	133	135	192	198
Corn grain	acres	20	80	80	65	
Feed corn grain	bushels	20	80	80	65	
Soybeans		226				
Alfalfa hay establishment	acres	2	2	2	2	1
Alfalfa hay 1-5 years	acres	14	14	14	14	7
Alfalfa hay 6-11 years	acres					7
Other hay establishment	acres		6	6		4
Other hay 1-5 years	acres		38	36		27
Other hay 6-11 years	acres					27

TABLE XIII

OPTIMAL FARM ORGANIZATIONS AT SPECIFIED MILK PRICE LEVELS, TEXAS SUB-GROUP 2

Activities	Units	Milk Price, per cwt				
		$9.40	$12.20	$13.40	$14.20	$20.00
Raise dairy replacements	head	52	80	122	164	12064
Build cow space				55	160	29912
Build parlor space			3	7	11	1201
Build heifer space	stalls					11859
Build hay storage			93		482	9262
Hired labor	hours		3120	9360	15600	178166
Sell cull calves	head	77	117	179	241	17795
Sell cull cows	head	29	44	67	90	6635
Number of cows	head	130	199	304	409	30160
Purchase 16% concentrate	tons	868	1329	2030	2630	273559
Purchase hay		241	370	565	760	9539
Other hay establishment	acres					7
Other hay 2-5 years	acres					41
Sell land	acres	48	48	48	48	

TABLE XIV

OPTIMAL FARM ORGANIZATIONS AT SPECIFIED MILK PRICE LEVELS, CALIFORNIA SUB-GROUP 1

Activities	Units	Milk Price, per cwt				
		$7.80	$10.20	$11.40	$12.20	$20.00
Raise dairy replacements	head	34	146	273	2116	5477
Build cow space	stalls			292	5559	15160
Build parlor space			1	15	226	610
Build heifer space	stalls				1778	5138
Build silage storage					133	148
Build hay storage				702	2698	5302
Maximum hired labor	hours		11710	24858	215737	566471
Sell cull calves	head	42	184	343	2661	6885
Sell cull cows	head	22	96	179	1391	3599
Number of cows	head	97	418	779	6047	15648
Purchase 16% concentrate	tons	626	2711	5053	47283	139048
Purchase hay		188	813	1515	2649	5328
Cotton		216	216	216		
Alfalfa hay establishment	acres				31	216
Alfalfa hay 1-5 years	acres				185	

one dollar above the average 1979 milk price and the highest price under $20.00 per hundredweight of milk at which milk is produced.

The Northeast region increases its herd size rather rapidly over the range of milk prices given in Table IX. Corn, as an alternative production possibility, is produced for sale only when the price of milk is at or below $5.15 per hundredweight. Above the $5.15 milk price, corn is no longer competitive with milk. At prices above the low price for milk shown here, there are only shifts in the acreages of crops used to feed dairy cattle. For example, when the milk price is $19.39 per hundredweight, the optimal organization is to buy more commercially mixed concentrates and to shift crop production from corn silage and hay production to all hay production.

The comparative advantage of the Corn Belt in the area of beef and soybean production is shown in Table X. In sub-group 8 of the Corn Belt, beef and soybeans are produced as an alternative to milk even when milk is priced at $13.00 per hundredweight. This explains the slow increase in the number of cows up to the $13.00 milk price. At some point above the $13.00 milk price, beef production is no longer competitive with milk, and the production pattern of this farm shifts out of beef production and into corn silage and corn grain which are fed to dairy cows.

The data presented in Table XI for sub-group 11 of the Lake States shows that soybeans and beef are produced at the low milk price of $5.45 per hundredweight. At a price of $10.74 per hundredweight of milk, soybeans are not in the solution but are replaced by milk production. At the $10.74 price of milk, beef production is not changed from the level found at the $5.45 milk price. Beef production in this sub-group begins to diminish at a milk price of $12.93 per hundredweight and is replaced by the milk producing activities. When milk prices reach a high of $19.49 per hundredweight, milk production is the sole activity of this particular representative farm.

Sub-group 5 of the Appalachian region (Table XII) exhibits a pattern of milk output response to increasing prices similar to the pattern displayed in the Northeastern region. In the Appalachian sub-group large acreages of soybeans are produced at the low milk price. As the milk price increases from $5.60 to $11.60 per hundredweight, soybeans become less competitive with milk, and at $11.60 per hundredweight for milk, soybeans are no longer produced. At prices above the $11.40 milk price, the land base for this sub-group is devoted entirely to producing crops used to feed dairy cows.

The data in Table XIII, presented as being representative of Texas, displays a pattern of farm organization dissimilar to any production patterns presented for other regions. Texas is somewhat different from the other regions examined in this study because the farms modeled have very few cropland acres. The optimal farm organizations for Texas sub-group 2 show that the maximal profit can be obtained by selling off the cropland acreage and by buying hay when milk prices are between $9.40 and $14.20 per hundredweight. At some price above $14.20 per hundredweight, maximum profit is attained by using the cropland to produce hay.

The crop land base of sub-group 1 of California (Table XIV) is used entirely in the production of cotton when milk prices are between $7.80 and $11.40 per hundredweight. Cow numbers are still quite sensitive to shifts in milk prices, however, since hay can be purchased. At a milk price above $11.40 per hundredweight, the land is shifted away from cotton production and into hay production. When this shift occurs, the number of cattle in the optimal farm organization increases significantly.

One of the significant differences among regions illustrated in the tables is the change in farm size as milk price levels increase. For example, when the milk price is between the average 1979 level and $20.00 per hundredweight, the number of cows increases approximately 4.2 times in the Northeast region. This is the smallest increase in cow numbers among regions. The region with the largest increase in cow numbers is Texas. The number of cows in Texas when milk is priced near $20.00 per hundredweight is approximately 99 times the number of cows in Texas when the milk price is at the 1979 level. It is beyond the scope of this study to say that the optimal farm structure would be 30 thousand cows in Texas when milk is $20.00 per hundredweight. Since there are many factors (e.g., management) involved in optimal farm structure that have been excluded in the models used in this study, the optimal farm organization at $20.00 milk price is probably very different from what is presented in these tables. It is however, reasonably safe to conclude from these results that farm size would increase and that the number of cattle in each region would increase if the price of milk were increased significantly above the 1979 levels.

Supply Schedules

The estimated supply schedules for each region are shown in Tables XV-XIX. The estimated supply functions for Appalachians, the Corn Belt, the Northeast, and the Lake States are plotted in Figure 3, and the

TABLE XV

ESTIMATED MILK SUPPLY SCHEDULE, NORTHEAST

Price ($/cwt)	Quantity (billions pounds)	Price ($/cwt)	Quantity (billions pounds)
5.00	6.2	15.14	40.1
5.10	7.1	15.20	41.1
5.11	10.1	15.33	43.2
5.24	11.6	15.40	45.0
5.31	12.1	15.80	46.1
5.37	13.8	15.99	48.7
5.46	14.0		
5.55	14.5	16.02	49.1
5.60	15.1	16.09	50.1
6.47	15.6	16.68	53.8
7.22	16.1	16.80	57.9
7.66	16.2		
		17.05	62.0
8.39	17.2	17.35	62.2
8.55	18.0	17.60	64.0
		17.69	68.9
9.04	18.5		
9.51	19.9	18.04	69.3
9.75	20.9	18.31	70.5
9.97	21.1	18.33	74.4
		18.71	75.1
10.64	23.1	18.78	77.1
		18.94	78.1
11.26	24.2	18.95	79.7
12.27	24.7	19.02	82.5
12.83	26.7	19.10	83.8
12.89	27.7	19.14	84.1
		19.39	86.7
13.07	31.5	19.54	87.8
13.14	32.2	19.59	89.6
13.69	33.5	19.60	90.0
13.81	34.1	19.65	93.7
14.35	35.7		
14.38	38.2		
14.58	39.2		

TABLE XVI

ESTIMATED MILK SUPPLY SCHEDULE, CORN BELT

Price ($/cwt)	Quantity (billions pounds)	Price ($/cwt)	Quantity (billions pounds)
6.40	1.0	14.00	20.9
6.60	1.4	14.20	20.9
6.80	1.5	14.40	24.4
		14.60	25.0
7.20	1.7	14.80	27.6
7.40	2.6		
7.60	3.3	15.00	28.9
7.80	3.4	15.20	30.0
		15.40	31.5
8.00	4.0	15.60	31.7
8.20	4.5	15.80	34.1
8.40	4.5		
8.60	4.6	16.00	34.3
8.80	5.7	16.20	35.1
		16.40	35.2
9.00	5.8	16.60	36.6
9.40	5.9	16.80	36.9
9.60	6.4		
		17.40	37.3
10.20	6.4	17.60	37.6
10.40	6.5		
10.60	6.7	18.00	38.3
10.80	6.7	18.40	39.5
		18.60	39.8
11.00	7.8	18.80	40.1
11.80	10.7		
		19.00	40.2
12.00	11.8	19.20	40.5
12.20	13.1	19.40	42.9
12.60	13.7	19.60	44.2
		19.80	44.3
13.00	15.4		
13.20	15.5		
13.40	15.9		
13.80	18.3		

TABLE XVII

ESTIMATED MILK SUPPLY SCHEDULE, LAKE STATES

Price ($/cwt)	Quantity (billions pounds)	Price ($/cwt)	Quantity (billions pounds)
5.00	3.1	13.00	42.6
5.20	3.6	13.20	42.6
5.80	8.0	13.40	43.5
		13.60	44.3
6.00	8.8	13.80	46.4
6.20	10.0		
6.40	10.8	14.00	47.5
6.60	10.8	14.20	50.7
		14.40	51.4
7.20	11.6	14.60	52.9
7.40	12.0		
7.60	12.0	15.00	53.1
7.80	13.9	15.20	53.4
		15.40	54.9
8.20	17.7	15.60	55.4
8.40	17.7	15.80	55.6
8.60	18.0		
8.80	18.4	16.00	57.3
		16.20	58.5
9.00	18.6	16.40	59.1
9.20	19.2	16.60	60.8
9.60	19.7	16.80	62.6
9.80	19.7		
		17.00	63.6
10.00	19.9	17.20	65.3
10.20	20.1	17.40	68.7
10.40	20.5	17.60	69.0
10.80	21.3	17.80	71.2
11.00	22.8	18.00	83.6
11.20	23.6	18.20	86.6
11.40	24.0	18.40	91.4
11.60	24.6	18.60	96.8
11.80	28.5		
		19.00	122.8
12.00	31.9	19.20	127.5
12.20	32.9	19.40	141.5
12.40	34.9	19.60	145.5
12.60	39.3	19.80	147.0
12.80	39.4		

TABLE XVIII

ESTIMATED MILK SUPPLY SCHEDULE, APPALACHIA

Price ($/cwt)	Quantity (billions pounds)	Price ($/cwt)	Quantity (billions pounds)
5.20	.6	14.00	15.0
5.40	.8	14.20	15.2
5.60	2.4	14.40	15.9
5.80	3.6	14.60	16.3
		14.80	17.0
6.00	3.7		
6.20	4.0	15.00	18.3
6.40	4.0	15.20	18.5
		15.40	18.6
7.00	4.1	15.60	18.8
		15.80	19.2
8.20	4.3		
8.40	4.5	16.00	20.2
8.80	5.1	16.20	21.2
		16.40	22.4
9.40	5.8	16.60	23.0
9.60	6.2	16.80	26.5
10.20	6.9	17.00	30.7
10.40	7.6	17.20	32.2
10.60	7.7	17.40	33.7
		17.60	34.2
11.00	8.3		
11.20	8.6	18.00	42.4
11.40	9.1	18.20	48.9
11.60	9.5	18.40	53.0
11.80	10.0	18.80	70.1
12.00	10.3	19.00	81.5
12.20	11.1	19.20	82.1
12.40	11.3	19.60	82.7
12.60	11.8	19.80	86.1
12.80	12.7		
13.00	13.4		
13.20	13.8		
13.40	13.8		
13.60	14.0		
13.80	14.4		

TABLE XIX

ESTIMATED MILK SUPPLY SCHEDULE, TEXAS

Price ($/cwt)	Quantity (billions pounds)
8.40	.8
8.60	1.1
9.40	1.7
9.60	1.8
10.40	2.0
11.20	2.2
11.40	2.3
11.80	2.5
12.20	2.8
12.40	3.1
12.60	3.6
13.00	3.9
13.40	4.5
13.60	4.8
13.80	5.0
14.00	14.0
14.20	20.3
14.60	21.2
14.80	43.0
15.00	43.4
15.40	65.2
15.80	104.3
16.20	178.1
17.00	251.9
19.80	266.1

estimated functions for California and Texas are plotted in Figure 4. The regional supply functions follow the same general patterns as the major sub-groups presented in Tables IX-XIV. The Appalachian, Lake States, and Northeast regions, for example, show substantial increases in milk production when milk prices increase from the low levels. The Corn Belt, on the other hand, exhibits a slower response to increases in the milk price when the milk price is between $5.00 and $10.00 per hundredweight. The Corn Belt is less responsive to price changes in this range due to the competitiveness of the non-dairy alternatives.

TABLE XX

ESTIMATED MILK SUPPLY SCHEDULE, CALIFORNIA

Price ($/cwt)	Quantity (billions pounds)
7.80	1.5
8.20	1.6
9.40	4.3
9.80	6.7
10.20	8.9
10.60	10.6
11.00	13.1
11.40	17.0
11.80	24.2
12.20	158.3
12.60	226.6
13.00	256.6
13.40	277.1
13.80	278.3
20.00	420.1

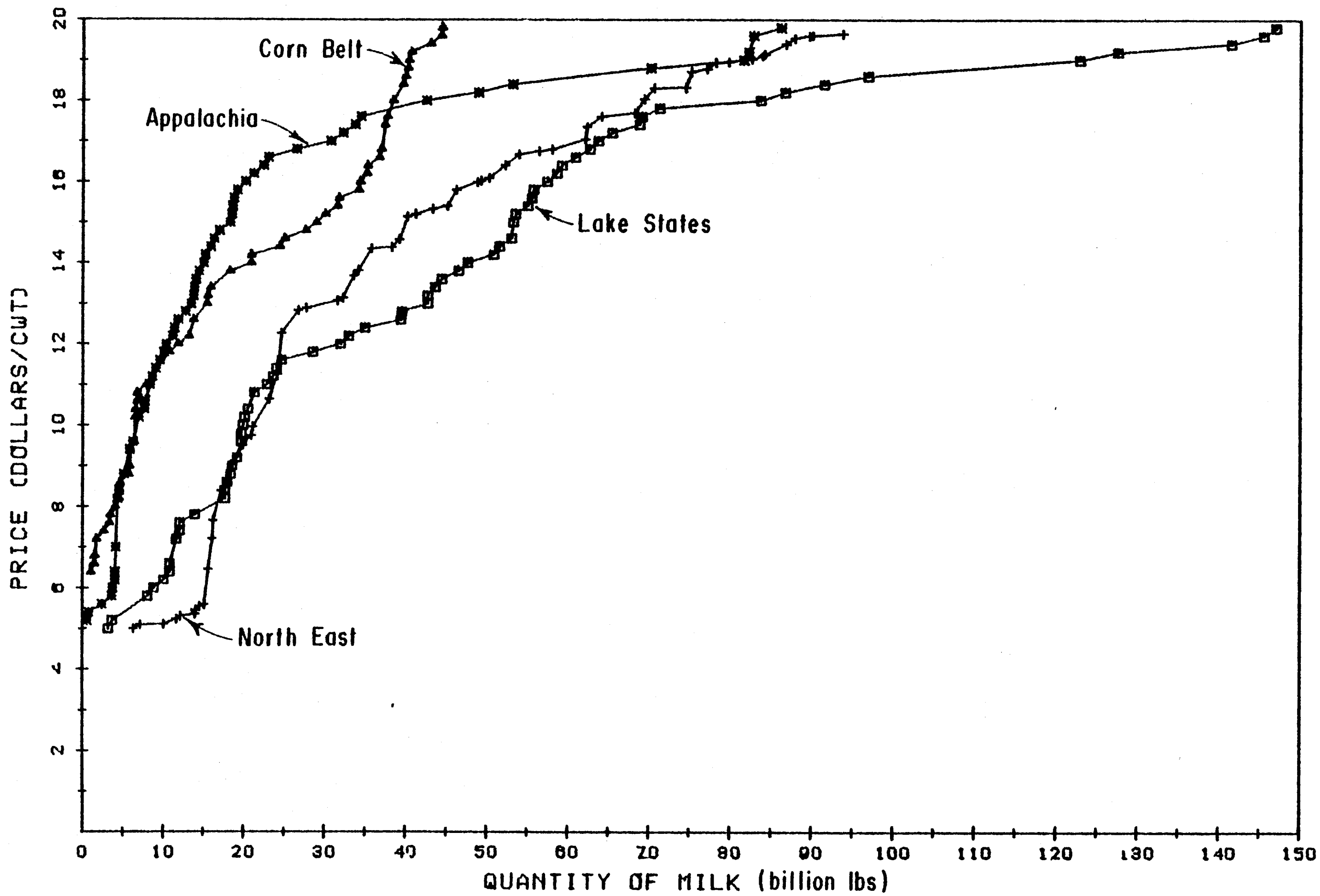

Figure 4. Estimated Supply Functions for the Northeast, Corn Belt, Appalachia, and Lake States Regions

As the price of milk approaches the actual 1979 average prices, the Appalachian and Northeast region supply functions (Figure 4) are not as responsive to price as they are at lower prices. The Corn Belt supply function is slightly more responsive to prices near the 1979 average milk price than it is at lower prices. Again, this is attributable to the increasing competitiveness of milk with the non-dairy alternatives at the higher milk prices. In the range of prices near the 1979 average prices, the Lake States' supply function becomes noticeably more responsive to price. This increased responsiveness can be attributed to the increased competitive position of milk in relation to the non-dairy alternatives.

At prices above the 1979 average milk price, the Appalachian, Lake States, Corn Belt, and Northeast regions are all increasingly responsive to changes in the milk price level. The Lake States and Northeast are noticeably more responsive than the Corn Belt and Appalachian regions at the higher milk prices. The supply function of the Corn Belt exhibits the same responsiveness of milk quantities to changes in the milk price that the Appalachian, Lake States, and Northeast regions exhibit, but at much higher milk prices. This is another indication of the presence of the non-dairy activities in the Corn Belt model.

The supply functions for Texas and California are shown in Figure 5. The supply function of California is highly responsive to price changes throughout the range of prices examined. At prices above the 1979 average milk price for California, the supply function is almost flat. The Texas supply function is not as responsive to price changes below the 1979 average milk price as the California function, but, like the California function, is relatively flat above the 1979

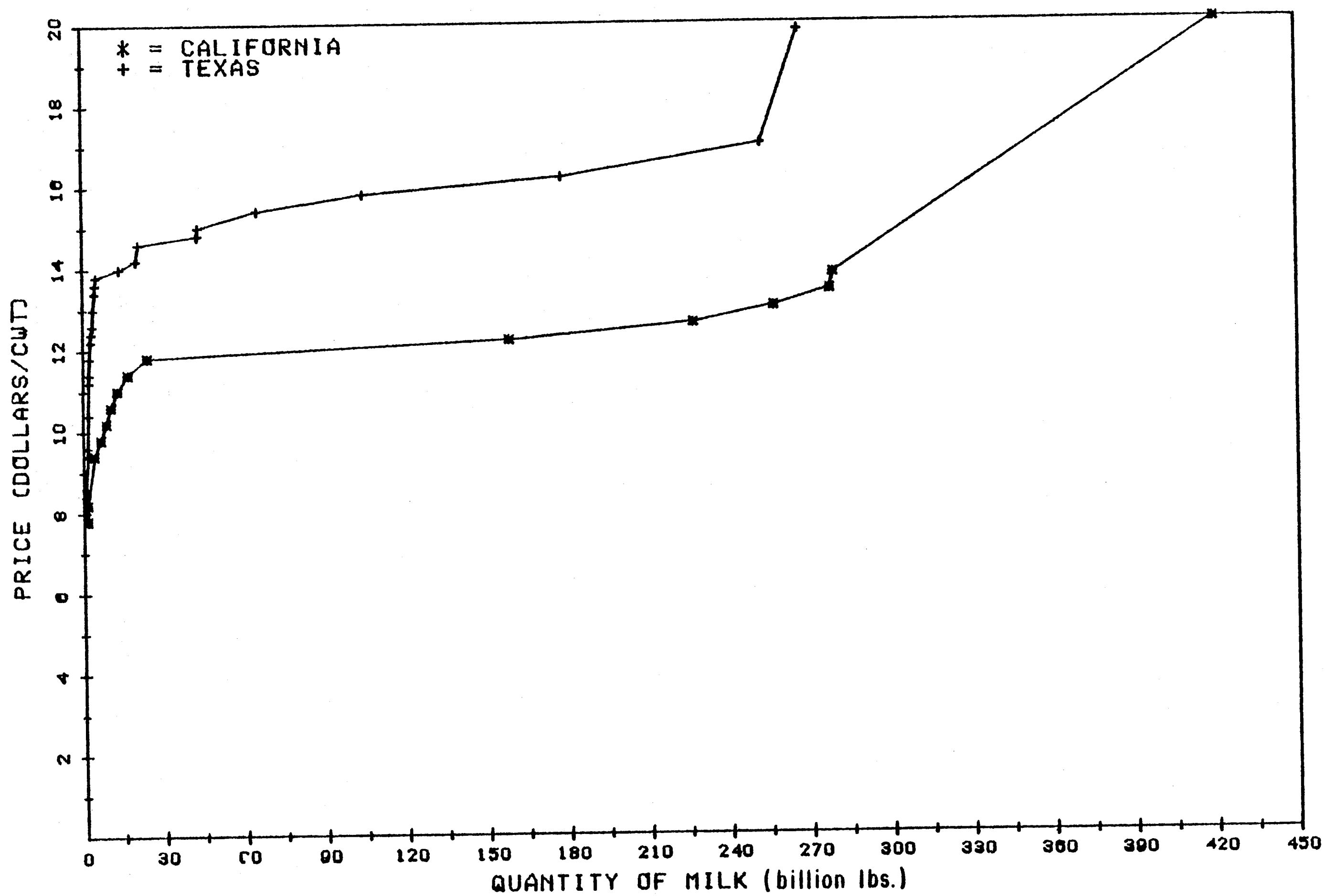

Figure 5. Estimated Supply Functions for California and Texas

price level. These two functions are different from the supply functions of the other four regions because of the presence of the purchase hay activities in the Texas and California models. This inclusion of the hay purchasing activities allows the Texas and California farms to expand at much faster rates than the remaining four regions.

Elasticities of Supply

Price elasticity of supply is the proportional change in quantity supplied divided by the proportional change in its own price. Because the supply functions generated by the methodology are actually a set of discrete points, point elasticities are not estimated. Instead, average or arc elasticities are calculated for each region. The calculated elasticities for each region are presented in Table XXI.

Three sets of elasticities are calculated. The first is for price changes between the actual 1979 average price for each region and one dollar below this price. The second is for prices in the range of 20 cents below to 20 cents above the 1979 actual prices. The final set of own price elasticities calculated are for prices with a range of the actual 1979 milk price to one dollar above this price.

The calculated elasticity for the Corn Belt are higher than those calculated for the Northeast and Lake States regions. These elasticities indicate that regions with more production alternatives to dairying will have higher own price elasticities for milk. The Corn Belt, as indicated by the calculated elasticities, has a larger comparative advantage in the non-dairy alternatives than do the Northeast and Lake States regions. The Northeast has the fewest alternatives to dairy production and thus has smaller own price elasticity estimates. While

TABLE XXI

OWN PRICE ELASTICITIES FOR MILK SUPPLY FOR ALL REGIONS
AT APPROXIMATELY $1.00 ABOVE THE ACTUAL 1979
MILK PRICE, $.20 ABOVE THE ACTUAL 1979
MILK PRICE, AND $1.00 BELOW THE
ACTUAL 1979 MILK PRICE

	Approximately $1.00 Below 1979 Milk Price		Approximately $.20 Above 1979 Milk Price		Approximately $1.00 Above 1979 Milk Price	
Region	Elasticity	Price Range ($/cwt)	Elasticity	Price Range ($/cwt)	Elasticity	Price Range ($/cwt)
Northeast	.64	(11.40-12.50)	.05	(12.50-12.80)	2.91	(12.50-13.50)
Corn Belt	4.50	(10.80-11.80)	5.61	(11.80-12.00)	4.34	(11.80-13.00)
Lake States	2.01	(10.80-11.60)	.936	(11.60-11.80)	4.72	(11.60-12.80)
Appalachia	2.94	(11.20-12.20)	4.24	(12.00-12.20)	2.71	(12.20-13.20)
Texas	4.08	(12.20-13.20)	.16	(13.00-13.20)	18.61	(13.20-14.20)
California	5.61	(10.60-11.40)	10.06	(11.40-11.80)	23.76	(11.49-12.60)

[a]Numbers in parentheses are the actual price ranges in which the elasticities were calculated.

the Appalachian region appears to have an elastic response to changes in the milk price, the elasticities, upon closer examination of the models, are not due to the non-dairy alternatives. The highly elastic response in the Appalachian regiona appears to be due to the large number of cropland acres per cow in the surveyed farms. Without these large acreages of cropland, the expansion of the dairy activities might not be possible and thus the elasticities of milk supply for the Appalachian region might be somewhat lower.

Because the milk supply functions of California and Texas, shown in Figure 5, appear to be quite different from those of the remaining four regions (Figure 4), one would expect the calculated elasticities to reflect the same differences. The elasticities for Texas and California show that milk response below the average 1979 levels is extremely elastic for both states. At prices above the 1979 average price levels, the calculated coefficients depict supply elasticity to be near infinity. While the nature of Texas and California dairy producing practices indicate the possibilities of more elastic functions than the other four regions, the response at the higher price levels for both Texas and California is suspect. It appears that factors which would limit dairy production in these areas have been neither recognized nor modeled in this analysis.

The elasticities estimated in this study tend to be somewhat higher than elasticities calculated in the studies shown in Table XXII. The long-run elasticities calculated by Hammond do not compare with any calculated in this study or in the other studies contained in the table. The calculated elasticities for the Northeast and Appalachian regions are similar for both this study and the Jackson study. The Lake States

TABLE XXII

SUMMARY OF ESTIMATED MILK SUPPLY ELASTICITIES

Authors	Estimating Technique	Region or State	Short-Run	Intermediate-run	Long-run
Chen, Courtney, and Schmitz	Regression	California	.29	--	2.52
Hammond	Regression	New England	.219	--	.359
		Mid Atlantic	.123	--	.258
		East North Central	.083	--	.152
		West North Central	.030	--	.101
		South Atlantic	.142	--	.227
		East South Central	.109	--	.299
		West South Central	.183	--	.285
		Mountain	.176	--	.236
		Pacific	.374	--	1.040
Jackson	Regression	Northeast	.2615	--	.804
		Corn Belt	.6440	--	1.9725
		Lake States	.1859	--	.7851
		Appalachia	1.3934	--	2.0309
		Southeast	1.5388	--	3.2551
		Delta	2.1722	--	3.3931
		Northern Plain	.4016	--	1.5650
		Southern Plain	1.1691	--	2.4245
		Mountain	.7827	--	1.4743
		Pacific	1.2067	--	1.3387
Lake States	Linear Programming	Lake States	--	3.16	--
Northeast Dairy Adjustment Committee	Linear Programming	Northeast	--	.78	--

and Corn Belt elasticities calculated in this study are larger than those in the Jackson study. The elasticity calculated for the Lake States region in this study is similar to the elasticity coefficient calculated in the Lake States study. The long-run elasticities calculated for the regions, including Texas and California, appear to be significantly higher in this study than those estimated in the other studies shown in Table XXII.

From these estimates of the own price elasticity of milk, it is clear that some wide discrepancies between the findings of the various studies exist. Obviously, one could achieve different results in an economic analysis of the dairy producing sector by using any one of the supply elasticities presented here. For example, if the impact of increasing the milk price is being assessed for the Corn Belt, the elasticities estimated by Hammond would lead to the conclusion that the increase would have little effect on the supply of milk. The elasticities from this study or from the Jackson study would lead researchers to far different conclusions.

Cross Price Elasticities

The cross price elasticities for the individual alternatives to milk production are given in Table XXIII. These data show that milk production in the Corn Belt and Lake States is more susceptible to changes in the prices of alternative agricultural products than in any of the other areas examined in this study.

For example, cross price elasticity of -2.305 indicates that milk production in the Corn Belt is very sensitive to changes in the beef price. The Lake States region also has a high cross price

TABLE XXIII

CROSS PRICE ELASTICITIES OF SELECTED INDIVIDUAL ALTERNATIVES TO MILK PRODUCTION BY REGION

Region	Beef	Hogs	Soybeans	Corn	Sorghum	Cotton
Northeast	NA	NA	NA	0.0	NA	NA
Corn Belt	-2.305	-.51	-.316	-.228	NA	NA
Lake States	-1.304	0.0	-1.51	-.304	NA	NA
Appalachia	0.0	-1.0176	-.56	-.19	NA	NA
Texas	0.0	NA	NA	NA	0.0	0.0
California	NA	NA	NA	0.0	NA	-.26

elasticity for beef, but milk production in this region is even more sensitive to changes in the price of soybeans. Changes in hog prices have greater impact on milk production in the Appalachian region than any of the other regions examined.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The dairy sector of the U.S. agricultural economy is increasingly subject to a wide range of exogenous forces. These forces originate in both the marketplace and in governmental policies and have the potential to create great changes in the economics of milk production. The existence of these exogenous forces and the magnitude of their possible impact on dairying make it desirable to have the ability to assess the extent to which these forces would change the supply of milk. Toward this end, many studies have been conducted in the past. Most of the previous studies, however, were conducted before 1975.

Estimation of regional own and cross price elasticities and making regional comparisons of the estimated elasticities are the main objectives of this study. Four geographic regions and two states (Northeast, Lake States, Corn Belt, Appalachian, Texas, and California) are examined in this analysis. These regions and states produce a major portion of the total milk produced in the United States. The elasticities obtained will provide economists a current basis from which to estimate the regional impact of the forces affecting the regional supply of milk.

This study uses the representative farm methodology to estimate the regional supply response of milk. Each region examined is stratified on the basis of homogeneous resource restrictions and a representative farm is modeled for each stratum. Supply schedules for each of the modeled farms are estimated using linear programming techniques. The individual supply schedules for strata in a region are then aggregated into regional supply schedules. Elasticities are calculated for the aggregated supply functions.

The own price elasticities indicate that for price changes ranging from the actual 1979 milk price to one dollar below this price, all regions except the Northeast are responsive to price changes. California had the highest elasticity (5.61) for this price range, while the Northeast (.64) had the lowest. The Corn Belt estimate (5.40) was very close to the estimate calculated for California.

The Northeast (.05), Lake States (.936), and Texas (.16) each showed inelastic supply response for price changes ranging from the 1979 actual price to 20 cents above the price. The other three regions had very elastic coefficients calculated, with California (10.06) again being the highest. The Corn Belt was once again the region with the second highest elasticity at 5.40.

Elasticities calculated for price changes ranging from the actual 1979 milk price to one dollar above this price show that all of the regions examined had elastic supply responses within this range. The elasticity estimates for Texas (18.61) and California (23.76) indicate that milk production in these two states is much more sensitive to price changes than it is in the other regions over the specified price range.

Cross price elasticities were estimated for the individual nondairy production alternatives for each region. The Northeast showed no milk supply response to changes in the corn price (the only non-dairy alternative in the Northeast). The non-dairy alternative with the largest impact on milk production in the Corn Belt was beef. The estimated cross price elasticity for beef in the Corn Belt was -2.305. Milk production in the Lake States is quite responsive to changes in the prices of both beef and soybeans. The cross price elasticities for beef and soybeans in the Lake States were -1.304 and -1.51, respectively. The Appalachian region is the only region examined in this study that showed a significant cross price relationship with hogs. With the exception of soybeans in the Lake States, none of the crop alternatives had much impact on milk production in any of the areas dealt with in this study.

Conclusions

Implications

Estimation of milk supply elasticities is not an end in itself. Generally, policy makers are more concerned with what the impacts of price changes might be for the entire economy of a region than on the supply response alone. The estimation of supply elasticities is, however, a necessary step in attaining this objective. The results obtained in this study indicate that there are very large differences in the regional response of milk production to changes in the milk price.

The estimated coefficients of elasticity obtained in this study show that the Northeast region is the least sensitive to changes in milk prices. The Northeast is less responsive to changes in the milk price due to the lack of any viable agricultural alternative to producing milk. The elasticity calculated at the high price range was somewhat more elastic than those calculated at the lower price ranges. This response is due to the ability, at these higher prices, of farms to move to more expensive production practices, such as buying more imported grains, which would increase milk production. Milk production in the Corn Belt is much more responsive to changes in the milk price than in the Lake States, but both regions have higher elasticities than the Northeast. In these two regions, the non-dairy alternative which has the largest impact on the milk supply is beef production. The high elasticities calculated for these two regions are due to the comparative advantage of the non-dairy alternatives over milk production.

The estimated elasticity coefficients for the Appalachian region show that milk production is quite sensitive to changes in the milk price for this region as well. However, upon close examination of the estimated cross price elasticities, it seems that there are no strong relationships between the non-dairy production alternatives and milk production. The high elasticities for the Appalachian region may exist because the farms surveyed have very large cropland bases. At low prices, this land was used in the models' sell land activities. As milk prices increased, the land was brought into uses associated with milk production.

Texas and California have the highest calculated own price elasticities of the four regions examined. These two regions possess an entirely different set of production limitations and potentials than the other regions. It is generally accepted that these two regions have greater capabilities for expanding dairy production than do the other areas included in this study. They would, therefore, be expected to be more responsive to changes in milk prices. The response estimated in this study may, however, be greater than can be realistically expected. The models used for these two regions imply an almost limitless growth potential for dairying when, in fact, there probably are some factors not included in the models which would limit the expansion of dairy farms in these regions.

Limitations

Most of the limitations of this study are related to the methodology used to estimate the regional supply functions. The linear programming procedure used assumes that each representative farm is operating in an identical environment void of risk and uncertainty and that the objective of each farm is to maximize profit. It is quite clear that this is not the case in the real world.

Another problem or limitation in the use of representative farms is the inability to handle interfirm transactions. This problem surfaces when trying to model the ability of buying and selling cattle and forages and the rental or purchase of additional land into representative firms within a region. The crux of the problem lies in the inability to balance sales and purchases within a region. Because of this limitation, only the Texas and California model included activities to purchase hay.

A third limitation inherent in any study that calculates macro estimates from micro estimates is aggregation error. Although the procedure used in this study is one that has been found to minimize the aggregation bias, it does not eliminate the problem.

The greatest fault with the linear programming methodology used in this study is that typically it will not predict current output levels. In some cases, it also does not come close to replicating the existing milk supply of the base year. Table XXIV gives the actual 1979 milk production and the estimated milk production that occurs at the 1979 average milk price by region. If a maximum of 20 percent error is used as a level of acceptability, only two regions would be considered as having accurate estimates. The Northeast and Texas had errors of 11.5 and 12.6 percent, respectively. The Corn Belt and Lake States are both under estimated by 31.4 percent, while Appalachian and California are over estimated by 41.8 and 35.8 percent, respectively. The results for the Corn Belt and Lake States suggest that the models used may be over constrained. The over estimations of supply for Appalachian and California suggests, on the other hand, that some constraints have not been included in the models that should have been.

Finally, all of the estimates calculated in this study are valid only in the context of the present milk price support program. This limitation is imposed on the findings presented here as the data base used to calculate these results was obtained under the price support system. Any researcher attempting to use the elasticities calculated in this study to estimate the impacts of price changes without the support system should be aware of this limitation.

Need for Further Study

The need for further investigation is evident in the area of production constraints. The ability of dairies in Texas and California

TABLE XXIV

ACTUAL AND ESTIMATED MILK PRODUCTION AT THE 1979
AVERAGE MILK PRICE BY REGION

Region	1979 Milk Price	1979 Actual Milk Production	Estimated Milk Production	Difference	
	Dollars per cwt	Million Pounds	Million Pounds	%	Million Pounds
Northeast	12.52	23,140	25,806	11.5	2,666
Corn Belt	11.89	15,527	10,741	-31.4	-4,876
Lake States	11.67	35,925	24,636	-31.4	-11,289
Appalachia	12.18	7,829	11,100	41.8	3,271
Texas	13.10	3,437	3,870	12.6	433
California	11.40	12,549	17,038	35.8	4,489

to expand needs further study. It is evident from the results of this study that there are limits to expansion in these regions that are not included in the models used here. Also, from the under estimation of the 1979 milk supply in the Lake States and the Corn Belt it appears that the models for these two regions were over constrained. Investigations in this area could lead to better models for the above regions and more accurate supply estimates.

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APPENDIXES

APPENDIX A

DELINEATION OF REPRESENTATIVE FARMS AND FARM ENTERPRISE DATA SYSTEM BUDGET LISTINGS

TABLE XXV

GROUP NUMBER FOR HOMOGENEOUS RESOURCE CLASSIFICATIONS OF DAIRY FARMS IN SIX U.S. REGIONS, 1979

Region and Acres per Cow	Average Stall Space per Cow		
	< 1.0	≥ 1.0 and < 1.5	≥ 1.5
		(Group Number)	
Northeast			
< 3	1	2	3
≥ 3 and < 4	4	5	6
≥ 4	7	8	9
Corn Belt			
< 3	1	2	3
≥ 3 and < 5	4	5	6
≥ 5	7	8	9
Lake States			
< 4	1	2	3
≥ 4 and < 5	4	5	6
≥ 5 and < 6	7	8	9
≥ 6	10	11	12
Appalachia			
< 2	1	2	3
≥ 2 and < 3	4	5	6
≥ 3 and < 4	7	8	9
≥ 4	10	11	12
Texas			
< 1	1	2[a]	
≥ 1	3	4[a]	
California			
none		1[b]	2

[a]Restriction is ≥ 1 stall per cow.

[b]Restriction is < 1.5 stalls per cow.

TABLE XXVI

FIRM ENTERPRISE DATA SYSTEM ACTIVITY AND FILE NUMBER FOR ACTIVITIES IN EACH REGION

Region and Activity	File Number
Northeast	
Corn for Grain	101
Corn for SIlage	94
Oats	103
Alfalfa	76
Other Hay	77
Corn Belt	
Finishing	368,569
Cow-Calf	133
Farrow-Finish	502,503
Corn for Grain	366
Corn for Silage	367
Oats	368
Soybeans	369
Winter Wheat	370
Other Hay	371
Alfalfa	365
Lake States	
Corn for Grain	300
Corn for Silage	236
Oats	210
Spring Wheat	212
Soybeans	211
Alfalfa	240
Other Hay	239
Farrow-Finish	502,503
Cow-Calf	133
Finishing	568,569

TABLE XXVI (Continued)

Region and Activity	File Number
Appalachia	
Corn for Grain	609
Corn for Silage	610
Soybeans	606
Winter Wheat	637
Alfalfa	603
Other Hay	
Texas	
Cow-Calf	278
Cotton	1080
Winter Wheat	1068
Grain Sorghum	1082
Coastal Bermuda Grass	1094
California	
Corn for Silage	1433
Corn for Grain	1353
Winter Wheat	1358
Cotton	1363
Alfalfa	1352

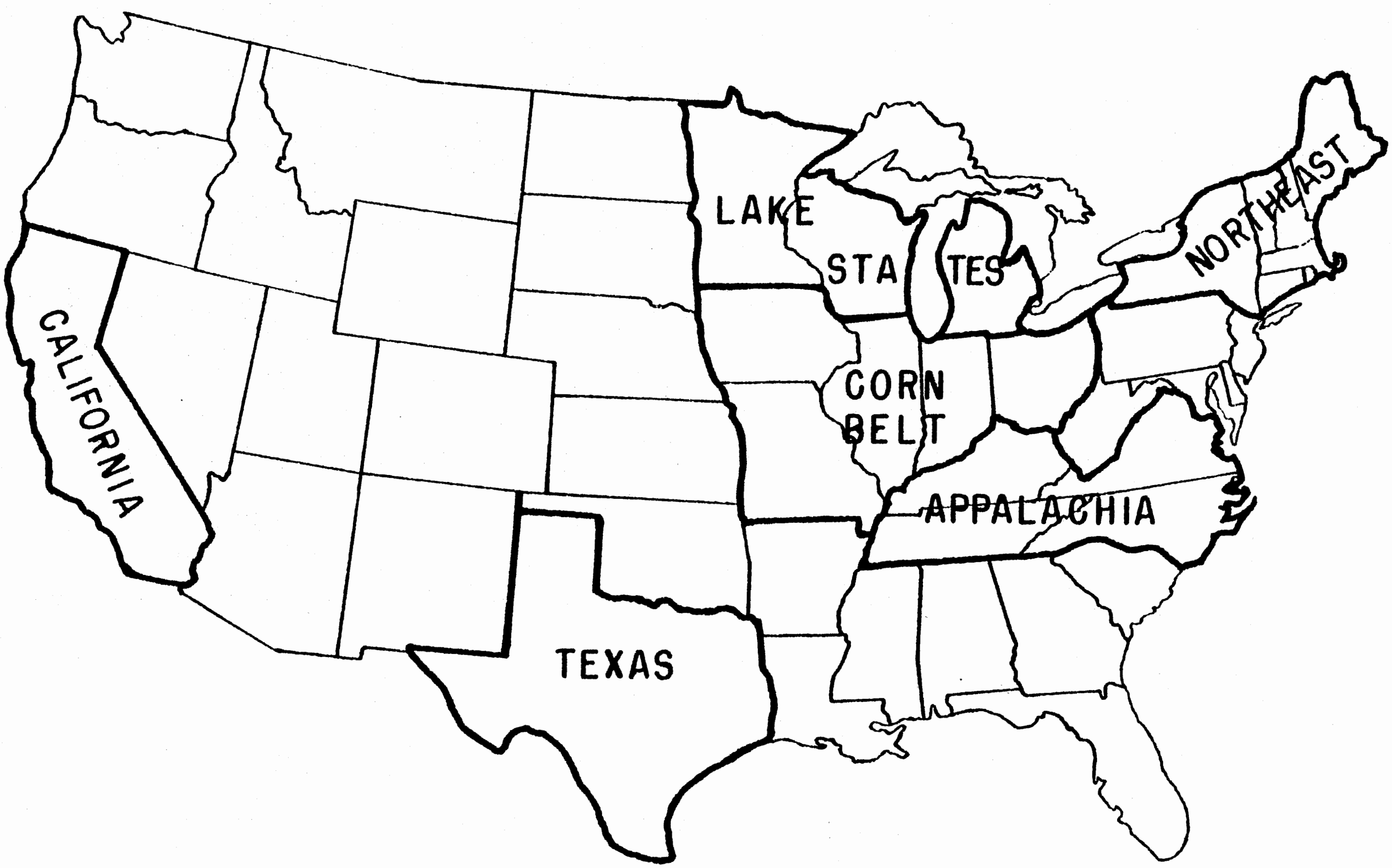

Figure 6. Major Dairy Producing Regions of the United States

APPENDIX B

ASSUMPTIONS AND DERIVATION OF COEFFICIENTS USED IN REGIONAL MODELS

TABLE XXVII

COST VALUES USED WITH BUILDING ACTIVITIES

The c_j values or variable costs consist of a basic cost component and the amortized value of the capital investment. The basic cost is the cost of taxes, depreciation, insurance, and repairs. These costs are estimated as six percent of the purchase price of the activity.

The interest rate used to amortize the capital investment for each activity is the simple average of the 1979 Federal Land Bank rate and the 1979 PCA rate. Regional interest rates are on the FLB and PCA district rates and are as follows:

Region	District	Interest Rate
Northeast	Springfield	9.225
Corn Belt	Louisville	9.945
Lake States	St. Paul	9.62
Appalachia	Louisville	9.945
Southwest	Houston	9.506
West	Sacramento	9.746

The assumed years of life are as follows:

Cattle and heifer housing	20 years
Hay barn	20 years
Bunker silo	15 years
Milking parlor	15 years
Grain storage	15 years

TABLE XXVIII

CAPITAL VALUES

The capital requirements are based on data taken from two studies conducted in Minnesota (Groble, 1980) and Washington (Washington State University, 1979). The following are the capital requirements used for each of the build facilities activities in the model:

Build Cow Space: Data from the Minnesota study. Assumed cost to add on cow space to existing buildings is:
Capital required per cow: $500.00

Build Bunker Silo: Data from the Washington State study. Assumed cost of building (40'x108'x10') is $19,180.00. Assumed tons of silage per cubic foot - .0128. Cost is:
Capital required per ton of silage: $176.00

Build Hay Barn: Data from the Washington State study. Assumed cost of building a 16'x20'x70' structure is $3,304.00. Assumed $2.36 building costs per square foot. Assumed 485 cubic feet per ton of alfalfa hay. Cost is:
Capital required per ton of hay: $71.53

Build Heifer Housing: Data from the Minnesota study. Assume a pole shed with feed bunk. Capital requirements from conventional free stall structure and addition to concrete lot is:
Capital required per heifer: $433.00

Build Grain Bin: Data based on cost estimates from private manufacturers and conversations with Charles Michael, USDA economist stationed at OSU. Bin costs assumed to be $1.25 per bushel with corn as average weight (56 lbs/bushel). Cost is:
Capital required per ton of grain: $44.64

Build Milking Parlor: Data based on personal interview with Oklahoma City AMPI warehousemen. Cost breakdown for a milking parlor is:

Fixed cost	$8,000.00
Cost per stall	$1,500.00
Cost per unit	$ 340.00

The build parlor activity is assumed to be an addition to and existing structure. The addition is in two-stall increments. The two stalls are assumed to be sufficient to milk an additional 25 cows.

Parlor capacities taken from manufacturers' specifications are:

Incline 3 stall parlor	30 cow maximum
Double 3 stall parlor	100 cows
Double 4 stall parlor	120 cows
Double 5 stall parlor	130 cows

Costs are:

Capital requirements for a 2 stall unit: $4,860.00

TABLE XXIX

REGIONAL MINIMUM AND MAXIMUM WAGE RATES AND THE IMPLIED ANNUAL INCOMES

Region	Principle State	Minimum Hourly Wage Rate	Maximum Hourly Wage Rate	Implied Annual Income[a]
Northeast	(NY)	6.08	12.63	39,405
Corn Belt	(OH)	7.29	11.80	40,809
Lake States	(WI)	6.69	11.63	40,216
Appalachia	(KY)	4.47	9.64	33,321
Texas	(TX)	5.88	10.83	39,936
California	(CA)	6.43	11.55	37,440

[a]Based on the maximum hourly wage rate and an assumed 60 hour work week.

TABLE XXX

LAND VALUES, AGRICULTURAL WAGE RATES, AND OPERATOR LABOR HOURS USED TO CALCULATE THE OBJECTIVE FUNCTION FOR SELL-LAND ACTIVITY

Region	Land Value per Acre (dol.)	Agricultural Wage Rate ($ per hr.)	Operator Labor (hours)
Northeast	642	3.06	3120
Corn Belt	1516	3.74	3120
Lake States	807	2.96	3120
Appalachia	792	3.21	3120
Southwest	354	3.23	3120
West	936	4.32	3120

TABLE XXXI

ALFALFA HAY SUPPLY SCHEDULES FOR TEXAS REPRESENTATIVE FARMS

Price ($ per ton)	Representative Farm Group 1	2	3	4
	quantity (tons)			
53.5	488	658	465	395
54.6	537	724	512	434
55.7	585	789	558	474
56.7	634	855	605	514
57.8	683	921	652	553
58.9	732	987	698	592
69.0	781	1053	744	632
61.0	830	1118	791	672
63.2	878	1184	838	711
64.3	927	1250	884	751

TABLE XXXII

ALFALFA HAY SUPPLY SCHEDULES FOR CALIFORNIA REPRESENTATIVE FARMS

Price ($ per ton)	Representative Farm Group 1	2
	quantity (tons)	
85	1515	1330
102	1742	1530
122.4	2003	1759
146.9	2304	2023
176.2	2650	2326
211.5	3047	2675
253.8	3504	3076
304.6	4030	3538
365.5	4634	4068
438.2	5329	4679

APPENDIX C

GRAPHICAL REPRESENTATION OF LINEAR PROGRAMMING MODELS AND DESCRIPTION OF MODEL ACTIVITIES

TABLE XXXIII

ACTIVITIES IN MODELS

Activity	Description	Units
RAISEREP	Transfer activity for dairy replacements	
BLD-COW	Build additional cow space	(Head)
BLD-PARL	Build additional milking parlor space	(2 Stall units)
BLD-BNKR	Build additional bunker silo capacity	(Tons dry matter)
BLD-HAY	Build additional hay storage capacity	(Tons dry matter)
BUILDHEF	Build additional heifer space	(Head)
BLDGRAN	Build additional grain storage capacity	(Tons dry matter)
BUYLAB1	Buy an additional man equivalent of labor	(Hours)
BUYLAB2	"	
BUYLAB3	"	
BUYLAB4	"	
BUYLAB5	"	
BUYLAB6	"	
BUYLAB7	"	
BUY-FUEL	Buy gasoline	(Gallons)
BUY-CONC	Buy 16% concentrate for dairy replacements	(Tons)
BUYHAY1 (Cal-Tex)	Buy additional hay for dairy cows	(Tons)
BUYHAY2	"	
BUYHAY3	"	
BUYHAY4	"	
BUYHAY5	"	
BUYHAY6	"	
BUYHAY7	"	
BUYHAY8	"	
BUYHAY9	"	
BUYHAY10	"	
FDPURHAY (Cal-Tex)	Feed purchased hay to dairy cows	(Tons)

TABLE XXXIII (Continued)

Activity	Description	Units
FEDCORN	Feed raised corn grain to dairy cows	(Acres)
FEDOATS	Feed raised oat grain to dairy cows	(Acres)
SELLMILK	Sell produced milk	(Cwts)
SELLCULL	Sell cull calves	(Head)
SELCULCW	Sell cull cows	(Head)
MP-___._	Dairy cow activity; blanks=production in cwts	(Head)
GRAIN16%	16% commercially mixed dairy concentrate	(Tons)
GRAIN20%	20% commercially mixed dairy concentrate	(Tons)
GRAIN24%	24% commercially mixed dairy concentrate	(Tons)
CORNSILG	Raised corn silage activity	(Acres)
CORNGRAN	Raised corn grain activity	(Acres)
OATGRAN	Raised oat grain activity	(Acres)
SOYBEANS	Raised soybean activity	(Acres)
SELSOYBN	Sell raised soybeans	(Bushels)
SORGGRAN	Raised grain sorghum	(Acres)
COTTON	Raised cotton	(Acres)
SELCLINT	Sell cotton lint	(Pounds)
SELCSEED	Sell cotton seed	(Pounds)
ALFHAYES	Alfalfa hay establishment activity	(Acres)
ALFH1-5	Alfalfa hay 1-5 year rotation activity	(Acres)
ALFH6-11	Alfalfa hay 6-11 year rotation activity	(Acres)
OTHAYES	Other hay establishment activity	(Acres)
OTHY1-5	Other hay 1-5 year rotation activity	(Acres)
OTHY6-11	Other hay 6-11 year rotation activity	(Acres)
SPRWHEAT	Raised spring wheat activity	(Acres)
WTRWHEAT	Raised winter wheat activity	(Acres)
SELCRNGR	Sell raised corn grain	(Bushels)
SELOATGR	Sell raised oat grain	(Bushels)
SELWHEAT	Sell raised wheat grain	(Bushels)

TABLE XXXIII (Continued)

Activity	Description	Units
SELSORG	Sell raised grain sorghum	(Bushels)
PURSOW	Purchase sows	(Head)
FARFINGH	Farrow to finish activity	(Head)
SELCLSOW	Sell cull sows	(Head)
SELSLHOG	Sell slaughter hogs	(Head)
VUILDHOG	Build hog facilities	(Head)
BUYSBOM	Buy soybean meal	(Cwt)
20% PROHG	Buy 20% protein mix for hogs	(Cwt)
CONMIXHG	Buy concentrate mix for hogs	(Cwt)
BUYBFCOW	Buy beef cows	(Bushels)
COWCALF	Cow-calf activity	(Bushels)
SELBFCUL	Sell beef cull cow	(Bushels)
SELSTRCU	Sell steer calves	(Head)
SELHFRCU	Sell heifer calves	(Head)
BYSTRCF	Buy steer calves	(Head)
BYHFRCV	Buy heifer calves	(Head)
FEDHFRCU	Feed heifer calves	(Head)
FEDSTRCU	Feed steer calves	(Head)
SELSLHEF	Sell slaughter heifers	(Head)
SELSLSTR	Sell slaughter steers	(Head)
TRNLNDA	Transfer type A land to sell	(Acres)
TRNLNDC	Transfer type C land to sell	(Acres)
SELLLAND	Sell land	(Acres)

TABLE XXXIV

RESTRICTIONS USED IN MODELS

Restriction	Sign	Description	Units
COWS	≥	Accounting row number of dairy cows	(Head)
CULL-CUS	≤	Dairy cull calves transfer	(Head)
REPL-REQ	≤	Dairy raised replacements transfer	(Head)
MILK-PRD	≤	Milk production	(Cwts)
DM-MIN	≤	Minimum dry matter requirements dairy cattle	(Tons)
DM-MAX	≤	Maximum dry matter requirements dairy cattle	(Tons)
NE-L-MIN	≤	Minimum net energy lactation - dairy cattle	(Meal)
CP-MIN	≤	Minimum crude protein requirements dairy cattle	(Tons)
CF-MIN	≤	Minimum crude fiber requirements dairy cattle	(Tons)
CF-MAX	≤	Maximum crude fiber requirements dairy cattle	(Tons)
REP-GRAI	≤	Required grain for dairy replacements	(Tons)
LABOR	≤	Minimum labor requirements livestock and crops	(Hours)
MAXLAB1	≤	Maximum labor available increment 1 (BUYLAB1)	(Hours)
MAXLAB2	≤	Maximum labor available increment 2 (BUYLAB2)	(Hours)
MAXLAB3	≤	Maximum labor available increment 3 (BUYLAB3)	(Hours)
MAXLAB4	≤	Maximum labor available increment 4 (BUYLAB4)	(Hours)
MAXLAB5	≤	Maximum labor available increment 5 (BUYLAB5)	(Hours)
MAXLAB6	≤	Maximum labor available increment 6 (BUYLAB6)	(Hours)
MAXHIRLB	≥	Accounting row hours of labor used	(Hours)
FUEL	≤	Fuel requirements livestock and crops	(Gallons)
CORN-MAX	≤	Maximum land for corn or grain activities	(Acres)

TABLE XXXIV (Continued)

Restriction	Sign	Description	Units
LAND-A	≤	Maximum land for grain and alfalfa activities	(Acres)
LAND C	≤	Maximum land for other hay activities	(Acres)
TRNSLLND	≤	Transfer row for SELLLAND activity	(Acres)
STALL-SP	≤	Maximum stall space - dairy cows	(Head)
MAXPRLCP	≤	Maximum milking parlor capacity	(Head)
HAY-STOR	≤	Maximum hay storage capacity	(Tons Dry Matter)
GRANSTOR	≤	Maximum grain storage capacity	(Tons Dry Matter)
CAPITAL	≥	Accounting row for capital requirements	(Dollars)
MAXHEFSP	≤	Maximum heifer space (dairy)	(Head)
MAXCULCW	≤	Dairy cull cows trainsfer	(Head)
TRNCORN	≤	Transfer corn grain	(Bushels)
TRNOATS	≤	Transfer oat grain	(Bushels)
TRNSOYBN	≤	Transfer soybeans	(Bushels)
TRNSORG	≤	Transfer grain sorghum	(Bushels)
TRNWHEAT	≤	Transfer wheat grain	(Bushels)
TRNHAY	≤	Transfer purchased hay	(Tons)
MAXH1	≤	Maximum purchased hay increment 1 (BUYHAY1)	(Tons)
MAXH2	≤	Maximum purchased hay increment 2 (BUYHAY2)	(Tons)
MAXH3	≤	Maximum purchased hay increment 3 (BUYHAY3)	(Tons)
MAXH4	≤	Maximum purchased hay increment 4 (BUYHAY4)	(Tons)
MAXH5	≤	Maximum purchased hay increment 5 (BUYHAY5)	(Tons)
MAXH6	≤	Maximum purchased hay increment 6 (BUYHAY6)	(Tons)
MAXH7	≤	Maximum purchased hay increment 7 (BUYHAY7)	(Tons)
MAXH8	≤	Maximum purchased hay increment 8 (BUYHAY8)	(Tons)

TABLE XXXIV (Continued)

Restriction	Sign	Description	Units
MAXH9	≤	Maximum purchased hay increment 9 (BUYHAY9)	(Tons)
MAXH10	≤	Maximum purchased hay increment 10 (BUYHAY10)	(Tons)
TOTHAY	≥	Accounting row total purchased hay	(Tons)
TRNCLINT	≤	Transfer cotton lint	(Pounds)
TRNCSEED	≤	Transfer cotton seed	(Pounds)
TRNSOW	≤	Transfer sow	(Head)
TRNCLSOW	≤	Transfer cull cow	(Head)
TRNSLHOG	≤	Transfer slaughter hog	(Head)
MAXHOGCP	≤	Maximum hog capacity	(Head)
MINPROHG	≤	Minimum protein supplement for hogs	(Cwts)
MINCONHG	≤	Minimum concentrate mix for hogs	(Cwts)
MINSBOM	≤	Minimum soybean meal for hogs	(Cwts)
TRNCOWS	≤	Transfer beef cows	(Head)
TRNBFCUL	≤	Transfer beef cull cows	(Head)
TRNSTRCU	≤	Transfer steer calves	(Head)
TRNHFRCU	≤	Transfer heifer calves	(Head)
TRNSLSTR	≤	Transfer slaughter steers	(Head)
TRNSLHEF	≤	Transfer slaughter heifers	(Head)
TRAN021	≤	Transfer alfalfa ALFHAYES to ALFH1-5	(Acres)
TRAN022	≤	Transfer alfalfa ALFH1-5 to ALFH6-11	(Acres)
TRAN024	≤	Transfer other hay OTHAYES to OTHY1-5	(Acres)
TRAN025	≤	Transfer other hay OTHY1-5 to OTHY6-11	(Acres)

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