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THE SUPPLY OF FLUID MILK IN THE DETROIT MILKSHED AS AFFECTED BY COST OF PRODUCTION

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PREFACE

The research reported herein was carried out by George E. Schuh, graduate assistant. It fulfills his obligations to the Michigan Agricultural Experiment Station as a graduate assistant and to the Graduate School, Michigan State University, for thesis research toward a Master of Science degree.

Glenn L. Johnson supervised both the Experiment Station research under Project 442, Michigan Agricultural Experiment Station, and the thesis research. After completion of the thesis, the work was completely redrafted by Schuh to bring it into more proper form as a Technical Bulletin. At this point, Schuh was inducted into military service. Subsequent drafts of the manuscript, chart preparation, and clearance procedures were carried out by Johnson who bears partial responsibility for the manuscript as project supervisor and its redrafter.

The Supply of Fluid Milk in the Detroit Milkshed As Affected by Cost of Production

By George E. Schuh

INTRODUCTION

A MAXIMUM NATIONAL PRODUCT is forthcoming from given resources only as mobile resources, such as labor and capital, are applied to immobile resources, such as land, in a geographic pattern which allows the greatest economic product to each unit of mobile resources. This involves as a first approximation the use of labor and capital so that equal returns are secured from the last unit of each resource used in each part of all businesses.

This study was undertaken as one step in attaining such use of resources in the farm economy. The need for regional supply and/or cost functions arises from the great dissimilarity in the distribution of resources, both human and physical, among the regions of this country. National use can be improved when supply responses are known for areas fairly homogenous with respect to the quantity, quality, and use of resources.

Underlying the major problem of maximizing gross national product through the optimum allocation of resources is the individual farmer. One of his most important questions is, "Which line of production will yield the largest returns to his resources and management?" A knowledge of supply responses for commodities in his locality, combined with a knowledge of expected returns for the products he contemplates producing, enables him to better answer this question.

The agricultural sector of the economy has adopted several more or less restrictive institutional arrangements in recent decades. With more specific reference to the problem at hand, we have Federal milk marketing orders, price support programs, and health regulations. More knowledge of the supply responses of fluid milk to changing prices make possible a more efficient operation of these institutional arrangements.

World War II further emphasized the need for knowledge of regional supply responses. In times of national emergency, food output increases in relative importance.

Two groups of estimates will be developed in this study. *First,* cost curves for typical dairy farms in the Detroit milkshed will be developed. Materials so developed will be used in analyzing costs at the farm. *Second,* information about costs at the farm will be used to develop a supply curve for the Detroit market area. This supply curve will be useful in regional and national analyses.

PROCEDURE

The technique used in this analysis is essentially an extension of a technique developed by Wells (25) and Johnson at the University of Kentucky. Their technique of developing cost of production data for dairy enterprises included the development of both a marginal and an average variable cost curve for the enterprise.

Traditional theory indicates that the portion of the marginal cost curve above the average variable cost curve is the short-run supply curve for the enterprise. Summation of the supply curves for separate farms yields an industry supply curve, assuming that input prices are not dependent on the amount of milk produced.

The present study *first* develops marginal and average variable cost curves for representative enterprises and *then* aggregates them into a supply curve for all fluid milk producers in the Detroit milkshed for the year running from October 1, 1951 to September 30, 1952. A procedure is also developed for adjusting this curve for different conditions existing in other years.

SOME ANALYTICAL PROBLEMS

Supply as it depends on the marginal cost of production. Ignoring dynamic considerations, the individual farm operator seeking to maximize profits undertakes further production so long as the revenue from additional output exceeds the cost of securing that output. The profit-maximizing farm operator expands production until marginal cost equals the price of the product. The marginal cost curve for a profit-maximizing farm is its short-run supply curve as it indicates how the operator adjusts production to changes in the price of his product in order to maximize profits.

Fig. 1 is a typical marginal cost curve in the short run. It is U-shaped because it is based on production relationships which reflect the law of diminishing returns.[1]

[1]Given a group of fixed factors, and applying a variable input to this bundle of fixed factors, output will increase first at an increasing rate, then at a decreasing rate; finally, total output will decrease with the addition of further units of the variable factor. This is the traditional law of diminishing returns and applies to any production process where at least some of the inputs are fixed for the firm.

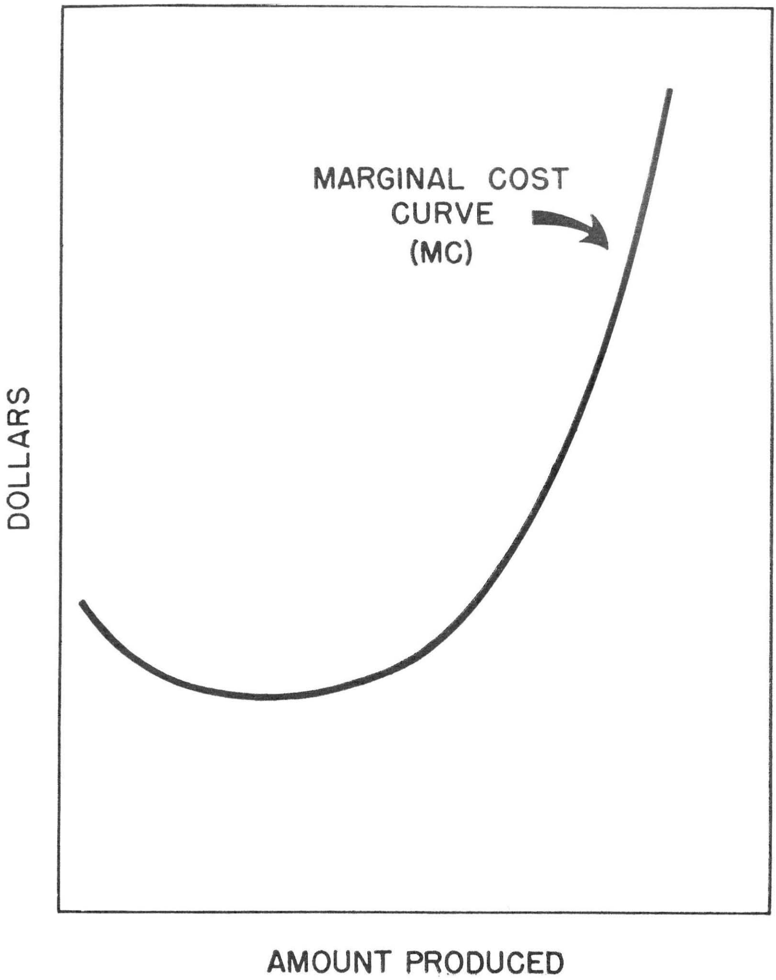


Fig. 1. A typical short-run marginal cost curve.

The increase in output resulting from each additional unit of a variable input is known as the marginal physical product. As output increases at an increasing rate, marginal physical product also increases; but when output increases at a decreasing rate, marginal physical product decreases. After the point of a maximum output is reached and output decreases with addition of further units of the variable factors, the marginal physical product curve is less than zero. A typical total physical product curve and its corresponding marginal physical product curve are given in Fig. 2.

Previously, marginal cost was defined as the additional cost necessary to secure an additional unit of output. Alternatively, it is marginal factor cost divided by marginal physical product, $\frac{\text{MFC}}{\text{MPP}}$. As marginal physical products fall off toward zero, marginal cost becomes infinitely large. This definition makes it obvious that the marginal cost curve is U-shaped if the law of diminishing returns holds.

Decision-making with respect to planning spans and lengths of run. Production decisions made in operating a farm business are made with respect to inputs which are controllable or variable. Some inputs

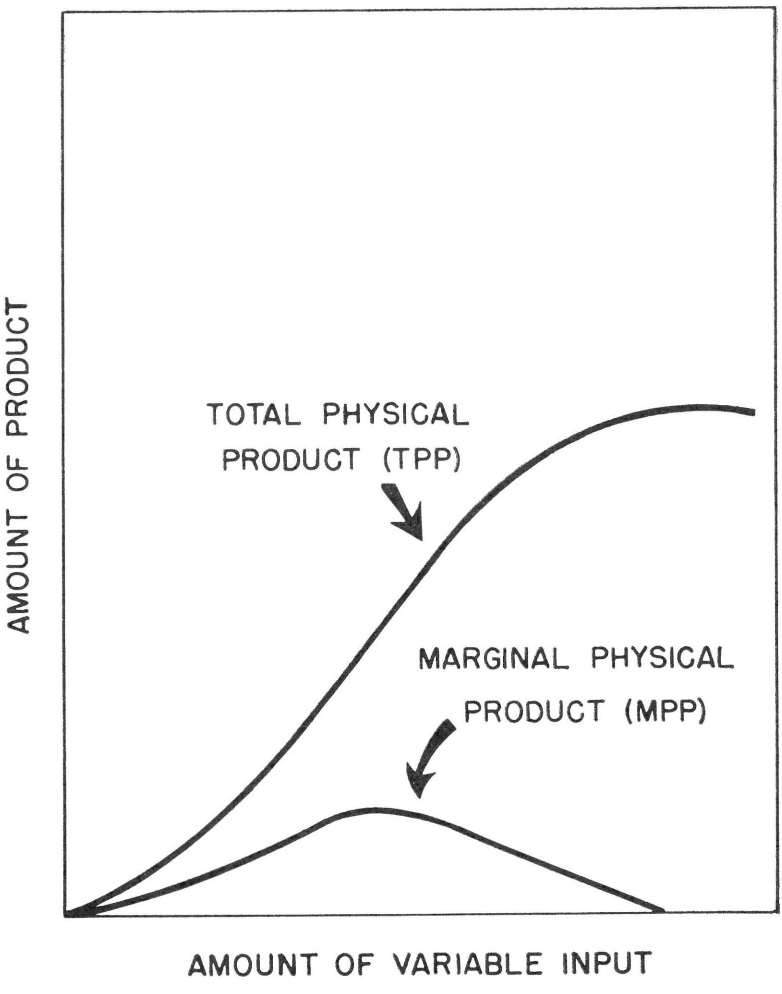


Fig. 2. Typical total and marginal physical product curve.

are varied from day to day, others from week to week, month to month, or year to year. All become variable if sufficient profits can be made by varying them; any of them remain fixed if it is unprofitable to vary them.

Typically, three planning spans or lengths of run are encountered for the dairy enterprise. The *short run* is that planning span in which most of the factors of production are fixed. The level at which the cows are fed and the combinations in which roughage and concentrates are fed are variable. In addition, certain other minor inputs and small portions of other inputs associated with the feeding level are variable. All other factors of production are fixed.

In a somewhat longer length of run or more inclusive planning span, the dairyman varies some of the factors fixed in the short run. This planning span is called the *intermediate length of run.* Within this span, the dairyman increases or decreases the size and quality of the herd by changing the breeding program or by purchasing and selling cows. Certain portions of equipment and labor associated with varying herd size and quality of cow are also varied. In this planning span, an upper limit on herd size is imposed by barn space.

In a still *longer length of run,* even more factors of production are variable; e.g., buildings and land. With the passing of time, a farmer may even acquire or lose managerial skill, thus making that variable, too.

These are only three of an infinite number of lengths of run which could be defined.[2] They are rather arbitrary, but they are meaningful in terms of farm operations.

Cost concepts are meaningful only with respect to specific lengths of run or planning spans. The longer the length of run, the more elastic the curves tend to be and the lower the proportion of fixed to variable costs.

The aggregation problem. A lateral summation of the supply (marginal cost) curves of individual producers is the supply curve for the industry. Supply curves so estimated have characteristics which create several problems. For instance, input prices which appear unvarying to each farmer sometimes vary with the amount of the input used by the total number of farms. For items with national markets and which are used in several lines of production (such as

[2]These three specific lengths of run were spelled out in a recent textbook: See Bradford, L. A., and G. L. Johnson (1953). *Farm Business Analysis.* John Wiley and Sons, New York, p. 243 ff.

corn, oats, soybean oil meal, and salt), this problem can probably be ignored when dealing with production in one of the many areas in which one product is produced in the total economy.

The demand for these inputs within the Detroit milkshed makes up a minor part of the effective demand for them from the entire economy. Thus, the relationship between the prices of these items and the quantity used in the Detroit milkshed will be disregarded as relatively unimportant.

The problem, however, is more acute for those inputs (such as labor, silage and pasturage) fixed in supply, either locally or on an individual farm basis, but variable within the individual farm between enterprises. Here the value of such items is very definitely a function of the quantity used on the particular farms under consideration. This problem is partially solved by holding the quantity of silage and pasture used constant at all of the feeding levels, thus eliminating this item as a component of marginal costs. Since labor cannot be held constant as feeding levels change, it is treated in an alternative way (see section on page 9).

Under the above assumptions, an estimate of the supply curve for a milkshed can be secured by laterally summing marginal cost curves for the farms in the milkshed.

The price responsiveness of farmers as entrepreneurs. Economic concepts indicate that farmers adjust milk production and their use of resources in response to changes in prices. However, it is often argued that farmers are not price responsive and that they increase their production in order to maintain income rather than restricting it when the prices of their products go down.

In addition to indicating that, as the price of milk falls, production is cut back; economic concepts indicate that, as input prices fall, production is expanded. As drops in input prices often accompany falls in milk prices, economic concepts indicate that such price changes should be expected to offset each other partially. The economic analyst thus faces what Marschak (15) and others term the problem of "identifying" these two opposing tendencies in studying supply responses.

To date, supply analysis has been carried out in two ways: historical-statistical, and synthetic or budgeting. The identification problem is much more acute for the historical method than for the synthetic method employed herein. The historical-statistical or time-series method is probably the oldest and most used technique of supply response analysis.

This method consists of securing a set of price-quantity observations secured over time and fitting a curve to them. These observations actually describe the point of intersection of a supply curve and a demand curve and, unless additional information is available (for example, on the nature of variables causing shifts in each curve), it is difficult to know whether a curve fitted to the observations describes demand, supply, or some uninterpretable combination of the two.

Many conclusions about the perversity and unresponsiveness of milk production to price changes result from failing to solve the "identification problem" which is the problem of securing an unambiguous estimate of one curve or the other.

The method of analysis used in this study consists of synthesizing the supply responses of individual firms and aggregating these into an industry supply response. Thus, the entire structure of the system is built upon a completely identified relationship. Starting with a production function derived from controlled experiments in which cause and effect are known, responses are built successively from individual cows, to farm, to industry. This is a major advantage of the synthesization technique in supply analysis.

Another factor entering into the analysis is the fixed nature of certain inputs used in the production of fluid milk. Labor is often fixed for a farm, together with pasture, silage and, often, hay. Since alternative uses for these items are few once commitments are made, they have a low opportunity cost. If the price of milk falls, their value in milk production is lower; however, no better alternative opportunity exists for them, and the level of output remains about the same. The present analysis treats pasture and silage as fixed assets and handles labor and hay very guardedly in this respect.

These considerations do not indicate that farmers are unresponsive to price. Quite the contrary. They indicate that farmers do consider price relationships in view of the fixed nature of certain assets when adjusting production, but that price changes sometimes offset each other. The present study attempts to conform to this analysis of the situation.

Delineation of the supply response area. Supply curves are more meaningful if the areas to which they apply have a degree of homogeneity as to quantity and quality of resources. The Detroit milkshed has a reasonable degree of homogeneity in climate, length of growing season, breed of cows, and institutional factors such as sanitary regulations and pricing methods.

Within this area, however, the production of fluid milk is still carried out under quite variable conditions. Thus, it was necessary to construct curves for each of 10 representative dairy farms of about equal importance in the shed. In order to set up these representative farms, information on major factors affecting production was needed. These include herd size, type of barn, and productive capacities of cows.

As secondary sources of data did not supply this information, a post card survey of members of the Michigan Milk Producers' Association was made. Results of this survey are summarized in Table 1.

Only short-run responses are considered in this study. The level at which the cows are fed and combinations of roughage and concentrates are regarded as variable. That part of labor associated with changes in the feeding level is variable, as are the additional milk

TABLE 1—Percentage distribution of farms, by herd size, type of barn, and average production per cow—October 1, 1951 to September 30, 1952,† Detroit milkshed*

Kind of barn and size of herd	Under 6,999 pounds Average 6,680 pounds*	7,000-8,999 pounds Average 7,970 pounds*	9,000 pounds and over Average 11,000 pounds*	Total
	Percent			
Stanchion				
2-10 cows, Average 8.3.......	12.75	11.43	9.49	33.67
11-15 cows, Average 12.9.....	8.59	10.63	10.45	29.67
16 cows and over Average 22.6.....	7.53	10.45	14.70	32.68
Total........	28.87	32.51	34.64	96.02
Pen type				
6-40 cows 16.3 average......	.....	.....	.....	3.98‡
Total.........	28.87	32.51	34.64	100.00

*In terms of 3.68 percent butterfat.
†A fiscal year is used as a base because data are more easily obtained in this way.
‡Average production: 8,350 pounds per cow.
SOURCE: Mail questionnaire, spring of 1953. Fifty percent response with one followup.

cans needed to handle the increased milk resulting from higher feeding levels. Electricity also varies with changes in milking time and the volume of milk to cool.

All other factors of production are assumed fixed at different levels for each of the 10 representative firms. The size of the herd is constant, the barn is fixed, and land is fixed. In aggregating individual supply responses, the number of producers, size of herds, and the productive capacity of cows are assumed fixed. Many of these assumptions are, however, rather easily relaxed when manipulating estimates for prediction purposes.

THE PHYSICAL INPUT-OUTPUT RELATIONSHIPS

FEED AND MILK

Feed is the major variable factor of production; milk is the output or product. The production function relating these variables is, therefore, the most important one for this study. The input-output relationships used are based on a combination of experimental data, survey data, and judgment.

Milk production in the planning span considered here is generally conceived to be a function of varying quantities of roughage, concentrates, and such associated inputs as labor, minor equipment, and electricity; these are combined with such fixed factors as the cow, the quality of her feed, the managerial ability of the farm operator, buildings, and the climate. Momentarily disregarding changes in the associated inputs such as labor, minor equipment, and electricity, the economic analysis for this length of run involves the traditional three-variable analysis of profit maximization. The problems of choice involve the combination in which to feed the roughage and concentrates and the amount to feed the cow.

The range over which the total digestible nutrient (TDN) intake of a particular cow can be varied has minimum and maximum limitations. Physically, the TDN intake must be at least enough to satisfy the maintenance requirements of the cow. The maximum TDN intake is determined by the cow's ability to handle grains and concentrates. The marginal physical product of TDN is zero at the lower extreme, increases, and then decreases to reach zero again at the upper extreme.

Cost curves assume least cost combination of variable inputs. On a production function, a series of least cost combinations is referred to as a scale or expansion line. The determination of the least cost combinations of roughage and concentrates presents a special problem in the case of the dairy cow. Fig. 3 will help the reader understand the following discussion.

Current thought among dairy specialists is that it is economical to fill a cow's stomach either with roughage or with roughages and concentrates.[3] Under the normal range of price relationships, the price

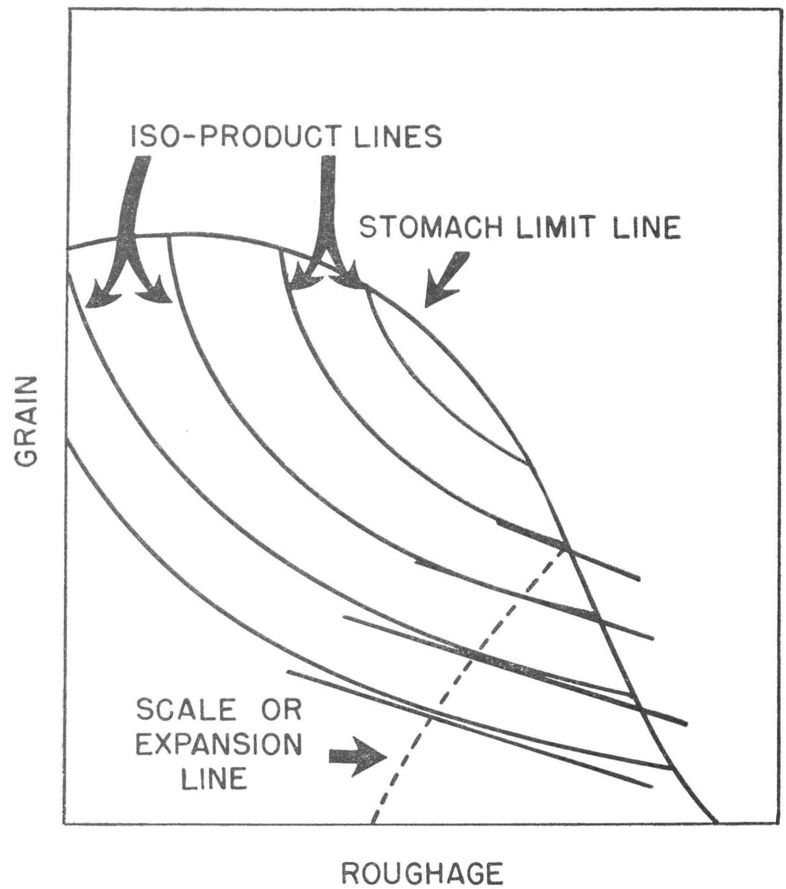


Fig. 3. Hypothetical milk production surface for cow in the grain roughage plane showing iso-product, stomach limit and scale or expansion lines under normal price relationships.

[3]In a rather new textbook, the following statement is found in a section discussing balancing rations: "The cows should be fed all the roughage that they will clean up." See Henderson, H. G., Carl W. Larson and Fred S. Putney (1947). *Dairy Cattle Feeding and Management.* 3rd ed. John Wiley and Sons. New York. p. 123.

Morrison (16) gives the following paragraph related to this subject. "Good milk production cannot be secured unless cows have an abundance of feed. When concentrates are so high in price in comparison with roughage that it is wise to feed less concentrates than normal, special care must be taken to keep the cows filled up with high-quality roughage. Otherwise, production will be seriously reduced." This only refers to good quality roughage, but he indicates that if a cow is worth keeping at all, she is more profitable if fed liberally.

of total digestible nutrients from roughage is such that the farmer can buy 3 pounds at an outlay which would buy only 2 pounds or less of total digestible nutrients from concentrates.

Under these conditions, the least cost combinations may involve all roughage to the cow's stomach limit, or it may involve all roughage up to a point and then more of both roughage and grain up to the cow's stomach limit line. In either case, from then on total digestible nutrient intake can be expanded only by substituting, at varying rates, high-valued digestible nutrients from concentrates for low-valued digestible nutrients from roughage.

The stomach limit line does not represent an absolute physical capacity. The quantity and weight of feed which a cow will hold in her stomach at any given time depends on the dry matter content, palatability and quality of the hay, as well as her age and general physical condition. The quantity which she will process in, say, a day, depends on digestibility; this, in turn, depends on texture, dry matter content, nutrient composition, and a great number of other variables of interest to dairy husbandrymen. The stomach limit lines used in this study are thought to apply (subject to "normal" disturbing variations) to the cows, roughages, concentrates, and conditions described.

It was originally decided that a ration consisting of 100 percent roughage would be the lowest level of feeding to consider in the study. Though this level was later dropped for the higher quality cows, it is discussed here for the sake of logical development.

It would seem that additional milk production could be secured from this point at a higher marginal cost per unit only because a high cost feed—concentrates—is being substituted for a low cost feed—hay. This, however, does not prove to be true; the presence of some grain evidently increases the efficiency with which roughage TDN are utilized, thereby reducing costs. This increase in efficiency indicates, in turn, that certain least cost combinations of grain and roughage are attained by limiting both rather than grain only as was done in these computations (see page 27).

Cost computations were made initially for six levels of feeding, ranging from 100 percent of the total digestible nutrients from roughage to one supplying 50 percent of the total digestible nutrients from roughage and 50 percent from concentrates. The method of arriving at the physical quantities and the implications of the results are described below.

Feed input-output relationships were needed for cows of the four different productive capacities selected for study. By converting the milk produced per cow (as determined by the post card survey) into 4 percent fat-corrected milk, it was observed that the amount of milk produced by each quality of cow compared quite closely (at the 1:4 level of grain feeding) with the four qualities of cows for which input-output relationships were plotted by Jensen et al. (13).

The per cow production figures acquired from the post card survey were assumed to be the result of a 1:4 rate of feeding. This assumption may or may not be correct, but it does provide a starting point in deriving the relationships and does not materially affect the shape of the curve, even if not correct (see page 30). These input-output relations were, therefore, taken as the basic data for this cost study.

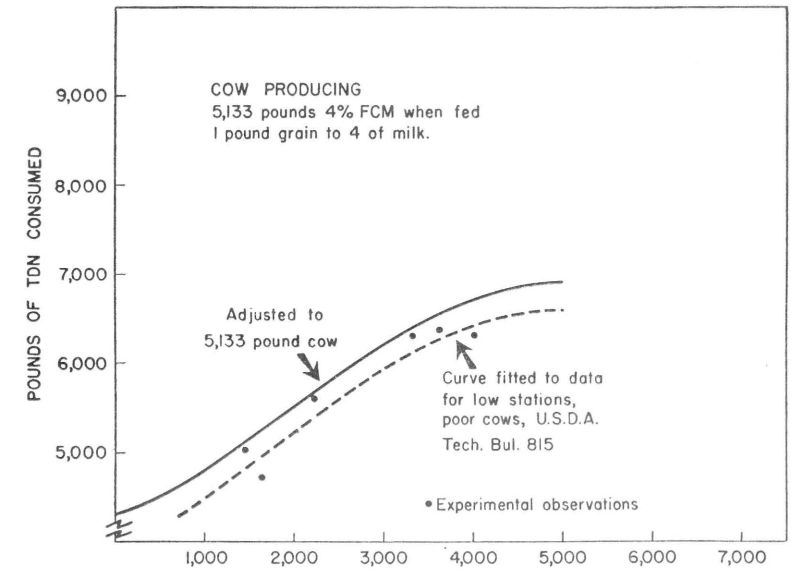
Cows in the Detroit milkshed get their total digestible nutrients from a combination of concentrates, hay, pasture, and silage. Silage and pasture were regarded as fixed over the range of the feeding variations.[4] This is reasonable since their productive value probably lies somewhere between salvage value and replacement cost.

This procedure eliminates the need to price pasture and silage directly. Indirectly, these items are priced in terms of the cost of hay and concentrates as changes in TDN consumption are computed in terms of hay and concentrates; i.e., the level of feeding is raised by adjusting hay downward and grain upward.

Experimental data reported by Jensen et al. (13, p. 43) indicate approximately how TDN intake increases as the level of grain feeding is raised. In order to estimate more accurately the increase in TDN intake as grain is substituted for hay along the stomach limit line, smooth curves were fitted to the data furnished by Jensen et al. relating grain consumption to TDN consumed per year for each quality of cow (Fig. 4). These curves were then adjusted up or down for the slight differences in productive capacity and weight of animal between the cows considered in this study and those reported on by Jensen et al. (see the dotted curves in Fig. 4.).

To illustrate this shift, a 1,200-pound cow capable of producing 5,133 pounds of milk at the 1:4 level of feeding can be compared in respect to grain and TDN consumption with the low stations-poor cows reported on by Jensen et al. It was estimated that when a low station-poor cow consumes 1,283 pounds of grain, she has a total

[4]For most Detroit milkshed dairy farms, the dairy cow is the main forage-consuming animal on the farm. Silage and pasture are often fixed assets for the dairy enterprise, the farmer being motivated neither to buy more nor sell any of his present supply.



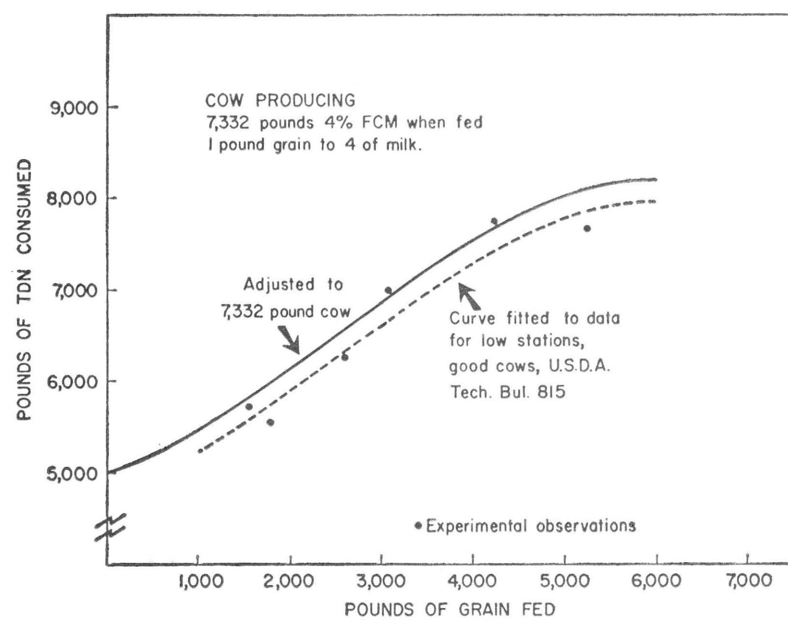
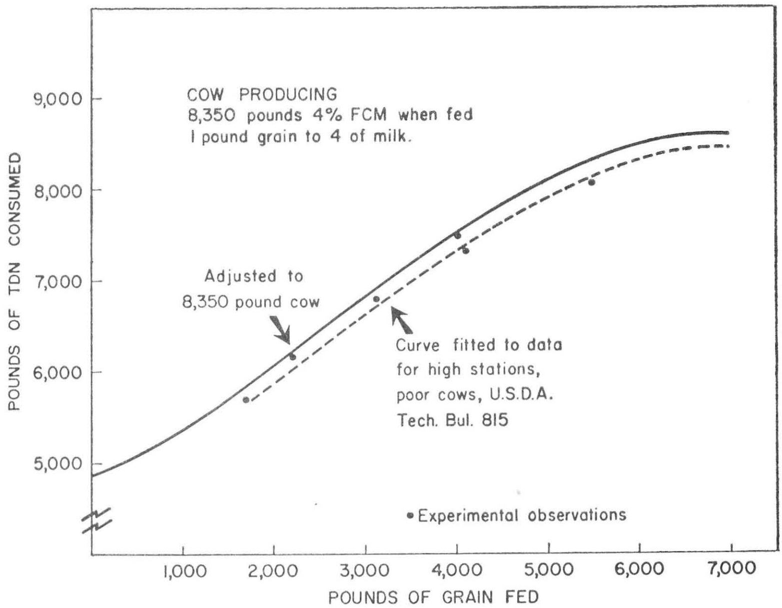
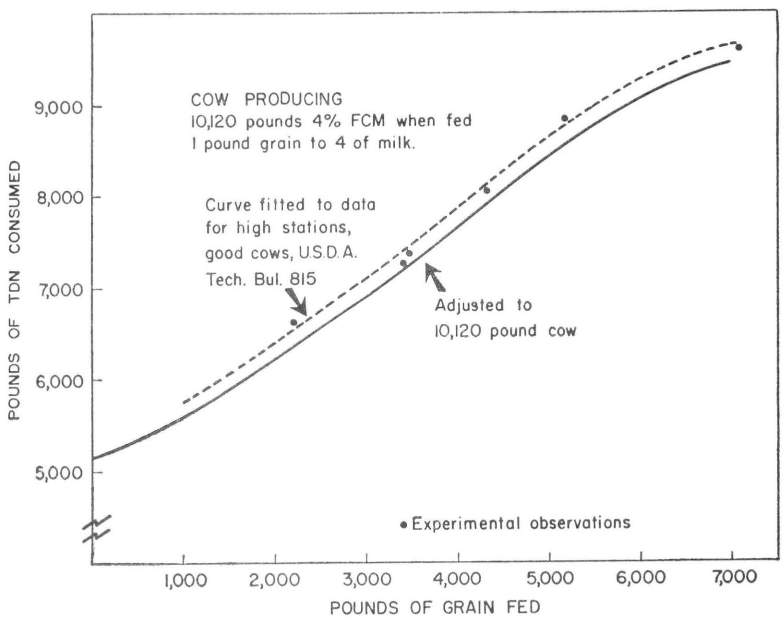


Fig. 4. Derivation of TDN – grain relationships for representative cows, free from roughage. Adapted from: Jensen, E.; J. W. Klein, E.





Rauchenstein, T. E. Woodward and R. H. Smith (1942). Input-output relationships in milk production. U. S. Dept. Agr. Tech. Bul. 815. 88 pp.

digestible nutrient intake of 4,977 pounds. This was found by reading from the input-output curve published by Jensen et al. for low station-poor cows, the TDN necessary to produce 5,133 pounds of milk; to this was added the maintenance requirement of 3,394 pounds of TDN for a 1,200-pound cow as reported by Morrison (16, p. 1147).

In Fig. 4, this rate of TDN intake was plotted against the respective grain intake for that quality of cow. Since this point was found to be above the line fitted to the data reported by Jensen et al., a second line was drawn through the point parallel to the first line. This was the curve from which the TDN intake was estimated as grain is substituted for hay in the ration. This was done for each quality of cow. The slope of the curve for the high quality cow was decreased slightly in order to keep from increasing the consumption of grain and hay simultaneously to secure sufficient total digestible nutrients.

At this stage, the curves represented the feeding ranges covered in the experiment. A downward extension of the curves was needed to carry the relationships down to the lowest level of feeding tentatively considered in the study—all nutrients being supplied by roughage. Experimental data reported by Mosely et al. (17), Sherwood and Dean (22), Headley (8), and Graves et al. (7) indicate that cows fed no grain will produce approximately 80 percent as much milk as when fed at a 1:6 grain-milk ratio. The derived curve was extended to the left in a straight line until a level of grain feeding of 1:6 was reached.

The total digestible nutrients needed to produce 80 percent as much milk and to maintain the cow were determined, and the intersection point on the ordinate axis was located. The curve from this point to the 1:6 point was drawn so that TDN would go up at an increasing rate when increments of grain were begun.

Studies by Redman (20 and 21) indicate a similar awareness of an extremely high rate of substitution of grain for hay along the stomach limit line for these initial increments of grain to a 100 percent roughage ration.

These relationships between concentrate and TDN intake were then used to determine the amount of grain in the ration at each feeding level for each different capacity cow. Hay was adjusted downward accordingly while pasture and silage were held constant. Input (feed)-output (milk) tables are given for the four cows of different productive capacity in Appendix Tables 1, 2, 3, and 4.

The rate of substitution of grain for hay varies considerably over the range considered. For the initial increments from the 100 percent roughage ration, the rate of substitution was high. For still more grain, the rate approached zero; this indicated an almost vertical stomach limit line. Still more grain added to the ration began again to substitute for hay at successively higher rates until the stomach limit line became almost horizontal.

This appears contrary to the findings of Hoglund (10), Morrison (16), and Wells (25), but it is consistent with the deductions of Redman (20) at the University of Kentucky and the experimental data presented by Jensen et al.

Hoglund used a constantly increasing rate of substitution along the stomach limit line, ranging from .15 for the first up to .99 for the last increments of grain. This appears to be an inadequate allowance for the first increments of grain. Further, it does not reflect the low rate of substitution which may exist where the stomach limit line may be almost vertical. Morrison (16) assumes a changing rate from between .6 and .8, while Wells (25) used a rate between .5 and .7. Redman (20), however, in delineating the stomach line, found it to be shaped as suggested by this study.

The data reported by Jensen et al. for different quality cows reflect the substitution rates determined earlier in this study. However, in combining all data, Jensen et al. arrived at an "average" rate of substitution of between .5 and .7. The present study is based on the Jensen et al. data.

In combining data from all cows together to get an "average" rate of substitution, Jensen et al. no longer were dealing with a single production function, but rather with segments of functions for a number of cows combined into an intercow function. The fallacy of combining points from unlike functions has been pointed out by Bronfenbrenner (4) and Reder (19).

Other feed inputs must be considered also. Investigation showed that vitamins and minerals supplied in the assumed ration were sufficient at all levels with the exception of salt which should be varied with the feeding level. The amount of salt needed at each feeding level for the different cows is given in Appendix Table 5. These amounts are based on the minimum recommendations by Morrison (16) of .75 ounce daily per 1,000 pounds live weight, plus .3 ounce for each 10 pounds of milk produced.

LABOR

As certain portions of labor vary with the level of feeding and milk production, labor is included in the variable and marginal cost computations. The labor data used were taken from unpublished cost studies conducted in the Detroit milkshed and from work simplification studies by Brown (2), Lowery (14), and Brown et al. (3).

From the cost study, base quantities of labor were determined at the 1:4 level of grain feeding for each quality of cow under given conditions of herd size and type of barn. Hours required per cow per year were then broken down into jobs for each of the respective herds (according to the relative importance of each job as determined in work simplification studies).

Only those portions of total labor requirements which are variable in the planning span being considered here are included in the computation of the marginal cost curves. Labor inputs for each level of feeding for the four different cows are presented in Appendix Tables 6 through 15, along with the rates for the respective jobs for each herd size.

MILK CANS

As the level of feeding is changed and more or less milk is produced, more or fewer cans are needed to handle the milk. The resultant changes in costs were estimated.[5]

ELECTRICITY

As more milk is produced, additional electricity is used for milk machine operation and cooling. When electrical appliances on several typical dairy enterprises were metered by the Michigan State University agricultural engineering department in 1952, 1 kilowatt hour per cow was used for cooling, while 1.38 kilowatt hours per cow per month were used for milking machine operation. Studies at Michigan State University showed that additional milk could be cooled at the rate of .98 kilowatt hour per 100 pounds of milk; the electric power used by the milking machine in milking an additional 100 pounds of milk was .0836 kilowatt hour.

These data may not be representative since power requirements vary considerably among farms. They indicate, however, something

[5]Average dairy deliveries were estimated at the various feeding levels for each of the representative herds; the number of cans needed was determined. This number was multiplied by two to follow practices in Michigan where the milk hauler makes only one stop at a farm per day. An annual charge for the cans was estimated on the basis of a 5-year life which was evenly distributed over the various feeding levels.

of the magnitude of electricity cost. As such costs make up a small part of the total variable costs, rather large proportional errors would not significantly influence marginal cost computations and the supply curve.

FEED GRINDING

As the level of feeding is raised, feeding and grinding costs also increase. Many producers in the Detroit milkshed have their feed ground either at a local elevator or by custom operators. The custom rate of 10 cents per 80-pound bag estimated by Vary (23) was used.

MANURE CREDIT

The value of fertilizer elements returned to the soil was estimated and deducted from variable costs of production.[6]

PRICING OF THE FACTORS OF PRODUCTION

Abstractly, for all inputs, cost is the sum of the quantity of each input used multiplied by the price of that input. Since estimation of quantities was discussed in the last section, pricing remains to be considered.

In general, inputs were valued on an "on-farm" basis. Due to the many alternative sources and uses for many of the inputs and differences in marketability, several methods were used in arriving at prices. Inputs whose prices are determined in essentially the same way are grouped together for purposes of discussion.

VARIABLE INPUTS WITH LITTLE OR NO SEASONAL VARIATION IN PRICE OR USE

Some inputs (such as milk cans, stock salt, nitrogen, phosphorus, potassium, electricity, and soybean oil meal) have little or no seasonal

[6]The value of fertilizer elements returned to the soil is determined partially by the amount of feed fed, feed composition, and the manner in which the manure is handled.

According to Morrison (16), 100 pounds of the hay considered contains 1.8115 pounds of nitrogen, .24 pound of phosphorus, and 1.9697 pounds of potassium; while 100 pounds of the grain mixture contains 2.58 pounds of nitrogen, .346 pound of phosphorus and .64 pound of potassium.

Dairy cows producing a good yield of milk and fed the usual types of a ration, excrete in feces and urine only about 70 percent of the nitrogen in their ration and 63 percent of the phosphorus. The proportion of potassium is considerably higher, about 86 percent. Under proper management, not over 25 to 30 percent of the nitrogen and practically none of the phosphorus and potassium are lost.

In this study, a 30 percent loss for nitrogen and a 5 percent loss for the phosphorus and potassium was assumed in stanchion barns. As somewhat more nitrogen can be saved with a pen-type barn, it was assumed that 80 percent of the nitrogen excreted would be returned to the fields for this type of barn.

In addition to the amounts of plant food it furnishes, farm manure also has other beneficial effects, including the addition of organic matter to the soil, the presence of certain acids which dissolve otherwise insoluable plant foods, and various beneficial kinds of bacteria. While the value of these items is not presently measurable, it is assumed sufficient to offset the cost of spreading and hauling the manure. Therefore, the total market value of the fertilizer elements reaching the fields was credited to the dairy enterprise.

variation in price or use and can be readily purchased in the market. For such inputs, a simple average of the quarterly prices paid by farmers as estimated by the office of the Michigan Agricultural Experiment Station's statistician was used.

VARIABLE INPUTS WITH SEASONAL VARIATIONS IN PRICE AND USE

Since both the use and value of feed grains and hay vary seasonally, monthly prices were weighted according to estimated monthly use in the dairy enterprise to determine annual price estimates.

Most farmers feed a lighter grain ration when pastures are lush. To allow for this in feeding grain, a 9 percent weighting was used for October through April, and a 7.4 percent weighting was used for May through September. To cover the cost of shelling corn, a 7 cents per bushel charge was added to the weighted average annual price of ear corn.

The largest share of the annual hay ration is fed in the winter months, with the level of feeding tapering off gradually in the spring and picking up gradually again in the fall. Thus, a 15 percent weighting was used for each month November through March, and 12.5 percent weighting was used for October and April.

LABOR—An Asset Often Fixed for the Farm but Variable Between Enterprises

The pricing of labor presented one of the more difficult problems in the study. For the individual Michigan farm, labor is often considered to be a fixed asset; this implies its earning power is less than opportunity cost and is greater than its off-farm disposable value. Under these conditions, a farm manager does not profit from buying more or selling it.

For the dairy enterprise, however, labor often has to be charged at its on-farm opportunity cost or its marginal value product in alternative uses on the farm. As the intensity of feeding and the amount of milk produced change, the amount of labor varies and must be priced. As an asset fixed for the farm as a whole, it should be priced at its earning power in the dairy or in alternative enterprises—whichever is higher.

If a firm is in a state of equilibrium, the labor input is allocated among enterprises so that its cost is equal to its marginal value productivity for each enterprise. Thus, its cost in one enterprise is its marginal value productivity in alternative uses. In order for one more unit of labor to be used in the dairy enterprise, it must earn at least its on-farm opportunity cost. If there are no on-farm alternatives other than the dairy enterprise, an additional unit of labor applied to it cannot be valued higher than earnings in the dairy enterprise so long as labor is a fixed asset as previously defined.

Estimates of the marginal value productivity of labor have been made in several studies conducted on Michigan farms. Computations for dairy farms in Ingham County, as made by Wagley (24) and modified by Johnson, place the marginal value productivity of labor at 67 cents per day. Since this study has been criticized for underestimating the earning power of labor, a comparison was made with data presented by Elwood et al. (6) in the farm business analysis report for area 5; and with data from a study made by Paul Wilkes (26). The results are indicated in Table 2.

Due to the nature of the computations, it is impossible to estimate the earning power of labor at the margin by methods used in preparing the Area 5 report and in the study made by Wilkes (26). There is, however, a high degree of consistency among the different studies. The evidence suggests that the Wagley-Johnson estimate of labor's marginal value productivity is not too low.

TABLE 2—Gross income, labor income, and estimated marginal value productivity of labor on selected Michigan farms, 1952

	Wagley data	Area 5 data	Wilkes data
Gross income/PMWU*.........	\$26.86†	\$22.18	\$25.47¶
Estimated MVP/day...........	.67	.....§	.....§
Labor income/PMWU..........	7.29‡	5.56	6.22**

SOURCE: Wagley (24), Elwood et al. (6), and Wilkes (26).
*Productive man work unit.

†Gross income/day, actually $\frac{d(\text{gross income})}{d(\text{labor})}$ at geometric means with

$$\frac{dx_i}{d(\text{labor})} = \frac{\text{antilog } \overline{\log x_i}}{\text{antilog } \overline{\log (\text{labor})}}$$

‡Labor income per day, actually $\frac{d(\text{gross income})}{d(\text{labor})} - \sum_{i=1}^{n} P_{xi} \frac{dx_i}{d(\text{labor})}$

with $\frac{dx_i}{d(\text{labor})}$ defined as in † and the i's are inputs other than labor.

§Not computable by this method.

¶ $\frac{d(\text{gross income})}{d(\text{PMWU})} = \frac{d(a + b \text{ PMWU})}{d(\text{PMWU})}$

** $\frac{d(\text{labor income})}{d(\text{PMWU})} = \frac{d(a' + b' \text{ PMWU})}{d(\text{PMWU})}$

For purposes of this study, however, pricing labor at 67 cents per day would not be justified because the dairy enterprise competes directly throughout the year with other farm enterprises. During the height of the planting season or during the height of the haying season, the cows still have to be milked. At these times, the marginal value productivity of labor is higher than for the year as a whole.

Fifty cents per hour was selected as a reasonable figure to use. This is below the going wage rate, but it is justified by the fixed nature of the labor and its low estimated earning power. It is above the annual estimated marginal value productivity for the reasons given above, and it is consistent with labor charges in other publications of the department of agricultural economics.

The prices used in computing the cost curves are found in Appendix Table 18.

COMPUTING TOTAL VARIABLE COSTS

Input and price data on inputs varying with feeding levels have been discussed and assembled. The problem of combining these data into meaningful cost estimates remains.

Total variable costs are found by summing input costs at each of the levels of feeding and subtracting the value of the fertilizer elements returned to the soil through the manure.

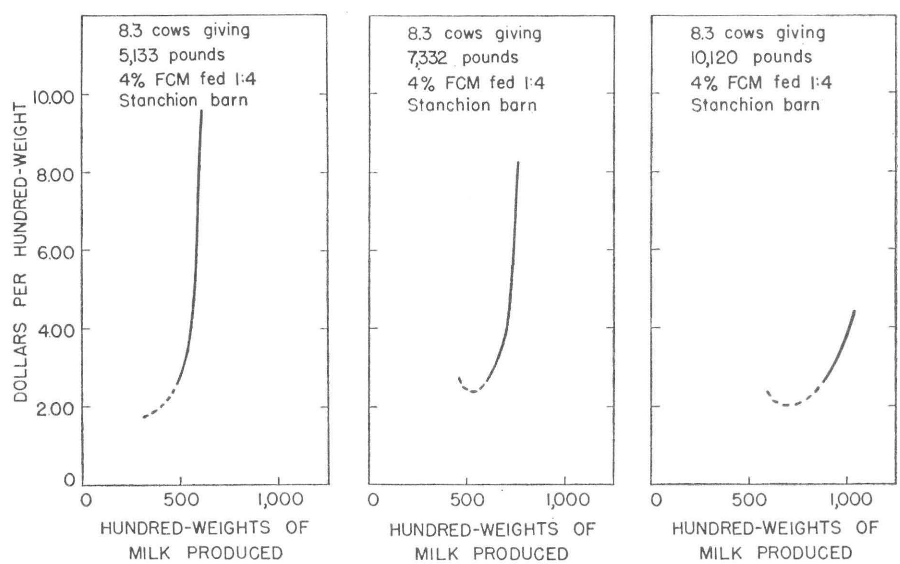


Fig. 5. Marginal costs of producing milk from cows of three different productive capacities; small (8.3 cows) herds, Detroit milkshed, 1952.

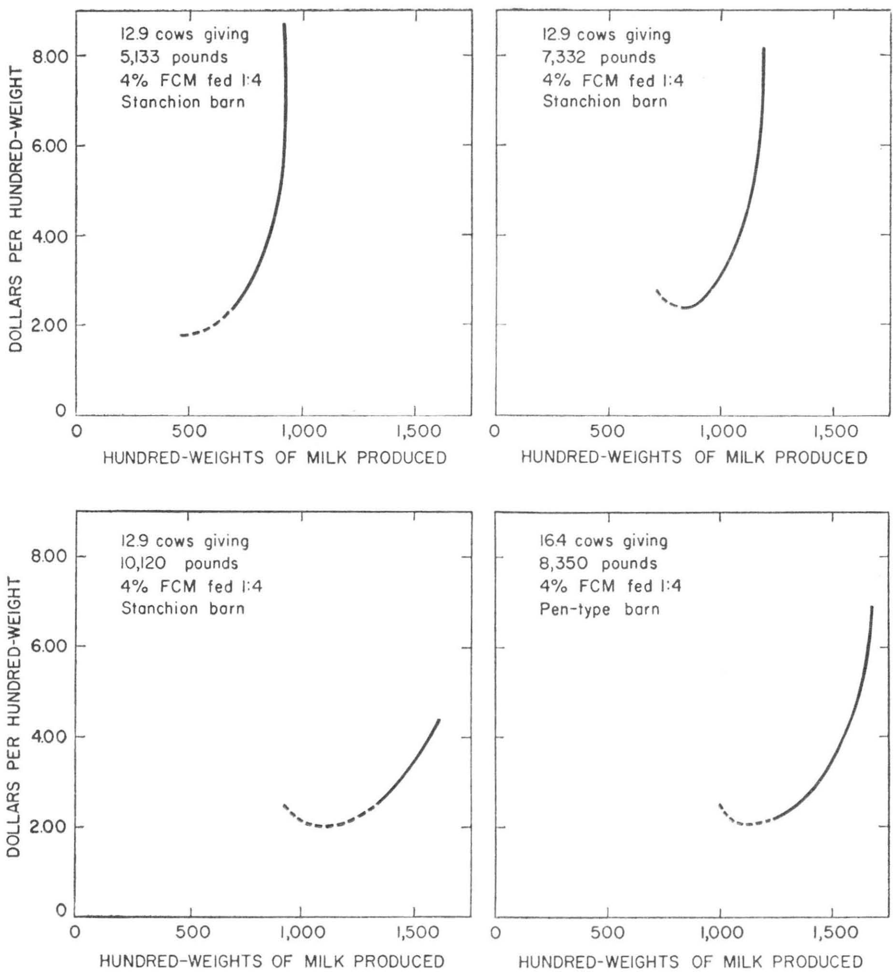


Fig. 6. Marginal costs of producing milk from cows of four different productive capacities; three in stanchion and one in pen-type barns; two herd sizes, Detroit milkshed, 1952.

COMPUTING MARGINAL COSTS

Marginal costs are determined by total variable costs. As feeding levels are raised, both total variable costs and milk production increase. Divide the increase in total variable costs from one level of feeding to the next higher level by the increase in milk production (in 100 pounds) that resulted from those additional costs; the figure is marginal cost per 100 pounds of milk.

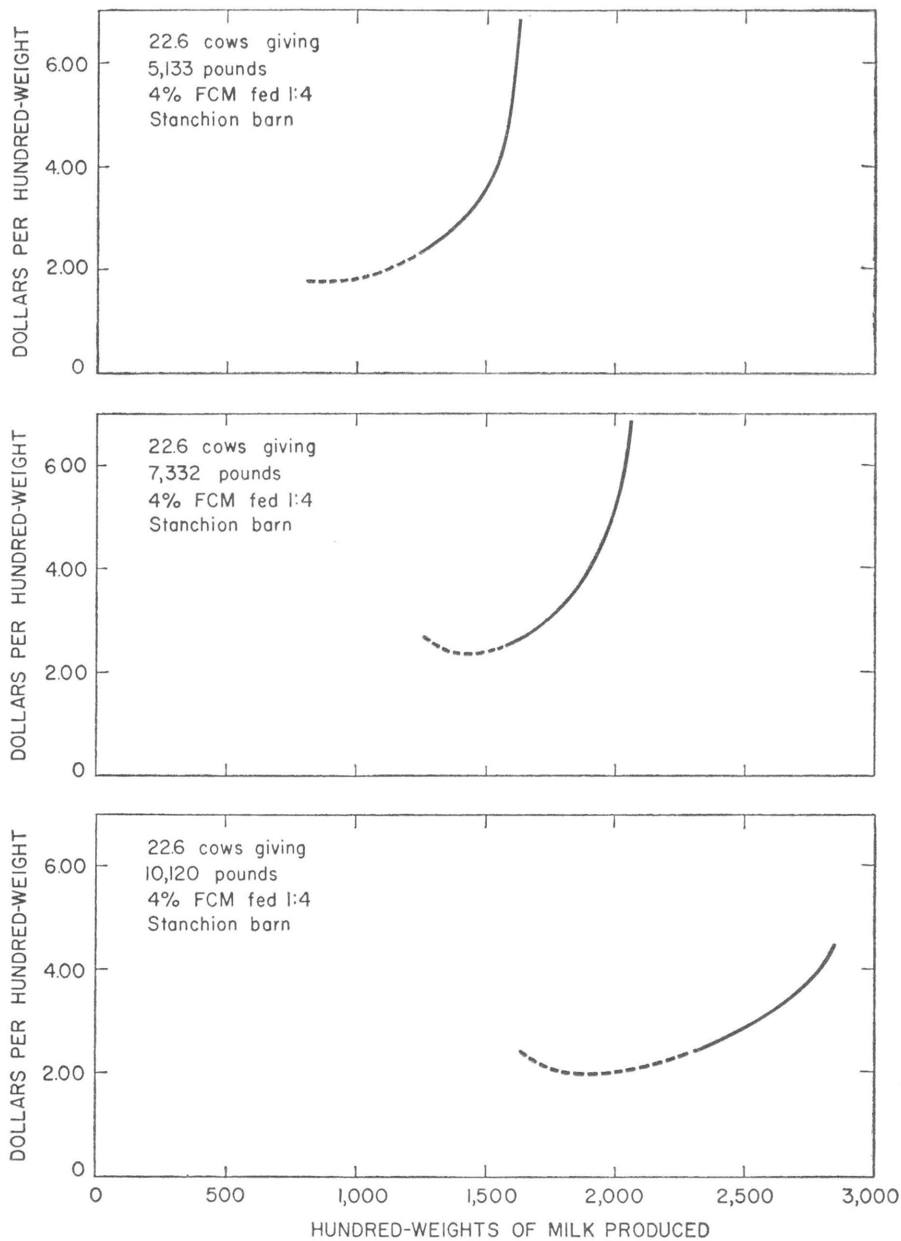


Fig. 7. Marginal costs of producing milk from cows of three different productive capacities; large (22.6 cows) herds, Detroit milkshed, 1952.

This resulting figure, however, is an "*average*" marginal cost per 100 pounds of milk between two feeding levels; it must be plotted midway between the quantity of milk produced at each level of feeding. Smooth curves, fitted graphically to such estimates for each of the typical herds, are presented in Figs. 5 to 7, while the marginal cost data are presented in Appendix Tables 19 to 28.

SIGNIFICANCE OF THE COST CURVES FOR PURPOSES OF AGGREGATION

Commonly accepted economic concepts indicate that the portion of the marginal cost curve above its intersection with the average variable cost curve is the supply curve of the firm in the short run. Though this is logical and straightforward from an abstract theoretical standpoint, modifications and developments have to be made in applying the concept. In the present problem, an extension of concepts has to be made to determine what portion of the marginal cost curve is the dairyman's rational short-run supply curve.

It was anticipated that the 100 percent roughage level of feeding would secure the lowest marginal cost of producing the milk. In computing marginal cost curves for milk production over this same length of run in certain areas of Kentucky, Wells (25) found this to be the case; the feeding recommendations of the dairy specialists (as mentioned earlier) seem to imply the same.

However, this was found not to be the case for high capacity cows. For the lowest capacity cow, the marginal cost does rise continually over the range studied. For higher capacity cows, however, the marginal costs first decrease and then increase with heavier feeding. This decrease in marginal costs as the initial increments of grain are added to the full roughage ration indicates that, for cows of these capacities, the least-cost combinations do not involve all the roughage the stomach can hold until a ration including substantial amounts of grain is reached (see Fig. 7). Apparently, the marginal physical product of grain is high, and it increases as initial increments of grain replace large quantities of roughage.

Although the marginal factor cost of TDN from all sources increases at this point as a high cost source of TDN is being substituted for a low cost source, production increases even more rapidly. Since marginal costs are found by dividing added costs by additional or marginal physical product, a lower marginal cost results from the rapidly increasing marginal physical productivity of total digestible nutrients. Marginal cost rises again, however, with subsequent additions of grain to the ration. This is due to the diminishing marginal physical productivity of total digestible nutrients as grain loses its ability to replace large quantities of roughage.

This ability to use grain to produce milk at a lower marginal cost appears related to the capacity of the cow. For the lowest capacity cow considered in this study, the marginal cost was lowest at the 100 percent roughage level of feeding. Since Wells (in his Kentucky study with marginal costs lowest at the 100 percent roughage level of feeding) had even lower quality cows, his work is consistent with these results.

At this point, a choice had to be made. The marginal cost curves could be used as they were now computed, using only those sections of the curve to the right of their minimum points. Or, the marginal cost curves could have been recomputed with the inputs combined as dictated by a scale line contrary to accepted feeding standards; in this case, marginal costs would increase continually over the range of the computations.

The second alternative was unattractive, as very little reliable data exist on the location of the scale line. Further, preliminary work by Denio Caul at Michigan State University indicates that if the price of milk drops below a minimum level on the marginal cost curve, the cow's earning power becomes so low that she will be disposed of at salvage value.[7] The lower portions of the curve are irrelevant for computing the area supply in the length of run under consideration. Therefore, the composite supply curve was based on computations for only those portions of the marginal cost curves to the right of the minimum levels. The minimum price for which a supply response can be ascertained for all of the 10 herds is $2.40.

The composite supply curve, therefore, is estimated from the solid line curves in Figs. 5 to 7, or from $2.40, up to and including $6.00 per hundredweight of milk. For the highest capacity cows, the marginal cost of producing milk, even at the most intensive level of feeding, does not go as high as 6 dollars. As estimates of the supply response up to this level of price were desired, the curves for these high capacity cows were extrapolated up to this amount. As the

[7]This is based on a definition of a fixed asset as presented by Bradford and Johnson (1). They state, on p. 321, that economic conditions ordinarily impose upper and lower limits on variations in the worth of a fixed asset. If the earning power (marginal value product) of an asset becomes greater than the cost of buying more of it, it becomes advantageous to add more of it. If this earning power drops below the salvage value of the asset, it becomes advantageous to sell it. If the marginal value product of any asset is within these limits, it is not advantageous to vary it, and it remains fixed.

extension was not large, this procedure probably detracts little from the accuracy of the estimates.

THE COMPUTATION OF THE COMPOSITE SUPPLY CURVE

AGGREGATING MICRO- INTO MACRO-RESPONSES

An average of 12,223 producers shipped milk to the Detroit market in the fiscal year under consideration. The number of these producers estimated to be represented by each of the 10 typical enterprises is given in Table 3. This breakdown is based on the results of the post card questionnaire sent to the members of the Michigan Milk Producers' Association.

The estimated response of each of the 10 typical herds at prices of $2.40, $2.50, and upward by 50-cent intervals to the 6-dollar level was multiplied by the number of similar herds in the milkshed. These results were then summed at each price level to get the total response data for the entire market area. These data are given in Appendix Table 29, which shows a total supply varying from 10.0 million hundredweight at $2.40 to 14.8 million hundredweight at $6.00 with 3.68 F.C.M.

TABLE 3—Types of herds and estimated number of producers of each type in the Detroit milkshed, October 1, 1951-September 30, 1952

Average number of milking cows in herd	Average production per cow in pounds*	Percent of herds of this type are of total herds	Number of producers with this type of enterprise
	Stanchion barns		
8.3	5,133	12.755	1,559
8.3	7,332	11.426	1,397
8.3	10,120	9.477	1,158
12.9	5,133	8.592	1,050
12.9	7,332	10.629	1,299
12.9	10,120	10.452	1,278
22.6	5,133	7.529	920
22.6	7,332	10.452	1,278
22.6	10,120	14.703	1,797
	Pen barns		
16.4	8,350	3.986	487
Total.........	....	100.000	12,223

*Four percent fat-corrected milk.

ADJUSTING THE COMPOSITE SUPPLY CURVE

The shape of this supply curve, being based on the experimental production functions for the four different type cows and their relative importance in the market, should be quite valid for 4 percent milk. To use the curve for predicting purposes, however, the curve should be presented in terms of 3.68 percent milk and must be shifted laterally to adjust for a bias (resulting from mail sampling) toward large producers.

Further, in using the curve for any year other than the base year, adjustments for year-to-year changes in number of producers, herd size, quality of cow, and input prices must be made because the curve does not account for supply changes due to these factors.

The curve was converted to 3.68 percent milk by multiplying the quantity produced at each of the specified prices used in locating the curve by 4 percent. This gave the butterfat produced at each price. The quantity of 3.68 percent milk was then determined by dividing the pounds of butterfat by .0368.

Due to the bias resulting from taking a post card sample of a special group of producers, it was expected that the unadjusted curve would indicate an excess of production at each price. The respondents to mail questionnaires are probably the larger, more efficient, more conscientious producers. Their herd size is probably larger than average, and their average production per cow is probably greater than the average for the universe sampled. The responsiveness of the supply data to price changes is probably quite valid because, as pointed out earlier, it is based on experimental production functions.

Therefore, the data can be corrected for bias by locating a point based on the actual production for the period October 1, 1951 to September 30, 1952, and the average price for the year preceding the period,[8] then shifting the data laterally[9] to pass through this point. The required lateral adjustment amounted to 5.0 million hundredweights of milk. This shift also corrects any errors resulting from assuming earlier a 1:4 rate of grain feeding (see p. 15).

Fig. 8 presents the aggregate supply curve for fluid milk in the Detroit milkshed for the period from October 1, 1951 to September

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[8]Comparisons were made between prices and production over a 6-year period. Comparing the reported production for a given year and the corresponding average price indicates there is a closer correlation between the price in the preceding year and current production than between the current price and production. This indicates that farmers base their expected price of milk on past experience.

[9]A lateral shift is used because the cost structure remains the same. The bias is the result of a greater production at each cost level. Holding the cost constant, and reducing the production at each level, would involve only a lateral shift in the curve.

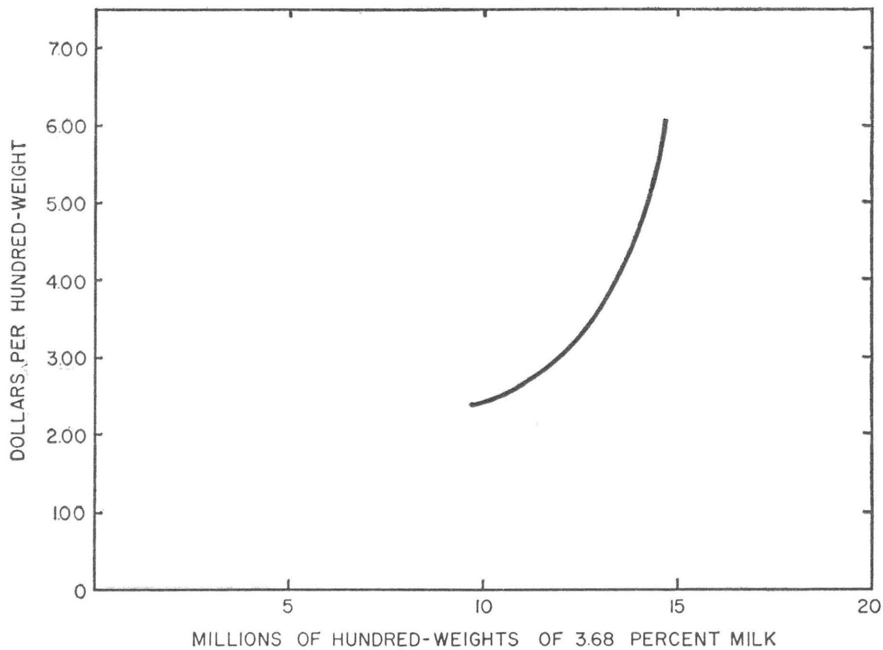

Fig. 8. Supply curve, Detroit milkshed, October 1, 1951 – September 30, 1952.

30, 1952. It is based on specific prices of inputs, fixed herds, and given producers.

ADJUSTING THE COMPOSITE SUPPLY CURVE FOR YEAR-TO-YEAR CHANGES IN INPUT PRICES, NUMBER OF COWS, AND PRODUCTIVE CAPACITY OF COWS

At least three adjustments have to be made in using the curve for year-to-year prediction purposes. In the first place, the curve shifts vertically in response to changes in input prices.

The curve can be rather easily adjusted for such price changes. Concentrates make up over 90 percent of marginal costs and are the most variable in price from year to year. Thus, the cost of 100 pounds of concentrates is a useful guide in estimating how much and in which direction (up or down) to shift the curve.

The United States Department of Agriculture publishes readily available estimates of the cost of 100 pounds of dairy feed concentrates in the United States. For the period under consideration, the cost of 100 pounds of grain was $3.74. Though this price is for a more expensive ration than used in these estimates, it is readily available; hence, it serves as a practical basis for quickly computing the results of year-to-year changes in input price.

In shifting the curve, the percentage change in cost per 100 pounds of the ration is regarded as approximating the percentage change in the marginal cost of producing milk. When the supply curve is shifted this much percentagewise, it is a reasonable approximation of the supply curve which would prevail under the changed price of concentrates.

This procedure can be illustrated by estimating the amount of milk produced in 1953. The cost of 100 pounds of grain ration dropped to $3.53—a 5.61 percent decrease from the fiscal year for which the original curve was computed. Multiplying $2.50, $4.00, and $5.50 by this percentage indicated that the curve should be lowered 14.0 cents, 22.4 cents, and 30.9 cents, respectively, at these three points.

The resulting supply curve indicates that, at the average blend price of $4.98 for the previous year (1952), 1953 milk production should be 1,447 million pounds. This assumes that the productive capacity of the cows remained constant and that the number of producers and the size of the herds did not change. Adjustment of the estimates to allow for these three changes makes it more accurate and adds a greater degree of dynamics to the analysis.

Milk production per cow has increased rather steadily over a long period of years. Over the 8-year period from 1944 to 1952, the average production per cow in Michigan increased 2.50 percent per year. The change in production has varied from year to year in response to changes on feeding. Thus, for the purposes of estimating changes in productive capacity, a trend is used.

1953 production is estimated from data for the year ending on September 30. Thus, the time differential is a year and a quarter, and the productive capacity of the cows is estimated to increase 3.10 percent rather than 2.50 percent. Multiplying 1,447 million by 3.10 percent indicates a 45 million increase due to an increase in the productive capacity of cows. This is added to the 1,447 million pounds to secure an estimate of 1,492 million pounds of milk.

A change in the number of producers or a change in the average size of the herd would be indicated by a change in the number of cows and heifers 2-years old and over being kept for milk, and the number of heifers 1- to 2-years old being kept for milk cows. The change in number of cows kept for milk in Michigan from January 1, 1952 to January 1, 1953 was an increase of 4 percent.[10] The number of heifers 1- to 2-years old being kept for milk cows increased 5.81 percent over the same period. A weighted average of these increases indicates that the number of milk cows per farm in the area may have increased by 4.6 percent during the period under consideration.

The estimate of 1,492 million pounds of milk was based on the changed cost structure and increased productive capacity of cows only. It must now be increased by 4.6 percent. The result is 1,561 million pounds.

The number of producers in the Detroit milkshed also increased around 5 percent from 1952 to 1953 according to Quackenbush and Jones (18). In 1953, producers entering the market had 10 percent fewer cows than the average. A total of 1,530 producers entered, while 916 left. Some of the changes in cow numbers resulting from these changes in number of producers have been accounted for previously.

This, in addition to the smaller size of entering herds, indicates that the 5 percent increase in entering herds should be reduced substantially to (perhaps arbitrarily) 2.5 percent. When the 1,561 million pound figure is increased this much, estimated 1953 production becomes 1,600 million pounds. The 1952 curve which was adjusted vertically for the 1953 input prices is now adjusted 151 million pounds laterally (Fig. 9).

Actual production for 1953 was 1,591 million pounds, giving an error in prediction of .6 percent. There was an actual change in production from 1952 to 1953 of 206 million pounds of milk or an increase of 14.8 percent. The direction of this sizable change and 104.4 percent of its magnitude was predicted.

The analysis does not include all factors which can affect production. It is felt, however, that if the major influencing factors are considered and the curve is adjusted annually for what is known about changes in productive capacity, number of cows and changes in costs, reasonably accurate estimates can be obtained over a period of years.

THE ELASTICITY OF SUPPLY IN THE SHORT RUN

The concept of price elasticity of supply is useful, especially for making policy recommendations. Price elasticity of supply is the

[10]January 1, 1952, was used as a base figure because figures are not given for October 1, 1951. Since 8 of the 12 months are in 1952, it is felt that the difference would not be significant.

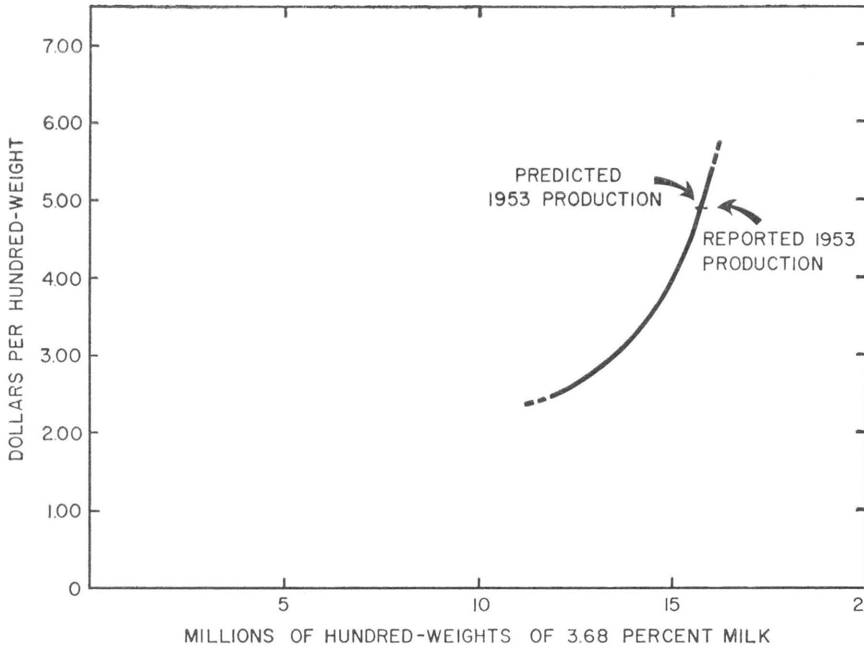

Fig. 9. Supply curve for Detroit milkshed, showing predicted and reported production, 1953.

percentage change in milk supplied resulting from a 1 percent change in the price of milk. In making recommendations that are going to influence large numbers of producers and consumers (such as in price support programs, in federal milk marketing orders and in adjusting production to meet wartime emergencies), more valid recommendations can be made if the elasticity of supply is known.

Supply elasticity estimates apply to specific situations, for elasticity changes with output, different lengths of run, input prices, and geographic locations. The present analysis contains elasticity estimates with respect to a limited geographic area, for a definite length of run, for alternative levels of input prices, at various prices for fluid milk, and at alternate levels of production.[11]

Since the elasticity estimates may vary at different points on the curve and for various levels of input prices, estimates were made at three points on each curve and curves were fitted mathematically for four different levels of input prices—one for the level that existed in

[11]See Appendix for method of calculating elasticity.

the fiscal year, 1951-52, two for the extremes in grain price fluctuations since 1900, and one midway between.[12] The curves for different levels of input prices were secured by making adjustments similar to those discussed in the last section, with the change in the cost of 100 pounds of concentrate ration being the criteria for shifting the curves.

An estimate was made for each curve at the 1,385 million pound level (the production for the fiscal year 1951-1952; at 1,100 million (a point selected to indicate the more elastic area of the curve); and at 1,450 million (to indicate the more inelastic levels). The results of these estimates are shown in Table 4.

For the 1951-52 supply curve, the elasticity of supply ranged from .57 at the 1,100 million pound level of production to .41 at the 1,400 million pound level of production. At 1,385 million pounds of production (the reported production for that year), the elasticity of supply was .43. This indicates that, in the length of run in which only feed and its associated inputs are variable, supply is relatively inelastic. Other things being equal, a 1 percent change in the price of milk should be expected to bring about something between a .41 and .57 percent change in supply, depending on input prices and the level of production.

It is commonly asserted that farmers maintain or expand milk production when prices fall. Examination of price and milk production data indicate that this is not far from the truth. Such facts, however, do not deny the accuracy of the above elasticity estimates. These estimates assume that the following are fixed: (1) nonfeed input prices; (2) herd sizes; and (3) number of herds.

[12]The four functions are, where Y = cents per hundredweight and X = quantity in millions of pounds:

With grain at \$4.00 a cwt: $Y = 31.12(X\text{-}10)^{1.4325} + 257$
With grain at \$3.74 a cwt: $Y = 29.13(X\text{-}10)^{1.43306} + 240$
With grain at \$2.50 a cwt: $Y = 19.44(X\text{-}10)^{1.4317} + 159$
With grain at \$1.00 a cwt: $Y = 7.632(X\text{-}10)^{1.4313} + 64$

TABLE 4—Elasticity of supply in the short run, three levels of production, and three levels of input prices, Detroit milkshed, October 1, 1951-September 30, 1952

Cost of grain per cwt.	Level of production (millions of pounds)		
	1,100	1,200	1,400
Dollars		Elasticity	
4.00	.57	.50	.41
3.74	.57	.50	.41
2.50	.57	.50	.41

With feed over 95 percent of the marginal cost of producing milk, percentage changes in feed prices equal to those in the price of milk would leave production virtually unchanged; shifts to higher producers (to be discussed in the following pages) would expand production.

IMPLICATIONS OF THE MATERIAL PRESENTED

The foregoing sections have presented, in logical sequence, the development of marginal and average variable cost curves for typical dairy enterprises in the Detroit milkshed. Herd size, quality of cow, type of barn, and level of feeding as they influence cost of production have been discussed, and their influences have been incorporated into the computations.

After the development of these cost data for the 10 representative herds, a supply curve for the Detroit milkshed was estimated. A discussion of how to manipulate these supply estimates for purposes of outlook work followed. Finally, the elasticity of milk supplied was discussed.

Certain scattered implications for both the cost and supply data were presented. The task of developing an overall, more integrated statement of these implications remains. The purpose of this last main section is to discuss the overall significance and implications of the estimates developed and presented in the study. It will begin with a discussion of on-the-farm aspects and build successively into broader industrywide, interregional, and national aspects.

HOW THE FARMER CAN MEET A COST-PRICE SQUEEZE

There are seven cost concepts for every planning span and set of prices: Total costs, average total costs, total fixed costs, average fixed costs, total variable costs, average variable costs, and marginal costs. Each of these seven different cost concepts are important for particular decisions. Some are useful in figuring profits, some have value in determining whether to produce or not to produce, and one helps indicate the level at which to produce.

This study presents estimates for two cost concepts, both of which are important to farm operators. The first of these is average variable costs. Average variable costs indicate whether or not a producer can continue to operate in the short run. More specifically, they indicate the price a farmer must receive if he is to cover his out-of-pocket or total variable costs. If the price falls below minimum average variable costs, the herd cannot be operated without incurring a loss on an out-of-pocket basis, not to mention the fixed costs over which the manager may not have control in the short run under consideration.

The second cost concept of use to farm operators is marginal cost. This concept is probably the most important of the seven for farm operators. Since marginal cost is the additional cost involved in producing additional units of output, it indicates the most profitable level of production. If the price of milk fails to cover the marginal cost of producing it, output has to be cut back to lower marginal costs. The farmer caught in a cost-price squeeze has to lower marginal costs in order to maximize his profits.

Given a specific length of run, marginal costs can be varied for a previously perfectly adjusted farm only by adjusting the level at which the variable factors of production are applied to the fixed factors. In this instance, the adjustable factors are feed (over 95 percent) and closely associated inputs. The law of diminishing returns decreases the efficiency with which feed is utilized at high feeding rates. Lowering feeding rates is, therefore, a way of reducing both average variable and marginal costs of producing milk.

Average variable cost and marginal costs of production for the representative herds are presented in Tables 5 and 6, respectively. For the curves fitted to these data, see pages 24-26.

Average variable costs—their levels and importance to dairy farmers. Table 5 indicates that at least two adjustments other than in rate of feeding will reduce average variable costs of production. The first of these, increases in herd size, reduces average variable costs for a given quality of cow, although not significantly. The explanation is that, for the length of run in which only feed is variable, the associated variable cost of labor makes up such a small part of the total variable costs that only small parts of the economies to scale resulting from increasing herd size are included. The same is true of economies resulting from the use of pen type barns.

In longer lengths of run in which the entire savings in labor per cow can be considered as herd size is varied, the larger producer and the pen type barn would have a significant competitive advantage. Also, if average total costs (which include fixed costs) were figured, the significant advantages found by Wells (25) for the larger herds would show up.

A second factor, however, does influence variable costs significantly. It is the productive capacity of the cow. In longer lengths of run, productive capacity of cows can be varied. When feeding all roughage to the small herds, average variable costs can be reduced from $1.35 per hundredweight to $0.94 or less per hundredweight by changing from the lowest to the highest capacity cow considered in this study. For the larger herds at the same level of feeding, average variable cost can be reduced from $1.28 to $0.89 or less per hundredweight by making the same change in capacity of cow.

When only 80 percent of the total digestible nutrients (TDN) are supplied by roughage, average variable costs can be reduced from $1.54 to $1.21 by changing capacity of cows for the small herds and from $1.49 to $1.16 or less for the larger herds. Eighty percent of TDN from roughage is near the typical rate of feeding and is meaningful on the average farm.

The study tentatively indicates that if TDN intake is to be reduced much below the level resulting from an 80 percent, free-fed roughage ration, roughage as well as grain should be restricted in the case of higher producers.

TABLE 5—Average variable costs of producing fluid milk in the short run as influenced by percent of TDN from roughage, herd size, and capacity of cow, Detroit milkshed, October 1, 1951-September 30, 1952

Kind of barn and capacity of cows in pounds, 4% FCM per year	Herd size	Percent of TDN from roughage					
		100	90	80	70	60	50
Stanchion barns	*Numbers*	*Dollars*					
5,133 lb.	8.3	1.35	1.43	1.54	1.75	2.00	2.25
	12.9	1.31	1.39	1.51	1.73	1.97	2.23
	22.6	1.28	1.37	1.49	1.70	1.95	2.20
7,332 lb.	8.3	1.11*	1.31*	1.48	1.68	1.94	2.20
	12.9	1.09*	1.28*	1.45	1.66	1.91	2.17
	22.6	1.08*	1.28*	1.45	1.65	1.90	2.16
10,120 lb.	8.3	.94*	1.08*	1.21	1.36	1.57	1.85
	12.9	.90*	1.04*	1.17	1.32	1.53	1.81
	22.6	.89*	1.04*	1.16	1.31	1.52	1.80
Pen type barns 8,350 lb.	16.4	.89*	1.06	1.21	1.40	1.67	1.96

*Costs for these higher capacity cows could probably be lowered by restricting roughage as well as grain feeding at these low levels of feeding.

TABLE 6—Marginal costs of producing fluid milk in the short run as influenced by percent of TDN from roughage, herd size, and capacity of cow, Detroit milkshed, October 1, 1951-September 30, 1952

Kind of barn and capacity of cows in pounds, 4% FCM per year	Herd size	Percent of TDN from roughage				
		90	80	70	60	50
Stanchion barns	*Numbers*	*Dollars*				
5,133 lb.	8.3	1.76	1.91	2.83	3.74	9.54
	12.9	1.74	1.91	2.80	3.70	9.59
	22.6	1.74	1.90	2.77	3.69	9.41
7,332 lb.	8.3	2.72*	2.34	3.08	4.38	8.26
	12.9	2.72*	2.32	3.06	4.33	8.17
	22.6	2.70*	2.31	3.03	4.30	8.17
10,120 lb.	8.3	2.39*	1.96	2.28	2.98	4.41
	12.9	2.40*	1.95	2.25	2.94	4.34
	22.6	2.40*	1.94	2.24	2.92	4.32
Pen type barns 8,350 lb.	16.4	2.49*	2.00	2.60	3.86	6.89

*Costs for these higher capacity cows could probably be lowered by restricting roughage as well as grain intake at these low levels of feeding.

Marginal costs—their levels and importance to dairy farmers. The data on marginal costs are of more value to dairy farmers than those on average variable costs. If a farmer is faced with lower prices for milk (either because of a reduction in effective demand within his market or because of the ability of competing areas to put milk on his market at lower prices), it becomes important that he be able to reduce his marginal cost of producing milk.

The data indicate that the dairy operator, with cows of given capacity, can reduce marginal costs by lowering the level at which grain is fed both proportionally and absolutely. While the amount of grain fed decreases with the proportion of grain fed, roughage consumption increases at varying rates. This variation causes the marginal cost of milk production to appear to behave somewhat erratically with respect to the proportional level of grain feeding.

This erratic behavior, however, is more apparent than real as the marginal cost of producing milk behaves more plausibly when it is figured in relation to total milk production. Figs. 5, 6, and 7 present the marginal cost of producing milk for cows of three different productive capacities within herds of four different sizes.

The data in these two figures show clearly how marginal costs of producing milk can be reduced by feeding for lower output, principally by substituting roughage for grain. They do not show, however, the advantage of shifting from low to higher producers when faced with falling milk prices. In fact, the figures indicate that the *minimum marginal* cost of producing milk varies little with productive capacity of cow and size of herd. In regard to marginal costs, farmers with poor or small herds can weather price declines as long as farmers with good or excellent large herds. The farmers with good cows and large herds find their advantages in average variable and average total costs and the quantity of milk produced.

Table 5, for instance, shows one of the advantages of having high producing cows. Average variable costs were consistently low for higher producers, regardless of feeding levels. In other research at the Michigan Agricultural Experiment Station, Caul (5) investigated the productive worth of cows of different productive capacities.

In these investigations, the amount of milk, as well as the relationship between the price and cost of producing milk, proved important in determining productive worth. Low producing cows, capable of producing small quantities of milk at low marginal costs, turned out to be worth more for slaughter than for milk production; while higher producing cows, capable of producing more milk at the same low marginal cost, were worth more for milk production than for slaughter. This indicates the advisability of *marketing* low producers, even if they are capable of producing at marginal costs lower than the price of milk, and replacing such animals with higher producers.

Some inconsistencies appear, at first, to exist in the marginal cost pattern of Table 6 for different capacity cows at a given level of feeding. These difficulties probably arise from differences in breeds, appetites, and quantities consumed for different proportions of grain to roughage in the rations. This does not detract greatly from the supply response estimates, but it does prevent certain generalizations on cost behavior and proportion of grain to roughage in the ration.

Producers with cows of the next higher capacity (an ability to produce 7,332 pounds of 4 percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk) can produce in the short run at 1952 costs as long as the price of milk is approximately above $3.50 per hundredweight. If the price drops much below this, they logically: (1) dispose of their cows and go into alternative income opportunities;

(2) replace their cows with some of higher capacity, or (3) accept lower returns on other fixed assets.

If competition drives prices down lower yet, the producer has the same alternatives which existed for lower quality cows. By shifting to cows of a still higher productive capacity of 10,120 pounds of 4 percent fat-corrected milk, marginal costs can be reduced to a minimum of $1.94 per hundredweight.

However, at something less than $2.50 per hundredweight, such cows would become worth more for slaughter than for milk production; and the producer would be faced again with the three previously outlined alternatives. If unable to shift to cows of this higher quality, he too will have to accept lower returns on other fixed assets or dispose of his cattle and seek alternative sources of income.

CONTROLLING PRODUCTION FOR THE OPERATION OF A PRICE SUPPORT PROGRAM

Since World War II, a dairy price support program has been in existence. Apparently, this program is based on the following convictions: (1) The price determined in a free market for milk is too low to provide the farmer with a "fair" income; or (2) such prices are too unstable and subject to manipulation to permit orderly marketing and efficient adjustment of production. In any event, prices have often been supported above the equilibrium level. This has resulted in failures to clear the market and, perhaps, higher income for the producers concerned. In the case of price supports for dairy products, large quantities of butter have been put in government storage, and methods of reducing these stocks have been sought.

Two policy implications can be drawn from the data presented herein. *First,* the supply of milk is relatively inelastic in the Detroit milkshed in the short run. Rather wide adjustments in the price of fluid milk have proportionally less short-run effect on the quantity of milk produced. However, supplies should be expected to be more elastic when changes in the price support level are given more time to work themselves out; the supply response is more elastic in longer lengths of run when capacity of cow and herd size are variable.

The *second* implication has to do with proposals for controlling production to prevent misallocation of resources as surpluses build up. It may be suggested, as a remedy, that milk production be controlled by freezing herd sizes for individual producers. Production control based on this policy would be only partially effective in reducing the supply of milk.

Despite the inelasticity of the above supply estimates based on given herd sizes, the absolute supply of fluid milk can vary considerably. By feeding given-sized herds to heavy levels, production can be greatly increased. In addition, there is the possibility of shifting to higher producing cows.

On some farms, production could be doubled by replacing the low quality cows with cows of high inherent producing ability and buying more feed, unless feeding rates and productive capacity were also controlled. While high feeding rates in response to high support prices would probably be uneconomic, the shift to higher producers would probably be economic; hence, it ought not to be discouraged. Thus, in addition to freezing of herd sizes, contraction would be required to exert effective control of milk production.

Also, production controls of this type would further disrupt the productive efficiency of the system. It has been pointed out previously that increasing herd size is very effective in reducing average total costs. Thus, production controls based on contracted herd size would result in reduced efficiency.

FEDERAL MILK MARKETING ORDERS

Individual producers in a fluid milk area have little or no bargaining power when dealing with milk handlers. Their problem is further complicated by the fact that all milk produced in a fluid milkshed is not used for fluid purposes. Some part (the proportion varies with the season) is used for cream and manufactured products.

Federal milk marketing orders have been instituted, in part, to balance the bargaining power of the producer and the handler and to price raw milk so as to equate supply with demand. This study indicates that milk production, despite a somewhat inelastic supply curve, is quite responsive in an absolute sense to price changes. More specifically, data on the price necessary to call forth a given production from a given dairy cow population are provided. These data are supplemented by procedures for adjusting for year-to-year changes in cow population, inherent production ability, and input prices.

Use of such estimates in milk market administration can reduce the economic wastes resulting when prices are set too high or too low to bring forth the required production, guiding resources into the wrong channels of production. When this happens, the consumer suffers from not having his wants properly satisfied; the producer, from low incomes; and the taxpayer, from high taxes. Proper allocation of resources increases aggregative well-being in the economy by maximizing consumer satisfactions and producer incomes within a given distribution of assets, wants, preferences, and desires.

INTERREGIONAL COMPETITION

Appraisal of the interregional competitive position of milk producers in an area requires complete supply and demand analysis for the products and areas under consideration. More specifically, complete analysis of the cost of production and supply functions for the competing areas are required on the supply side. On the demand side, complete demand analyses for the product in its different uses in the different markets served by the competing producing areas are required.

This study has concentrated upon cost of production and supply responses in the Detroit milkshed. As such, the results are cornerstones in future work to be done on the competitive position of milk producers in the Detroit milkshed. However, the absence of data on the cost of production and supply responses in other areas (to say nothing of the dirth of demand analysis) prevents anything other than the most tentative conclusions concerning the competitive position of the Detroit milkshed milk producers.

SUMMARY AND CONCLUSIONS

The purpose of this study was to estimate a short-run supply curve for fluid milk in the Detroit milkshed. The short run considered deals with changes in production involving feeding levels and associated inputs. A mail survey was taken of the producers in the milkshed to determine the conditions under which fluid milk was produced with respect to herd size, average production per cow, and type of barn. The results of this survey were used in setting up 10 typical herds representing production conditions in the area and in determining their relative importance. Cost and supply estimates were secured by synthesizing the short-run marginal cost curves for the 10 typical herds in the Detroit milkshed and aggregating these curves into a short-run supply curve for the shed.

A marginal cost curve was estimated for each of these 10 herds by using a budget process and utilizing various sources of secondary data, some experimental in origin. In the short run, milk production for a herd is varied by changing the level of feeding, substituting grain for roughage and vice versa. The basic input-output relationships for constructing the marginal cost curves are from experimental data which treat grain and roughage as inputs and milk as a product. Certain other inputs (such as salt, minor equipment, various portions of labor, and electricity) are varied with the level of feeding and also must be considered. Data on these inputs were secured from a variety of experimental and survey sources.

On the assumption that the cows were fed all the hay they were able to eat, six alternative levels of grain feeding were studied. These ranged from a ration containing no grain to one in which 50 percent of the TDN was derived from grain. For each of these levels, the physical quantities of the various inputs and the amount of milk produced were determined. These quantities were multiplied by their respective prices and the results summed to determine the total variable cost of producing milk in this short length of run.

From this information, the marginal cost of producing 100 pounds of milk was determined by taking the change in variable costs from one level of feeding to the next and dividing by the change in milk production. The marginal cost so determined was an average marginal cost over the range from one feeding level to the next higher level. These costs were plotted and a smooth curve fitted to them. This curve yielded estimates of the marginal cost of each unit of output.

From the marginal cost data for each of the typical herds, the quantity of milk each type producer would supply at prices ranging from $2.40 to $6 per 100 was determined. The quantity at each price was multiplied by the number of producers represented by that typical herd. This was done for each of the 10 typical herds. The resulting production at each price was summed to get a supply curve for all of the producers in the Detroit milkshed. A consideration of both the individual marginal cost curves and the aggregate supply curve leads to the following general conclusions:

1. In short lengths of run, herd size does not significantly influence average variable and marginal cost of production.
2. Productive capacity of cows is a significant but uncontrollable factor influencing the average variable and marginal cost of production *in the short run.*
3. Both average variable and marginal cost of production can be reduced by lowering the rate of grain feeding.

4. High producing cows are more effective in reducing cost at low levels of feeding than at high levels. To avoid losses in times of low milk prices, it is relatively more important that farmers change from low to high producing cows than it is when milk prices are high. To make profits, it is always important to shift to high producers.
5. Within the length of run being considered, marginal costs can be varied by adjusting the level of grain feeding; high marginal costs being associated with high levels of feeding and conversely.
6. Generally, marginal costs of producing milk can be reduced in a somewhat longer length of run by moving from low to high producing cows. However, a categorical statement cannot be made; this is partly due to incompleteness and inadequacies in experimental data.
7. In the short run, elasticity of supply in the Detroit milkshed varies around .426, depending on the level of production.
8. Production controls based on restricting the herd size of the individual producer would be only partially effective in controlling the production of fluid milk. In addition to increasing feeding levels, production could be maintained by shifting to higher producers.
9. The production of fluid milk can be regulated by adjusting the price of milk and the cost of the inputs used in producing it.

APPENDIX

CALCULATING THE ELASTICITY OF SUPPLY

To SECURE mathematical expressions of elasticity at various points on the supply curves, it was necessary to express them algebraically. Since the supply relationships appear exponential, it was decided to fit a modification of the form $Y=aX^b$ where a and b are the parameters to be determined. This function is linear in its logarithmic form and can easily be fitted by ordinary least squares regression.

A slight modification of usual techniques for fitting this function was made to deal with the problem at hand. The axes were adjusted so that the curve was not forced through the origin. In unmodified form, the function exhibits constant elasticity throughout its range. By adjusting the axes in relation to the curve, the function was made to

(1) exhibit varying elasticities with respect to the original axes, and

(2) fit the data more precisely.

The elasticity at any point on the curve was then obtained by multiplying $\frac{dX}{dY}$ at the point by the inverse ratio of the coordinates (with respect to the original axis):

$$E=\frac{dX}{dY}\cdot\frac{Y}{X}$$

(The reader should be cautioned that Y is price, the *independent* variable; X is quantity supplied, the *dependent* variable. This is contrary to traditional procedures in placing dependent and independent variables on cartesian coordinates.)

APPENDIX TABLE 1—Annual feed inputs and milk production of dairy cows, production ability—5,133 pounds of milk, fed at different levels, 305-day lactation period, predominantly Holstein cows,† typical hay and pasture for the area, 1,200-pound cows,‡ 4 percent fat-corrected milk, Detroit milkshed, October 1, 1951-September 30, 1952§*

Level of feeding		TDN for milk production**	Hay††		Grain‡‡		Milk production
TDN¶ from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent	*Pounds*						
100	4,342	948	1,646	3,578	0	0	3,289
90	4,500	1,106	1,354	2,943	450	600	4,055
80	5,012	1,618	1,313	2,854	1,003	1,337	5,222
70	5,725	2,331	1,311	2,850	1,718	2,990	6,277
60	6,455	3,061	1,171	2,546	2,588	3,450	7,166
50	6,795	3,401	705	1,532	3,394	4,525	7,416

SOURCE: Synthesized from data reported in U.S. Department of Agriculture Technical Bulletin No. 815.

*Producing ability of the cows is adjusted to 5,133 pounds of 4 percent fat-corrected milk when fed 1 pound of grain for each 4 pounds of milk produced.

†Guernseys, Jerseys, Ayrshire, Red Polled, and mixed breeds are present.

‡Maintenance requirement is 3,394 pounds of total digestible nutrients.

§Pasture and silage were held constant over all feeding levels.
  a. Pasture consisted of 100 days supplying 14 pounds of total digestible nutrients a day and 50 days supplying 4 pounds of total digestible nutrients a day for a total of 1,600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent bluegrass.
  b. Silage was fed at the rate of 30 pounds daily for the 215 days not on pasture. It consisted of 17 percent total digestible nutrients by weight for a total of 1,096 nutrients.

¶Total digestible nutrients.

**Total digestible nutrients supplied by rations minus maintenance requirement.

††Hay consists of average quality mixed hay furnishing 46 percent total digestible nutrients by weight (assumes they eat only 92 percent of what is fed). Hay is made up of 30 percent alfalfa, 20 percent clover, 37.5 percent brome, and 12.5 percent timothy.

‡‡Grain ration is 75 percent total digestible nutrients by weight. The grain ration consists of 40 percent corn and cob meal, 20 percent shelled corn, 20 percent oats, and 20 percent soybean oil meal.

APPENDIX TABLE 2—Annual feed inputs and milk production of dairy cows, production ability—7,332 pounds of milk, fed at different levels, 305-day lactation period, predominantly Holstein cows,† typical hay and pasture for the area, 1,200-pound cows, ‡ 4 percent fat-corrected milk, Detroit milkshed, October 1, 1951-September 30, 1952§*

Level of feeding		TDN for milk production**	Hay††		Grain‡‡		Milk production
TDN¶ from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent	*Pounds*						
100	4,991	1,597	2,295	4,989	0	0	5,222
90	5,375	1,981	2,139	4,650	540	720	5,945
80	6,010	2,616	2,114	4,596	1,200	1,600	7,112
70	6,740	3,346	2,019	4,389	2,025	2,700	8,166
60	7,560	4,166	1,842	4,004	3,022	4,030	9,027
50	8,090	4,696	1,352	2,939	4,042	5,390	9,416

SOURCE: Synthesized from data reported in U.S. Department of Agriculture Technical Bulletin No. 815.

*Producing ability of the cows is adjusted to 7,332 pounds of 4 percent fat-corrected milk when fed 1 pound of grain for each 4 pounds of milk produced.

†Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

‡Maintenance requirement is 3,394 pounds of total digestible nutrients.

§Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying 14 pounds of total digestible nutrients a day and 50 days supplying 4 pounds of total digestible nutrients a day for a total of 1,600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent bluegrass.
b. Silage was fed at the rate of 30 pounds daily for the 215 days not on pasture. It consisted of 17 percent total digestible nutrients by weight for a total of 1,096 nutrients.

¶Total digestible nutrients.

**Total digestible nutrients supplied by rations minus maintenance requirement.

††Hay consists of average quality mixed hay furnishing 46 percent total digestible nutrients by weight (assumes they eat only 92 percent of what is fed). Hay is made up of 30 percent alfalfa, 20 percent clover, 37.5 percent brome, and 12.5 percent timothy.

‡‡Grain ration is 75 percent total digestible nutrients by weight. The grain ration consists of 40 percent corn and cob meal, 20 percent shelled corn, 20 percent oats, and 20 percent soybean oil meal.

APPENDIX TABLE 3—Annual feed inputs and milk production of dairy cows, production ability—8,350 pounds of milk, fed at different levels, 305-day lactation period, predominantly Holstein cows,† typical hay and pasture for the area, 1,200-pound cows,‡ 4 percent fat-corrected milk, Detroit milkshed, October 1, 1951-September 30, 1952§*

Level of feeding		TDN for milk production**	Hay††		Grain‡‡		Milk production
TDN¶ from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent	*Pounds*						
100	4,866	1,472	2,170	4,717	0	0	5,732
90	5,150	1,756	1,939	4,215	515	687	6,444
80	5,712	2,318	1,872	4,070	1,144	1,525	7,667
70	6,470	3,076	1,834	3,986	1,940	2,587	8,888
60	7,450	4,056	1,773	3,854	2,981	3,975	9,945
50	8,276	4,882	1,436	3,121	4,144	5,525	10,527

SOURCE: Synthesized from data reported in U.S. Department of Agriculture Technical Bulletin No. 815.

*Producing ability of the cows is adjusted to 8,350 pounds of 4 percent fat-corrected milk when fed 1 pound of grain for each 4 pounds of milk produced.

†Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

‡Maintenance requirement is 3,394 pounds of total digestible nutrients.

§Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying 14 pounds of total digestible nutrients a day and 50 days supplying 4 pounds of total digestible nutrients a day for a total of 1,600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent bluegrass.

b. Silage was fed at the rate of 30 pounds daily for the 215 days not on pasture. It consisted of 17 percent total digestible nutrients by weight for a total of 1,096 nutrients.

¶Total digestible nutrients.

**Total digestible nutrients supplied by rations minus maintenance requirement.

††Hay consists of average quality mixed hay furnishing 46 percent total digestible nutrients by weight (assumes they eat only 92 percent of what is fed). Hay is made up of 30 percent alfalfa, 20 percent clover, 37.5 percent brome, and 12.5 percent timothy.

‡‡Grain ration is 75 percent total digestible nutrients by weight. The grain ration consists of 40 percent corn and cob meal, 20 percent shelled corn, 20 percent oats, and 20 percent soybean oil meal.

APPENDIX TABLE 4—Annual feed inputs and milk production of dairy cows, production ability—10,120 pounds of milk, fed at different levels, 305-day lactation period, predominantly Holstein cows,† typical hay and pasture for the area, 1,200-pound cows,‡ 4 percent fat-corrected milk, Detroit milkshed, October 1, 1951-September 30, 1952§*

Level of feeding		TDN for milk production**	Hay††		Grain‡‡		Milk production
TDN¶ from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent			*Pounds*				
100	5,172	1,778	2,476	5,382	0	0	6,888
90	5,422	2,028	2,182	4,743	544	725	7,611
80	5,955	2,561	2,069	4,498	1,190	1,587	8,888
70	6,700	3,306	1,998	4,343	2,006	2,675	10,333
60	7,775	4,381	1,967	4,276	3,112	4,150	11,862
50	9,110	5,716	1,858	4,039	4,556	6,075	13,166

SOURCE: Synthesized from data reported in U.S. Department of Agriculture Technical Bulletin No. 815.

*Producing ability of the cows is adjusted to 10,120 pounds of 4 percent fat-corrected milk when fed 1 pound of grain for each 4 pounds of milk produced.

†Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

‡Maintenance requirement is 3,394 pounds of total digestible nutrients.

§Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying 14 pounds of total digestible nutrients a day and 50 days supplying 4 pounds of total digestible nutrients a day for a total of 1,600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent bluegrass.
b. Silage was fed at the rate of 30 pounds daily for the 215 days not on pasture. It consisted of 17 percent total digestible nutrients by weight for a total of 1,096 nutrients.

¶Total digestible nutrients.

**Total digestible nutrients supplied by rations minus maintenance requirement.

††Hay consists of average quality mixed hay furnishing 46 percent total digestible nutrients by weight (assumes they eat only 92 percent of what is fed). Hay is made up of 30 percent alfalfa, 20 percent clover, 37.5 percent brome, and 12.5 percent timothy.

‡‡Grain ration is 75 percent total digestible nutrients by weight. The grain ration consists of 40 percent corn and cob meal, 20 percent shelled corn, 20 percent oats, and 20 percent soybean oil meal.

APPENDIX TABLE 5—Salt used per cow annually at different feeding levels, four qualities of cows, Detroit milkshed, October 1, 1951-September 30, 1952*

Feeding level (percent TDN) from roughage	Average production capacity of cow			
	5,133 pounds†	7,332 pounds†	8,350 pounds†	10,120 pounds†
	Pounds			
100	26.6	30.3	31.3	33.4
90	28.1	31.6	32.6	34.8
80	30.3	33.8	34.9	37.1
70	32.3	35.8	37.2	39.9
60	33.9	37.4	39.1	42.7
50	34.4	38.2	40.2	45.2

*These amounts are based on a requirement of .75 ounce of salt daily per 1,000 pounds live weight, plus .3 ounce in addition for each 10 pounds of milk produced. Morrison, F. B. (1950). *Feeds and Feeding.* The Morrison Publishing Company, Ithaca. 1190 pp.

†These quantities are the production per cow when fed at the rate of 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 6—Labor requirements, hours per cow per year, 8.3-cow herd, stanchion barn averaging 5,133 pounds of milk, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	6.52	6.52	6.52	6.52	6.52	6.52
Feeding silage...............	6.85	6.85	6.85	6.85	6.85	6.85
Cleaning mangers and cleaning and bedding barn.......	16.30	16.30	16.30	16.30	16.30	16.30
Tying and untying cows and putting in and out of barn...	8.59	8.59	8.59	8.59	8.59	8.59
Miscellaneous...............	6.85	6.85	6.85	6.85	6.85	6.85
Milking machine preparation..	10.10	10.10	10.10	10.10	10.10	10.10
Idle time and waiting.........	7.17	7.17	7.17	7.17	7.17	7.17
Washing udders, strip testing, and stripping.............	13.37	13.37	13.37	13.37	13.37	13.37
Total of this section....	75.75	75.75	75.75	75.75	75.75	75.75
Jobs that vary with feeding level:						
Feeding hay.................	4.74	4.49	4.45	4.45	4.33	3.93
Feeding grain...............	0	1.35	2.58	4.16	6.09	7.89
Preparing equipment.........	9.61	9.85	10.21	10.54	10.82	10.90
Pouring up milk and handling.	1.34	1.87	2.12	3.13	3.98	4.22
Milking machine operation....	7.62	8.00	8.70	9.33	9.86	9.88
Idle time and waiting.........	1.24	1.01	.66	.34	.07	0
Total of this section......	24.55	26.57	28.72	31.95	35.15	36.82
Total of both sections....	100.30	102.32	104.47	107.70	110.90	112.57

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 7—Labor requirements, hours per cow per year, 8.3-cow herd, stanchion barn, averaging 7,332 pounds of milk, Detroit milk-shed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
Jobs that vary with herd size but not with feeding level:	*Hours*					
Moving equipment and wash water to and from barn.....	6.52	6.52	6.52	6.52	6.52	6.52
Feeding silage...............	6.85	6.85	6.85	6.85	6.85	6.85
Cleaning mangers and cleaning and bedding barn.......	16.30	16.30	16.30	16.30	16.30	16.30
Tying and untying cows and putting in and out of barn...	8.59	8.59	8.59	8.59	8.59	8.59
Miscellaneous...............	6.85	6.85	6.85	6.85	6.85	6.85
Milking machine preparation..	10.10	10.10	10.10	10.10	10.10	10.10
Idle time and waiting.........	7.17	7.17	7.17	7.17	7.17	7.17
Washing udders, strip testing, and stripping..............	13.37	13.37	13.37	13.37	13.37	13.37
Total of this section......	75.75	75.75	75.75	75.75	75.75	75.75
Jobs that vary with feeding level:						
Feeding hay.................	5.29	5.15	5.13	5.05	4.90	4.47
Feeding grain...............	0	1.51	2.98	4.81	7.02	9.29
Preparing equipment.........	10.20	10.43	10.80	11.13	11.40	11.52
Pouring up milk and handling.	2.12	2.81	3.92	4.93	5.75	6.12
Milking machine operation....	7.62	7.99	8.69	9.32	9.84	10.07
Idle time and waiting.........	1.29	1.07	.72	.40	.28	0
Total of this section......	26.52	28.96	32.24	35.64	39.19	41.47
Total of both sections....	102.27	104.71	107.99	111.39	114.94	117.22

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 8—Labor requirements, hours per cow per year, 8.3-cow herd, stanchion barn, averaging 10,120 pounds of milk, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
Jobs that vary with herd size but not with feeding level:	*Hours*					
Moving equipment and wash water to and from barn	6.52	6.52	6.52	6.52	6.52	6.52
Feeding silage	6.85	6.85	6.85	6.85	6.85	6.85
Cleaning mangers and cleaning and bedding barn	16.30	16.30	16.30	16.30	16.30	16.30
Tying and untying cows and putting in and out of barn	8.59	8.59	8.59	8.59	8.59	8.59
Miscellaneous	6.85	6.85	6.85	6.85	6.85	6.85
Milking machine preparation	10.10	10.10	10.10	10.10	10.10	10.10
Idle time and waiting	7.17	7.17	7.17	7.17	7.17	7.17
Washing udders, strip testing, and stripping	13.37	13.37	13.37	13.37	13.37	13.37
Total of this section	75.75	75.75	75.75	75.75	75.75	75.75
Jobs that vary with feeding level:						
Feeding hay	5.45	5.19	5.09	5.03	5.00	4.91
Feeding grain	0	1.69	3.13	4.94	7.40	10.61
Preparing equipment	10.73	10.96	11.36	11.82	12.30	12.71
Pouring up milk and handling	3.71	4.40	5.62	7.00	8.46	9.71
Milking machine operation	7.62	7.95	8.15	9.01	9.93	10.71
Idle time and waiting	1.66	1.44	1.06	.63	.18	0
Total of this section	29.17	31.63	34.41	38.43	43.27	48.65
Total both sections	104.92	107.38	110.16	114.18	119.02	124.40

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 9—Labor requirements, hours per cow per year, 12.9-cow herd, averaging 5,133 pounds of milk, Detroit milkshed, October 1, 1, 1951-September 30, 1952*

Jobs	Feeding level† 100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	5.85	5.85	5.85	5.85	5.85	5.85
Feeding silage...............	6.15	6.15	6.15	6.15	6.15	6.15
Cleaning mangers and cleaning and bedding barn.......	14.64	14.64	14.64	14.64	14.64	14.64
Tying and untying cows and putting in and out of barn...	7.71	7.71	7.71	7.71	7.71	7.71
Miscellaneous...............	6.15	6.15	6.15	6.15	6.15	6.15
Milking machine preparation..	9.11	9.11	9.11	9.11	9.11	9.11
Idle time and waiting.........	6.44	6.44	6.44	6.44	6.44	6.44
Washing udders, strip testing, and stripping.............	12.00	12.00	12.00	12.00	12.00	12.00
Total of this section......	68.05	68.05	68.05	68.05	68.05	68.05
Jobs that vary with feeding levels:						
Feeding hay.................	4.27	4.06	4.03	4.03	3.93	3.59
Feeding grain...............	0	1.32	2.46	3.55	4.88	6.11
Preparing equipment.........	8.81	8.99	9.28	9.51	9.72	10.46
Pouring up milk and handling	1.07	1.26	1.80	2.75	3.55	3.78
Milking machine operation....	6.79	7.22	7.86	8.44	8.93	9.07
Idle time and waiting.........	1.00	.82	.54	.28	.06	0
Total of this section......	21.94	23.67	25.97	28.56	31.07	33.01
Total of both sections....	89.99	91.72	94.00	96.61	99.12	101.06

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 10—Labor requirements, hours per cow per year, 12.9-cow herd, averaging 7,332 pounds of milk, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	5.85	5.85	5.85	5.85	5.85	5.85
Feeding silage...............	6.15	6.15	6.15	6.15	6.15	6.15
Cleaning mangers and cleaning and bedding barn.......	14.64	14.64	14.64	14.64	14.64	14.64
Tying and untying cows and putting in and out of barn...	7.71	7.71	7.71	7.71	7.71	7.71
Miscellaneous...............	6.15	6.15	6.15	6.15	6.15	6.15
Milking machine preparation..	9.11	9.11	9.11	9.11	9.11	9.11
Idle time and waiting.........	6.44	6.44	6.44	6.44	6.44	6.44
Washing udders, strip testing, and stripping.............	12.00	12.00	12.00	12.00	12.00	12.00
Total of this section......	68.05	68.05	68.05	68.05	68.05	68.05
Jobs that vary with feeding level:						
Feeding hay.................	4.74	4.63	4.61	4.54	4.41	4.05
Feeding grain...............	0	1.47	2.76	4.02	5.54	7.09
Preparing equipment.........	9.41	9.58	9.71	9.96	10.16	10.25
Pouring up milk and handling.	1.80	2.45	3.50	4.64	5.41	5.76
Milking machine operation....	6.79	7.17	7.75	8.28	8.71	8.90
Idle time and waiting.........	1.22	1.00	.65	.33	.21	0
Total of this section......	23.96	26.30	28.98	31.77	34.44	36.05
Total of both sections....	92.01	94.35	97.03	99.82	102.49	104.10

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 11—Labor requirements, hours per cow per year, 12.9-cow herd, averaging 10,120 pounds of milk, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	5.85	5.85	5.85	5.85	5.85	5.85
Feeding silage...............	6.15	6.15	6.15	6.15	6.15	6.15
Cleaning mangers and cleaning and bedding barn.......	14.64	14.64	14.64	14.64	14.64	14.64
Tying and untying cows and putting in and out of barn...	7.71	7.71	7.71	7.71	7.71	7.71
Miscellaneous...............	6.15	6.15	6.15	6.15	6.15	6.15
Milking machine preparation..	9.11	9.11	9.11	9.11	9.11	9.11
Idle time and waiting.........	6.44	6.44	6.44	6.44	6.44	6.44
Washing udders, strip testing, and stripping.............	12.00	12.00	12.00	12.00	12.00	12.00
Total of this section......	68.05	68.05	68.05	68.05	68.05	68.05
Jobs that vary with feeding level:						
Feeding hay.................	4.86	4.65	4.57	4.52	4.50	4.42
Feeding grain...............	0	1.66	2.71	3.95	5.64	7.84
Preparing equipment.........	9.66	9.83	10.13	10.47	10.83	11.14
Pouring up milk and handling.	3.30	3.95	5.10	6.40	7.77	8.94
Milking machine operation....	6.79	7.16	7.54	7.97	8.43	8.82
Idle time and waiting.........	1.26	1.12	.86	.57	.27	0
Total of this section......	25.87	28.37	30.91	33.88	37.44	41.16
Total of both sections....	93.92	96.42	98.96	101.93	105.49	109.21

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 12—Labor requirements, hours per cow per year, 22.6-cow herd, averaging 5,331 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	5.26	5.26	5.26	5.26	5.26	5.26
Feeding silage...............	5.52	5.52	5.52	5.52	5.52	5.52
Cleaning mangers and cleaning and bedding barn.......	13.15	13.15	13.15	13.15	13.15	13.15
Tying and untying cows and putting in and out of barn...	6.93	6.93	6.93	6.93	6.93	6.93
Miscellaneous...............	5.52	5.52	5.52	5.52	5.52	5.52
Milking machine preparation..	8.15	8.15	8.15	8.15	8.15	8.15
Idle time and waiting.........	5.79	5.79	5.79	5.79	5.79	5.79
Washing udders, strip testing, and stripping..............	10.79	10.79	10.79	10.79	10.79	10.79
Total of this section......	61.11	61.11	61.11	61.11	61.11	61.11
Jobs that vary with feeding level:						
Feeding hay.................	3.94	3.81	3.79	3.79	3.73	3.53
Feeding grain...............	0	1.31	2.38	3.06	4.10	5.05
Preparing equipment.........	7.97	8.12	8.35	8.56	8.74	8.79
Pouring up milk and handling	1.02	1.22	1.56	2.45	3.20	3.41
Milking machine operation....	6.15	6.61	7.19	7.72	8.16	8.28
Idle time and waiting.........	.86	.71	.48	.29	.11	0
Total of this section......	19.94	21.78	23.75	25.87	28.04	29.06
Total of both sections....	81.05	82.89	84.86	86.98	89.15	90.17

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 13—Labor requirements, hours per cow per year, 22.6-cow herd averaging 7,332 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
Jobs that vary with herd size but not with feeding level:	*Hours*					
Moving equipment and wash water to and from barn.....	5.26	5.26	5.26	5.26	5.26	5.26
Feeding silage...............	5.52	5.52	5.52	5.52	5.52	5.52
Cleaning mangers and cleaning and bedding barn.......	13.15	13.15	13.15	13.15	13.15	13.15
Tying and untying cows and putting in and out of barn...	6.93	6.93	6.93	6.93	6.93	6.93
Miscellaneous...............	5.52	5.52	5.52	5.52	5.52	5.52
Milking machine preparation..	8.15	8.15	8.15	8.15	8.15	8.15
Idle time and waiting.........	5.79	5.79	5.79	5.79	5.79	5.79
Washing udders, strip testing, and stripping..............	10.79	10.79	10.79	10.79	10.79	10.79
Total of this section......	61.11	61.11	61.11	61.11	61.11	61.11
Jobs that vary with feeding level:						
Feeding hay.................	4.21	4.14	4.13	4.08	3.91	3.83
Feeding grain...............	0	1.45	2.51	3.50	4.70	5.92
Preparing equipment.........	8.36	8.50	8.73	8.94	9.11	9.19
Pouring up milk and handling.	1.56	2.17	3.15	4.03	4.75	5.07
Milking machine operation....	6.15	6.44	7.02	7.55	7.98	8.17
Idle time and waiting.........	.94	.80	.57	.32	.15	0
Total of this section......	21.22	23.50	26.11	28.42	30.60	32.18
Total of both sections....	82.33	84.61	87.22	89.53	91.71	93.29

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 14—Labor requirements, hours per cow per year, 22.6-cow herd, averaging 10,120 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	5.26	5.26	5.26	5.26	5.26	5.26
Feeding silage...............	5.52	5.52	5.52	5.52	5.52	5.52
Cleaning mangers and cleaning and bedding barn.......	13.15	13.15	13.15	13.15	13.15	13.15
Tying and untying cows and putting in and out of barn...	6.93	6.93	6.93	6.93	6.93	6.93
Miscellaneous...............	5.52	5.52	5.52	5.52	5.52	5.52
Milking machine preparation..	8.15	8.15	8.15	8.15	8.15	8.15
Idle time and waiting.........	5.79	5.79	5.79	5.79	5.79	5.79
Washing udders, strip testing, and stripping..............	10.79	10.79	10.79	10.79	10.79	10.79
Total of this section......	61.11	61.11	61.11	61.11	61.11	61.11
Jobs that vary with feeding level:						
Feeding hay.................	4.30	4.17	4.12	4.09	4.08	4.03
Feeding grain...............	0	1.63	2.50	3.48	4.81	6.54
Preparing equipment.........	8.71	8.85	9.10	9.39	9.69	9.91
Pouring up milk and handling.	2.85	3.56	4.64	5.86	7.15	8.08
Milking machine operation....	6.15	6.42	6.80	7.23	7.69	8.08
Idle time and waiting.........	1.21	1.07	.81	.52	.22	0
Total of this section......	23.22	25.70	27.97	30.57	33.64	36.64
Total of both sections....	84.33	86.81	89.08	91.68	94.75	97.75

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 15—Labor requirements, hours per cow per year, 16.4-cow herd, averaging 8,350 pounds of milk, pen type barn, Detroit milk-shed, October 1, 1951-September 30, 1952*

Jobs	Feeding level†					
	100	90	80	70	60	50
	Hours					
Jobs that vary with herd size but not with feeding level:						
Moving equipment and wash water to and from barn.....	3.89	3.89	3.89	3.89	3.89	3.89
Feeding silage..............	3.24	3.24	3.24	3.24	3.24	3.24
Cleaning mangers and cleaning and bedding barn.......	8.24	8.24	8.24	8.24	8.24	8.24
Tying and untying cows and putting in and out of barn...	12.36	12.36	12.36	12.36	12.36	12.36
Miscellaneous...............	6.56	6.56	6.56	6.56	6.56	6.56
Milking machine preparation..	5.89	5.89	5.89	5.89	5.89	5.89
Idle time and waiting.........	2.64	2.64	2.64	2.64	2.64	2.64
Washing udders, strip testing, and stripping..............	6.56	6.56	6.56	6.56	6.56	6.56
Total of this section......	49.38	49.38	49.38	49.38	49.38	49.38
Jobs that vary with feeding level:						
Feeding hay.................	3.23	3.13	3.10	3.08	3.05	2.90
Feeding grain...............	0	2.79	3.55	4.51	5.76	7.15
Preparing equipment.........	7.96	8.10	8.34	8.59	8.80	8.92
Pouring up milk and handling.	1.32	1.70	2.33	3.36	4.25	4.74
Milking machine operation....	4.44	4.73	5.22	5.71	6.13	6.36
Idle time and waiting.........	1.07	.93	.69	.44	.23	0
Total of this section......	18.02	21.38	23.23	25.69	28.22	30.07
Total of both sections....	67.40	70.76	72.61	75.07	77.60	79.45

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Four percent fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

†Percent of total digestible nutrients from roughage.

APPENDIX TABLE 16—Some labor requirements for jobs varying with feeding level, stanchion barn, hours per cow per year, different herd sizes, Detroit milkshed, October 1, 1951-September 30, 1952*

Jobs	Herd size		
	8.3	12.9	22.6
		Hours	
Handling 150 pounds of hay	.06	.05	.03
Handling 600 pounds of grain	1.00	.60	.54
Preparing equipment for 700 pounds additional milk	.22	.16	.14
Pouring up and handling 700 pounds additional milk	.67	.63	.59

SOURCE: Synthesized from data secured from sources indicated on page 20.

*Labor requirements for pen type barns with 16.4-cow herds are the same as the labor requirements for stanchion barns with 22.6-cow herds.

APPENDIX TABLE 17—Fertilizer elements reaching fields from manure, various quality cows, Detroit milkshed, October 1, 1951-September 30, 1952

Capacity* and nutrient	Feeding level (percent TDN from roughage)					
	100	90	80	70	60	50
			Pounds			
5,133						
N	31.76	33.71	42.24	54.25	66.18	70.80
P	5.14	5.47	6.87	8.84	10.80	11.57
K	53.56	46.97	49.23	53.80	54.80	44.94
7,332						
N	44.28	50.38	61.02	73.09	86.49	94.23
P	7.17	8.17	9.92	11.90	14.10	15.38
K	74.68	73.11	76.58	78.84	79.54	70.21
8,350						
N	47.85	52.68	63.32	77.81	96.53	111.49
P	6.78	7.48	9.00	11.08	13.77	15.92
K	70.61	66.44	68.34	72.25	77.03	73.59
10,120						
N	47.77	51.27	59.99	72.37	90.42	112.65
P	7.73	8.31	9.75	11.78	14.74	18.38
K	80.57	74.53	75.05	78.02	84.20	90.01

SOURCE: Synthesized from secondary data based on the composition of feeds and the percentage reaching the fields as indicated by Morrison, F. B. (1950). *Feeds and Feeding.* The Morrison Publishing Company, Ithaca. 1190 pp.

*Amount of 4 percent fat-corrected milk produced when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 18—Prices for October 1951-September 1952, Detroit milkshed

Item	Unit	Price
Shelled corn*.........	70 pounds.......	$1.69
Corn and cob†.........	70 pounds.......	1.62
Oats†................	32 pounds.......	.83
Soybean oil meal‡.....	100 pounds.......	5.58
Grain ration§.........	100 pounds.......	3.04
Milk cans‡...........	10-gallon can.....	10.62
Stock salt‡...........	100 pounds.......	1.42
Hay¶................	100 pounds.......	1.06
Nitrogen‡............	pound...........	.13
Phosphorous‡.........	pound...........	.09
Potassium‡...........	pound...........	.06
Shelling corn**........	bushel...........	.07
Crushing corn**.......	80-pound bag.....	.10
Electricity‡...........	kilowatt hour......	.028
Labor††.............	hour.............	.50

*A 7-cent charge per bushel is added to the cost of a bushel of corn and cob meal to cover shelling charges.

†The average monthly price is weighted according to estimated use in the dairy enterprise: a 9 percent weighting for October through April, and a 7.4 percent weighting for May through September.

‡For these inputs with little or no seasonal variation in price or use, the average of the average quarterly price as secured from the Michigan agricultural statistician's office is used.

§Based on a grain ration made up of 40 percent corn and cob meal, 20 percent shelled corn, 20 percent oats, and 20 percent soybean oil meal.

¶Hay consists of 30 percent alfalfa, 20 percent red clover, 37.5 percent brome, and 12.5 percent timothy. The average monthly prices for hay were weighted at 15 percent for November through March, and 12.5 percent for October and April.

**Based on usual custom charges in Michigan; Vary, K.A.(1953). Rates for custom work in Michigan, 1952 and 1953. Mich. State Univ. Ext. Folder 161. 8 pp.

††Based on the approximate on-farm opportunity cost on Michigan dairy farms.

APPENDIX TABLE 19—Variable cost, feed and associated inputs variable, 8.3-cow herd, average 5,133 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	151.39	337.35	577.81	870.50	1,141.76
Corn crushing	....	4.98	11.10	19.01	28.64	37.56
Electricity	12.10	13.99	16.87	19.48	21.68	22.30
Hay	314.79	258.93	251.09	250.74	224.00	134.79
Labor	101.88	110.26	119.19	132.59	145.87	152.80
Milk cans	1.70	1.70	1.70	1.70	1.70	1.70
Salt	3.14	3.31	3.57	3.80	4.00	4.05
Total variable costs	433.61	544.56	740.87	1,005.13	1,296.39	1,494.96
Manure credit	64.78	63.85	75.23	91.93	106.81	107.41
Net variable costs	368.83	480.71	665.64	913.20	1,189.58	1,387.55
Average variable costs	1.35	1.43	1.54	1.75	2.00	2.25
Marginal cost per hundredweight	....	1.76	1.91	2.83	3.74	9.54

SOURCE: Synthesized from secondary data presented herein.

*5,133 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 20—Variable costs, feed and associated inputs variable, 12.9-cow herd, average 5,133 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	235.30	524.31	898.05	1,352.95	1,774.51
Corn crushing	....	7.74	17.25	29.54	44.50	58.37
Electricity	18.80	21.74	26.22	30.27	33.49	34.45
Hay	489.25	402.43	390.26	389.71	348.14	209.49
Labor	141.52	152.67	167.38	184.21	200.40	212.92
Milk cans	3.40	3.40	3.40	3.40	3.40	3.40
Salt	4.88	5.15	5.55	5.91	6.22	6.30
Total variable costs	657.85	828.43	1,134.37	1,541.09	1,989.10	2,299.44
Manure credit	100.69	99.23	116.92	142.88	166.00	166.94
Net variable costs	557.16	729.20	1,017.45	1,398.21	1,823.10	2,132.50
Average variable costs	1.31	1.39	1.51	1.73	1.97	2.23
Marginal cost per hundredweight	....	1.74	1.91	2.80	3.70	9.59

SOURCE: Synthesized from secondary data presented herein.

*5,133 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 21—Variable costs, feed and associated inputs variable, 22.6-cow herd, average 5,133 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	412.22	918.57	1,573.32	2,370.29	3,108.86
Corn crushing	....	13.56	30.22	51.75	77.97	102.26
Electricity	32.93	38.09	45.94	53.04	59.02	60.70
Hay	857.15	705.03	683.70	682.75	609.92	367.00
Labor	225.32	246.12	268.38	292.33	316.85	328.38
Milk cans	5.10	5.10	5.10	5.10	5.10	5.10
Salt	8.56	9.02	9.72	10.36	10.89	11.04
Total variable costs	1,129.06	1,429.14	1,961.63	2,668.65	3,450.04	3,983.34
Manure credit	176.39	173.85	204.83	250.32	290.71	292.48
Net variable costs	952.67	1,255.29	1,756.80	2,418.33	3,159.33	3,690.86
Average variable costs	1.28	1.37	1.49	1.70	1.95	2.20
Marginal cost per hundredweight	....	1.75	1.90	2.77	3.69	9.41

SOURCE: Synthesized from secondary data presented herein.

*5,133 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 22—Variable costs, feed and associated inputs variable, 8.3-cow herd, average 7,332 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	181.73	403.71	681.26	1,016.85	1,360.00
Corn crushing	....	5.98	13.28	22.41	33.45	44.74
Electricity	17.32	19.11	21.99	24.59	26.72	27.68
Hay	439.35	409.11	404.36	386.15	352.27	258.58
Labor	110.06	120.18	133.80	147.90	162.64	172.10
Milk cans	2.55	2.55	2.55	2.55	2.55	2.55
Salt	3.57	3.73	3.99	4.22	4.41	4.50
Total variable costs	572.85	742.39	983.68	1,269.08	1,598.89	1,870.15
Manure credit	90.33	96.87	111.39	127.01	143.46	148.12
Net variable costs	482.52	645.52	872.29	1,142.07	1,455.43	1,722.03
Average variable costs	1.11	1.31	1.48	1.68	1.94	2.20
Marginal cost per hundredweight	....	2.72	2.34	3.08	4.38	8.26

SOURCE: Synthesized from secondary data presented herein.

*7,332 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 23—Variable costs, feed and associated inputs variable, 12.9-cow herd, average 7,332 pounds milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
			Dollars			
Concentrates...........	....	282.36	627.46	1,058.83	1,580.40	2,113.74
Corn crushing..........	....	9.29	20.64	34.83	51.99	69.53
Electricity.............	26.92	29.70	34.18	38.23	41.54	43.03
Hay....................	682.19	635.84	628.45	600.15	547.51	401.88
Labor..................	154.54	169.64	186.92	204.92	222.14	232.52
Milk cans..............	3.40	3.40	3.40	3.40	3.40	3.40
Salt...................	5.55	5.79	6.20	6.56	6.85	6.99
Total variable costs.	872.60	1,136.02	1,507.25	1,946.92	2,453.83	2871.09
Manure credit..........	140.38	150.56	173.12	197.41	222.97	230.22
Net variable costs..	732.22	985.46	1,334.13	1,749.51	2,230.86	2,640.87
Average variable costs..	1.09	1.28	1.45	1.66	1.91	2.17
Marginal cost per hundredweight.......	....	2.72	2.32	3.06	4.33	8.17

SOURCE: Synthesized from secondary data presented herein.

*7,332 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 24—Variable costs, feed and associated inputs variable, 22.6-cow herd, average 7,332 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	494.67	1,099.26	1,855.01	2,768.77	3,703.14
Corn crushing	....	16.27	36.16	61.02	91.08	121.81
Electricity	71.36	74.23	82.08	89.17	94.96	97.58
Hay	1,195.16	1,113.95	1,101.02	1,051.42	959.19	704.06
Labor	239.78	265.55	295.04	321.14	345.78	363.64
Milk cans	5.95	5.95	5.95	5.95	5.95	5.95
Salt	9.72	10.16	10.86	11.49	12.00	12.25
Total variable costs	1,521.97	1,980.78	2,630.37	3,395.20	4,277.73	5,008.43
Manure credit	245.94	263.78	303.30	345.85	390.65	403.33
Net variable costs	1,276.03	1,717.00	2,327.07	3,049.35	3,887.08	4,605.10
Average variable costs	1.08	1.28	1.45	1.65	1.90	2.16
Marginal cost per hundredweight	....	2.70	2.31	3.03	4.30	8.17

SOURCE: Synthesized from secondary data presented herein.

*7,332 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 25—Variable costs, feed and associated inputs variable, 8.3-cow herd, average 10,120 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates...........	....	182.95	400.43	674.94	1,047.13	1,532.83
Corn crushing..........	....	6.02	13.17	22.20	34.44	50.42
Electricity.............	35.93	37.72	40.88	44.45	48.23	51.45
Hay....................	473.51	417.29	395.73	382.10	376.20	355.35
Labor..................	121.06	131.26	142.80	159.48	179.57	201.90
Milk cans..............	3.40	3.40	3.40	3.40	3.40	3.40
Salt...................	3.94	4.10	4.37	4.70	5.03	5.33
Total variable costs.	637.84	782.74	1,000.78	1,291.27	1,694.00	2,200.68
Manure credit..........	97.43	98.65	109.39	125.74	150.50	180.10
Net variable costs ..	540.41	684.09	891.39	1,165.53	1,543.50	2,020.58
Average variable costs..	.94	1.08	1.21	1.36	1.57	1.85
Marginal cost per hundredweight.......	....	2.39	1.96	2.28	2.98	4.41

SOURCE: Synthesized from secondary data presented herein.

*10,120 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 26—Variable costs, feed and associated inputs variable, 16.4-cow herd, average 8,350 pounds of milk, pen type barn, Detroit milkshed, October 1, 1951-September 30, 1953*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	342.52	760.30	1,289.78	1,981.78	2,754.54
Feed grinding	....	11.27	25.01	42.43	65.19	90.61
Electricity	36.94	40.42	46.39	52.35	57.51	60.35
Hay	820.00	732.74	707.53	692.92	669.98	542.55
Labor	147.76	175.32	190.48	210.66	231.40	246.58
Milk cans	5.10	5.10	5.10	5.10	5.10	5.10
Salt	7.28	7.59	8.12	8.65	9.12	9.37
Total variable costs	1,017.08	1,314.96	1,742.93	2,301.89	3,020.08	3,709.10
Manure credit	181.51	188.73	215.53	253.33	301.92	333.61
Net variable costs	835.57	1,126.23	1,527.40	2,048.56	2,718.16	3,375.49
Average variable costs	.89	1.06	1.21	1.40	1.67	1.96
Marginal cost per hundredweight	....	2.49	2.00	2.60	3.86	6.89

SOURCE: Synthesized from secondary data presented herein.

*8,350 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 27—Variable costs, feed and associated inputs variable, 12.9-cow herd, average 10,120 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	284.30	622.35	1,049.04	1,627.46	2,382.39
Feed grinding	....	9.35	20.47	34.51	53.54	78.37
Electricity	33.91	36.69	41.59	47.14	53.01	58.02
Hay	735.94	648.56	615.05	593.86	584.70	552.29
Labor	166.86	182.98	199.37	218.52	241.49	265.48
Milk cans	5.10	5.10	5.10	5.10	5.10	5.10
Salt	6.12	6.37	6.80	7.31	7.83	8.28
Total variable costs	947.93	1,173.35	1,510.73	1,955.48	2,573.13	3,349.93
Manure credit	151.44	153.32	170.01	195.43	233.91	279.92
Net variable costs	796.49	1,020.03	1,340.72	1,760.05	2,339.22	3,070.01
Average variable costs	.90	1.04	1.17	1.32	1.53	1.81
Marginal cost per hundredweight	....	2.40	1.95	2.25	2.94	4.34

SOURCE: Synthesized from secondary data presented herein.

*10,120 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 28—Variable costs, feed and associated inputs variable, 22.6-cow herd, average 10,120 pounds of milk, stanchion barn, Detroit milkshed, October 1, 1951-September 30, 1952*

Variable inputs	Feeding level (percent of TDN supplied by roughage)					
	100	90	80	70	60	50
	Dollars					
Concentrates	....	498.10	1,090.33	1,837.83	2,851.22	4,173.77
Corn crushing	....	16.38	35.87	60.46	93.79	137.30
Electricity	83.62	88.49	97.08	106.80	117.09	125.87
Hay	1,289.31	1,136.24	1,077.54	1,040.41	1,024.36	967.58
Labor	262.38	290.41	316.06	345.44	380.13	414.03
Milk cans	8.50	8.50	8.50	8.50	8.50	8.50
Salt	10.72	11.16	11.92	12.80	13.72	14.50
Total variable costs	1,654.53	2,049.28	2,637.30	3,412.24	4,488.81	5,841.55
Manure credit	265.32	268.59	297.85	342.38	409.81	490.39
Net variable costs	1,389.21	1,780.69	2,339.45	3,069.86	4,079.00	5,351.16
Average variable costs	.89	1.04	1.16	1.31	1.52	1.80
Marginal cost per hundredweight	....	2.40	1.94	2.24	2.92	4.32

SOURCE: Synthesized from secondary data presented herein.

*10,120 pounds fat-corrected milk when fed 1 pound of grain to 4 pounds of milk.

APPENDIX TABLE 29—Response of producers at various prices for fluid milk, Detroit milkshed, October 1, 1951-September 30, 1952

Price	Mail questionnaire		Adjusted to actual prod. 3.68 F.C.M.
	4. F.C.M.	3.68 F.C.M.	
dollars	*million cwt.*	*million cwt.*	*million cwt.*
2.40	13	15.0	10.0
2.50	14	15.4	10.4
3.00	15	16.7	11.7
3.50	16	17.8	12.8
4.00	16	18.3	13.3
4.50	17	18.9	13.9
5.00	17	19.2	14.2
5.50	18	19.6	14.6
6.00	18	19.8	14.8

APPENDIX TABLE 30—Response of producers at various prices for fluid milk, Detroit milkshed, 1953

Price	3.68 F.C.M.
dollars	*million cwt.*
2.27	11.5
2.36	11.9
2.83	13.2
3.30	14.3
3.77	14.8
4.25	15.4
4.72	15.7
5.19	16.1
5.66	16.3

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