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A SHORT RUN SUPPLY CURVE ESTIMATE FOR FLUID MILK, DETROIT MILK SHED, OCTOBER, 1951 - SEPTEMBER, 1952

by

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A THESIS

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TABLE OF CONTENTS

Chapter IV

Chapter V

Chapter VI

LIST OF TABLES

LIST OF FIGURES

LIST OF FORMS, APPENDIX A

LIST OF TABLES, APPENDIX B

CHAPTER I

INTRODUCTION

Purpose and Relevance of the Study

To guide the Michigan farmer. This study was undertaken primarily as part of a research program designed to help farmers as they seek to adjust to a world whose dominant characteristic is change. More specifically, its purpose is to help the Michigan dairy farmer assess his cost position and ability to supply milk relative to producers from neighboring states. Combined with other studies, this analysis enables the Michigan dairy farmer more adequately to size up his situation with respect to the future. It can serve as a guide in adjusting present operations to meet changing conditions.

To augment consumer well being. Beyond guidance to the individual producer, the present study may serve indirectly to augment consumer well-being. The channeling of milk from the farm to the consumer has become heavily burdened with more or less restrictive institutional arrangements in recent decades. Federal Milk Marketing Orders have altered the distribution of the right to produce milk within the economy. If the administrators of these programs can have better information on how the amount of milk supplied will vary in response to price changes, they can more competently recommend price adjustment, thereby making both the consumer and producer better off.

A price support program for dairy products has been instituted since World War II with an apparent malallocation of consumption and resources leading to large surpluses of butter in government warehouses. This study, combined with others designed to appraise the demand side of the problem, and more fully the supply side, will enable price support programs to be developed that are more efficient in their allocation of resources.

<u>To illustrate the use of theory in analyzing a problem.</u> A third purpose of the study was to illustrate the use of theory in analyzing a problem. Experimental and other data compiled at this and other institutions are combined with the classical static theory developed and elaborated since the time of Adam Smith and with a technique developed by James A. Wells[1] at the University of Kentucky. Use of this technique produces marginal cost curves for several representative firms in the Detroit milk shed. These are then aggregated into a milk shed supply curve through the use of proportions derived from a mail survey conducted in the Spring of 1953[2]. The result is an estimate of the supply curve for fluid milk in the area under study, assuming that the number of producers and size of herd does not increase, that the quality of cow remains constant and that prices of variable inputs remain constant.

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[1] Wells, J. A., "A Technique for Synthesizing Cost of Production Data - With Special Reference to Dairy Enterprises in Green and Taylor Counties of Kentucky," (unpublished Master's thesis, Department of Farm Economics, University of Kentucky, 1951).

[2] See specimens in Appendix A.

Description of Michigan Agriculture in Relation to the Detroit Milk Shed

Importance of dairying as an enterprise in the State. Michigan, as a state, ranks ninth in the number of milk cows and heifers on hand as of January 1, 1953[3]. Some form of dairying is the predominant type of farming in the state, other alternatives being beef cattle, sheep, swine, specialized vegetable or fruit farms, and some crop farms. The relative importance of the different types is indicated by Table I.

TABLE I

VALUE OF FARM SALES, BY PRODUCTS, MICHIGAN, 1949

Product	Thousands of dollars
Crops	
Fruits and nuts	30,600
Vegetables	17,497
Horticultural specialties	15,994
All other crops	120,578
Livestock and livestock products	
Dairy	143,115
Poultry and poultry products	41,215
All other livestock and livestock products	101,581
Forest products	
All forest products	3,031
Total value of products sold	473,612

SOURCE: Michigan Agricultural Statistics, May, 1953, p. 49.

[3] Michigan Agricultural Statistics, May, 1953, p. 5.

For further information as to the importance of dairying in Michigan, see Table II.

TABLE II

NUMBER OF FARMS, BY TYPE OF FARM, MICHIGAN, 1949

Type of farm	Number	Percent
Cash-grain	15,037	9.7
Other field crops	1,995	1.3
Vegetable	2,545	1.6
Fruit and nut	4,710	3.0
Dairy	45,729	29.4
Poultry	5,268	3.4
Livestock other than dairy and poultry	10,777	6.9
General, primarily crops	1,990	1.3
General, primarily livestock	5,993	3.8
General, crop and livestock	11,195	7.2
Miscellaneous and unclassified	50,350	3.2
All Farms	155,589	100.0

SOURCE: Michigan Agricultural Statistics, May, 1953, p. 7.

For the relative importance of cash receipts from dairying, see Table III.

TABLE III

CASH FARM RECEIPTS FROM SALES OF DAIRY PRODUCTS COMPARED WITH TOTAL CASH RECEIPTS FROM FARM MARKETINGS AND TOTAL STATE INCOME (INCOME PAYMENTS TO INDIVIDUALS), MICHIGAN, 1951

Cash farm receipts from sales of dairy products	198,830,000 dollars
Total cash receipts from farm marketings	725,272,000 dollars
Income payments to individuals	11,352,000,000 dollars
Ratio of cash dairy receipts to total cash farm receipts	27.4 percent
Ratio of cash dairy receipts to total income payments	1.75 percent

SOURCE: _Michigan Agricultural Statistics_, May, 1953, p. 11.

Feed production in the state. Corn, winter wheat, oats, barley, and soybeans were the principal feed grains grown on Michigan farms in 1952. Production and disposition figures are given in Table IV for the feed grains and hay.

Winter wheat and soybeans are principally cash crops while corn, oats, barley and hay are produced for use as feed. Of the 1,698,000 acres of corn grown in Michigan in 1952, 83.5 percent was utilized for grain; 12.4 percent for silage; and 3.4 percent for hogging down, grazing and forage.[4] Total corn silage production for the state was

[4] _Ibid_, p. 19.

TABLE IV

PRODUCTION AND FARM DISPOSITION OF SELECTED CROPS-MICHIGAN, 1952

Crop	Production	Used on farm where grown			Sold
		Seed	Feed	Farm household	
			Thousands		
Corn - bushels	83,200	—	67,759	9	15,432
Winter wheat - bushels	36,440	2,289	5,830	37	28,284
Oats - bushels	50,786	—	43,168	—	7,618
Barley - bushels	2,552	—	1,991	—	561
Soybeans - bushels	1,748	105	52	—	1,591
All hay - tons	3,538	—	3,131	—	407

SOURCE: *Michigan Agricultural Statistics*, May, 1953, p. 18.

2,071,000 tons.[5] No specific figures were available on the breakdown of hay production into kinds, other than that 39.3 percent of the farms in Michigan reported some acreage of alfalfa cut for hay and 38.7 percent reported some acreage of clover-timothy cut for hay in 1950.[6]

Description of The Detroit Milk Shed

This thesis is directly concerned with fluid milk production in the Detroit milk shed. Having described Michigan agriculture and the

[5] *Ibid*, p. 19.

[6] *Ibid*, p. 17.

importance of dairying in the state as a setting or background, a more detailed description of the conditions under which fluid milk is produced for the Detroit market follows.

Location. In 1952, the milk shed for the Detroit market encompassed approximately two-thirds of the lower peninsula. Approximately 70 percent of the milk cows in the state were concentrated in this area.[7] Within this geographic area, though, many producers shipped to local markets such as Lansing, Muskegon, Bay City, and Midland, rather than to Detroit. The approximate boundaries of these smaller milk sheds are indicated in Figure 1.

Production conditions. In order to set up representative firms for purposes of deriving the marginal cost curves, information was needed as to herd size, type of barn, and quality of cow. Secondary sources of data did not supply information of this nature, so a mail survey was taken of producers in the Detroit milk shed.

Results of the questionnaire in describing conditions under which fluid milk is produced for the Detroit market are summarized in Table V.

The marginal cost curves which were constructed for each of these representative conditions of production were weighted according to the indicated percentages in aggregating the composite supply curve. (See Chapter IV).

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[7] Ibid, p. 8.

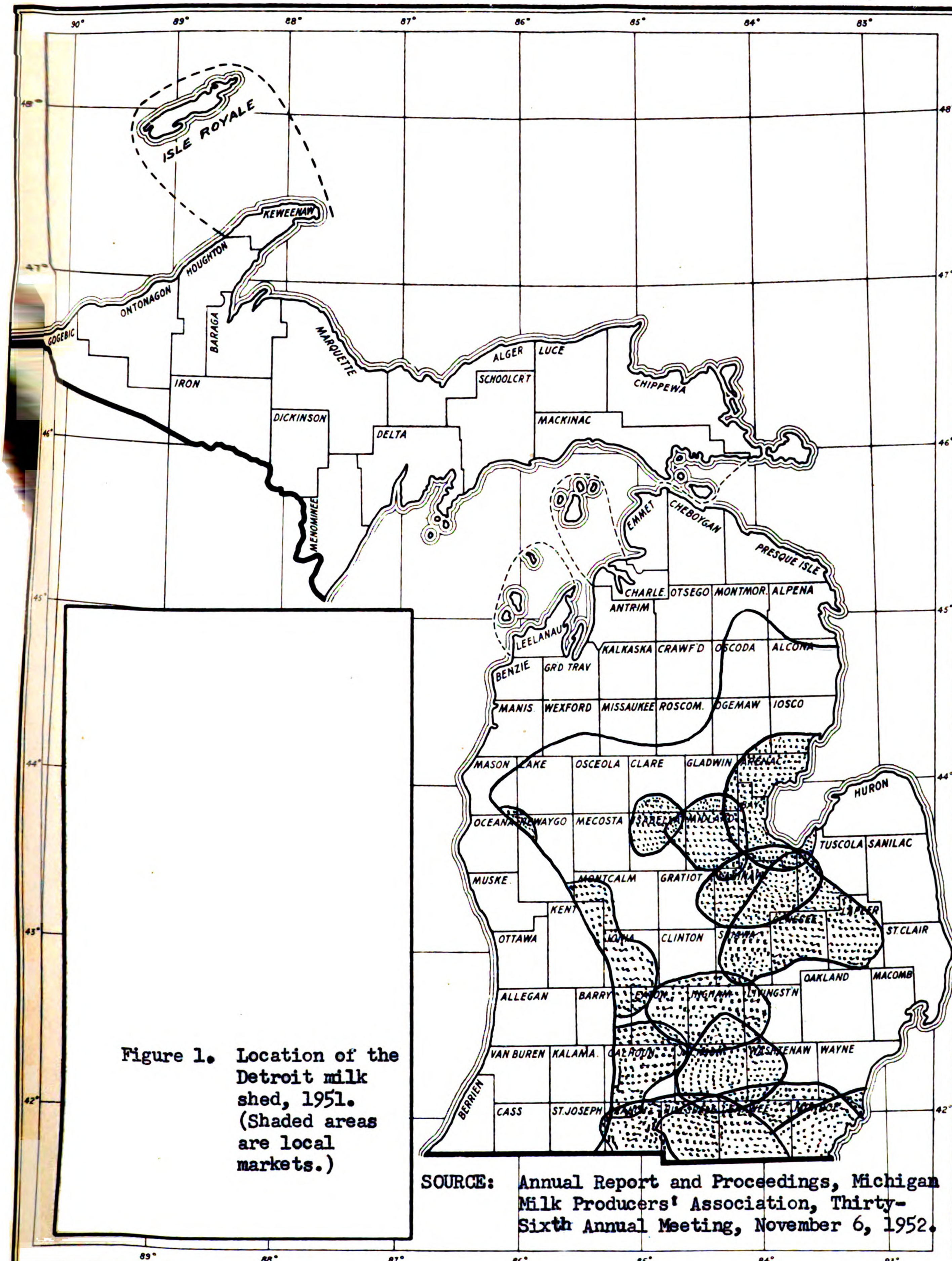

Figure 1. Location of the Detroit milk shed, 1951. (Shaded areas are local markets.)

SOURCE: Annual Report and Proceedings, Michigan Milk Producers' Association, Thirty-Sixth Annual Meeting, November 6, 1952.

TABLE V

HERD SIZE, TYPE OF BARN, AND AVERAGE PRODUCTION PER COW* - PERCENTAGE OCCURENCE IN THE DETROIT MILK SHED - OCTOBER 1, 1951 - SEPTEMBER 30, 1952

Stanchion barn	Under 6999 pounds Average 5580 pounds	7000-8999 pounds Average 7970 pounds	9000 pounds and over Average 11,000 pounds	Total
		Percent		
2-10 cows Average 8.3	12.754	11.426	9.488	33.657
11-15 cows Average 12.9	8.591	10.628	10.451	29.670
16 cows and over Average 22.6	7.528	10.451	14.703	32.682
Total	28.873	32.505	34.631	96.015
Pen type barns	5000-14,000 pounds Average 9077 pounds			
6-40 cows 16.3 average	3.985			3.985
				100.000

*In terms of 3.68 percent butter fat.

Kind of cattle found. Holstein is the predominant breed of dairy cow in the area under consideration. These cows are large in size and for purposes of calculating feed and other inputs, an average weight of 1,200 pounds is assumed. The quality of these cows is indicated in Table V.

Type of feed fed. Feed fed to dairy cattle varies considerably between farms. Hay consists of alfalfa, red clover, brome, and timothy, grown separately or in mixtures. Pasture consists of the same forage crops plus blue grass, the pasture season lasting approximately 150 days. The grain ration for the most part is made up of corn and cob meal, shelled corn, oats, and soybean meal. Silage is essentially all corn silage although increasing amounts of grass silage are being used.

CHAPTER II

RESUME' OF TECHNICAL LITERATURE AND FRAMEWORK FOR THE PROBLEM

Resume' of Relevant Literature

According to Mighell and Black[1] two procedures have been followed in the past in attempts at supply curve determination. The first of these - the historical-statistical procedure - consists of correlating prices and the amount produced over a period of years in the past, giving consideration to other important variables that may have influenced this relationship.

Probably the first study along these lines dealing with dairy production was made in the Twin Cities market by Emil Rauchenstein in 1926.[2] A little later, Ezekiel, Rauchenstein, and Wells did similar work for the Bureau of Agricultural Economics in material that was published in 1932.[3]

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[1] Mighell, R. L., and Black, J. D., Interregional Competition in Agriculture, Harvard University Press, Cambridge, Massachusetts, 1951, p. 46.

[2] Ibid, p. 74.

[3] Ezekiel, M., Rauchenstein, E., and Wells, O. V., Farmers' Response to Price in the Production of Market Milk (Processed), United States Department of Agriculture, Bureau of Agricultural Economics, (Washington, 1932).

A similar analysis in the Richmond area of Vermont by A. R. Gans and M. Ezekiel also gave significant results.[4] But when John M. Cassels in his Study of Fluid Milk Prices published in 1937 repeated the Vermont analysis using the period 1921 - 1931, in contrast with the years 1917 to 1925 used by Ezekiel, he obtained results with little or no significance.[5] A repetition of the Twin Cities study made by Paul Quintus in the early 1930's gave results much like those of Cassels'.[6]

Further analysis of the Vermont data by Cassels and Malenbaum showed that most of the correlation occurred in the earlier years.[7] Finally, Steward Johnson repeated the Vermont analysis including the whole period from 1917 to 1937 and came out with results substantially the same as those of Cassels'.[8] The conclusion that Black reaches is that a short period of years is not likely to furnish an adequate historical sample, and that if a long period of years is included, the results are likely to be out of date and no longer fit the current situation.[9]

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4 Mighell, R. L., and Black, J. D., Op. cit., p. 74.

5 Ibid, p. 74.

6 Ibid, p. 75.

7 Ibid, p. 75.

8 Ibid, p. 75.

9 Ibid, p. 75.

It appears that a historical trend must be established to get valid results, and that by the time this trend has been established, it is no longer applicable. A partial solution to this problem can be found by setting up a model with an equation explaining each one of these factors. These equations are then solved simultaneously to secure more valid results.[10]

In the usual analysis of responses of milk production to prices of milk, such as those previously mentioned, account has been taken also of the price of feed, usually in the form of a ratio of milk to feed prices. The supply curves obtained in such cases are supply curves, though, in the sense of partial equilibrium analysis, because the effect of the changing cost is removed. In an area where the dairy herds are mostly fed on forage and grain grown for that purpose, milk prices alone can be used in the analysis, unless some other enterprise, like hogs, is a strong competitor for the grain.

The second approach to the problem is called the operating-unit or case method, by means of which attempts have been made to construct supply curves by determining the amount which individual producers can most advantageously produce at different levels of prices.

There are two methods usable in this form of analysis. The first of these methods is typified by Mighell and Black's[11] analysis

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10 Johnson, G. L., has indicated the possibility of doing this in a published criticism of Mighell and Black's book. (The Journal of Political Economy, The University of Chicago Press, Chicago, Illinois, p. 184.)

11 *Op. cit.*, Mighell and Black, p. 46.

and consists of estimating or constructing a budget of the expenses and receipts for the entire farm business with several alternative organizations. This is done for what is considered to be a representative farm under three different price structures to determine the individual response to price changes. The composite schedule for the area under consideration is then found by a simple multiplication operation.

A second method is the one used in this study. A survey is taken of the area under consideration to determine the composition of the aggregate of producers with respect to scale of operation, type of barn, and quality of cows. From the information so gained typical dairy enterprises are constructed, for each of which a marginal cost curve for a specified length of run is determined from experimental data through a budget process. This gives the individual response to price changes within that planning span.

These individual responses are then aggregated according to the proportions dictated by the survey into the composite supply curve.

Conceptual Framework for the Problem

At this point, a rather complete elaboration of the relevant theory to be used is appropriate.

Selection of relevant theory. Economic theory has been divided and classified in many ways. One of these classifications follows:

Statics	Dynamics
Micro-statics	Micro-dynamics
Macro-statics	Macro-dynamics

In addition to being general - applying to the analysis of both the firm and the consumer - this classification admits the possibility of showing the inter-relationships between the various sections.

A static analysis at the micro-economic level under conditions of perfect competition provides an appropriate initial framework from which useful concepts can be developed for guidance in working out the problem. A micro-economic approach is taken because the firm is the primary economic unit being analyzed. The supply curve estimate is an aggregate of individual supply curves.

Static analysis is used mainly because it provides a rather fully developed, yet simple, theory of the firm. If more fully developed a dynamic analysis would provide answers that the present analysis cannot, such as how the entrepreneur responds in the presence of imperfect knowledge about prices, weather, production responses, and marketing programs, to mention only a few such items.

If a dynamic theory of this nature were more fully developed it would approximate the real world more closely than static theory. Since such theory is not developed adequately, certain assumptions have to be made with the realization that the resultant theory only roughly approximates reality. This is the condition into which all empirical work eventually falls, differences being only matters of degree.

Perfect competition is assumed because this does approximate conditions in the area under study. Each individual producer is assumed so small relative to the aggregate that he cannot significantly influence the price of either his factors of production or the product he sells. The demand curves he faces when buying his variable factors of production are perfectly elastic, that is, no matter how much he buys, within the limits set by his fixed factors, the prices of the variable inputs remain substantially the same. This also applies when he is selling his product. There tends to be one price and no matter how small or how large his output, the price remains the same.

Certain inputs that are fixed for the firm but variable between enterprises have to be priced, too. Examples of these are silage, pasture and labor. Inputs of this nature can be priced at their on-farm opportunity costs.

If the firm is in a state of equilibrium, the input that is fixed for the firm but variable between enterprises, will be allocated among those enterprises so that MFC = MVP for each enterprise and its MFC in one enterprise will be its MVP in an alternative use. In order for one more unit of one of these inputs to be used in the dairy enterprise, it must be paid at least the on-farm opportunity cost which is ✓ the MVP sacrificed by diverting it from an alternative enterprise. If there are no on-farm alternatives other than the dairy enterprise, an additional unit of the input applied to it cannot be valued higher than its respective MVP so long as the input is a fixed asset for the firm.

<u>Assumptions needed to secure the selected system.</u> Because finite minds are not capable of handling a theory which would reproduce exactly the infinitely complex conditions of the real world, certain simplifying assumptions have to be made. This is not a criticism of theory. In part

it is a justification for it. The human mind is finite. The real world exists in infinite dimensions. The only way the finite mind can grasp the infiniteness of the real world is to make simplifying assumptions and classifications.[12]

In addition, it is necessary to have a set of concepts in which there are N variables and for which there are N consistent, non-duplicating relationships. When these conditions are satisfied we have a unique explanation for each of the internally determined variables. In solving such a system for any one of the internally determined variables, given the values of the exogenous variables and the relations between the endogenous ones, a unique, single valued magnitude is ascertained. The law of diminishing returns, assumptions of perfect competition, and the assumption of a rational stage of production assure us of having such a set of concepts.

The following assumptions are needed to satisfy these conditions for a static analysis at the micro-economic level for a dairy farm in the Detroit milk shed:

1. The production functions are fixed as they existed between October 1, 1951 and September 30, 1952.

2. Certain of the resources are fixed for the firm and industry in this way:

    a. All assets for the firm are fixed except for those associated with the length of run in which the feeding level and associated inputs are variable.

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[12] Knight, F. H., Risk, Uncertainty and Profit, Houghton Mifflin and Company, Boston and New York, 1921, p. 207.

b. Those assets which spell out the size of the industry are fixed except for those associated with that short length of run in which the feeding level and associated assets are variable.

3. Those resources associated with the changing feeding level such as hay, labor, milk cans, and salt are not fixed in total quantity, but can be purchased or disposed of at the going market rates or the on farm opportunity cost.

4. The institutional make-up of the milk shed is assumed constant for the period under consideration.

a. There will be no change in the Federal Milk Marketing Order.

b. There will be no production controls other than those embodied in institutions existing October 1, 1951.

c. The regulations regarding health and sanitation will be constant.

5. The farmers in operating their businesses act in a rational manner.

6. The farmer as an individual has perfect knowledge and foresight.

7. The farmer in operating his business seeks to maximize his profits.

8. There are N firms in the market, where N is a very large number.

9. The product - milk - is homogeneous; the elasticity of substitution between one firm's product and the products of the remaining N-1 firms producing milk is infinite.

10. The cross-elasticity of demand between the firm's price and the sales of the other N-1 firms (conceived as a unit) is zero.

11. Certain of the factors of production - corn, oats, salt, soybean oil meal, corn crushing service, electricity, hay, and milk cans are assumed to be perfectly elastic in supply and are priced at their off-farm opportunity cost.

12. Other factors - pasture, silage, and labor - which are fixed for the firm but variable between enterprises, are priced at their on-farm opportunity costs. (A specific treatment of these is given later in the paper.)

13. The farmer buys and sells his factors free of coercion in a free or open market.

The body of theory which is to serve as a conceptual framework has been selected and the assumptions necessary to assure an identified system have been spelled out. The conceptual framework can now be developed, starting with an analysis of relevant production functions and carrying it through the derivation of the marginal cost curves to their aggregation into a supply curve for the area and farms under study.

Production functions. Production can be conceived of as a functional relationship between the factors of production and output. Symbolically this would be presented thusly: $Y = f(X_1, X_2, \ldots, X_n)$, where Y stands for output and $X_1, \ldots, X_n$ stands for the factors of production. The f signifies that output depends in some definite way on the factors of production.

The theory of the production function can be found in one of several college theory books, such as, Stigler[13], Boulding[14] or Weintraub[15],

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[13] Stigler, G. J., The Theory of Price, The Macmillian Company, New York, New York, 1950, pp. 109 - 115.

[14] Boulding, K. E., Economic Analysis, Harper and Brothers, New York, New York, 1948, pp. 498 - 509, 671 - 709.

[15] Weintraub, S., Price Theory, Pitman Publishing Corporation, New York, New York, pp. 52 - 70.

and will not be developed in detail here. The theory is most easily envisioned when output (Y) is conceived to be a function of two variable inputs, X_1 and X_2, with $X_3, \dots, X_n$ fined. Plotting X_1 on the ordinate axis of a Cartesian coordinate and X_2 on the abscissae, output is conceived of as rising from the surface of the coordinate in a third dimension. Points of equal elevation can be indicated by contour lines much as is done on a regular surface map. These contour lines connecting points of equal height are called isoproduct lines, and are illustrated in Figure 2.

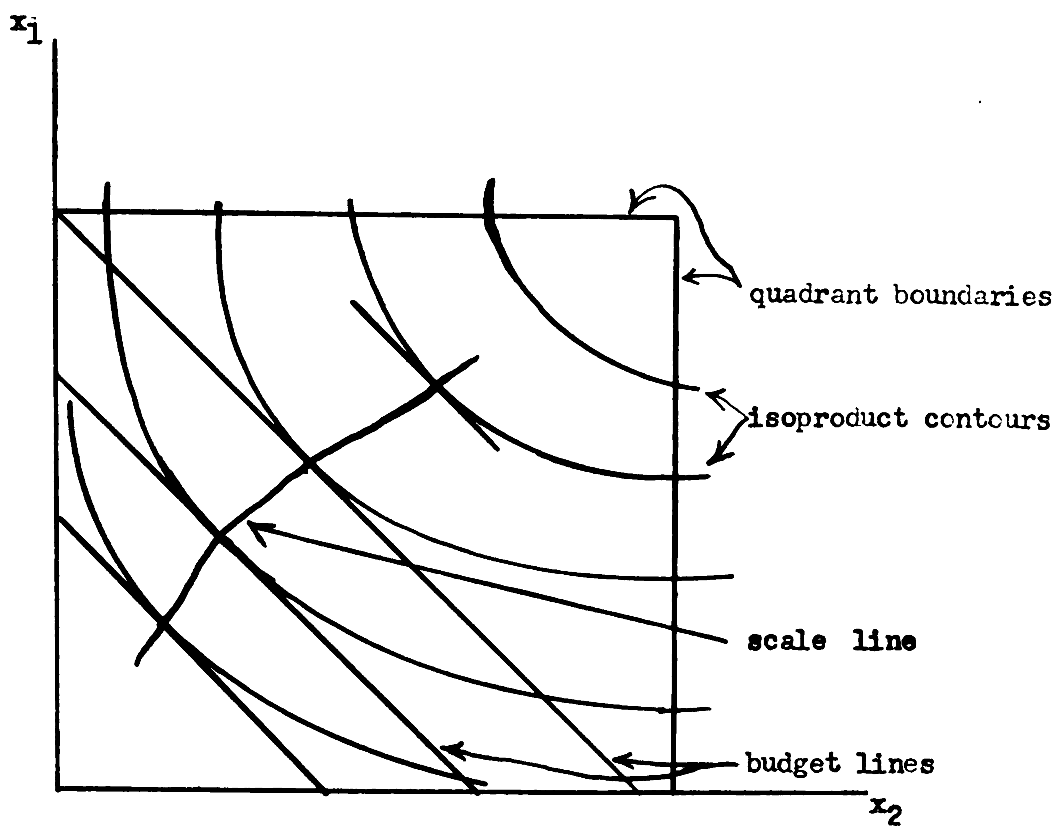

Figure 2. Production surface for three variable analysis.

The significant portion of this diagram is the area within which a rational entrepreneur would operate. This area of rationality can be delineated by drawing in isoclines, which connect points on each isoproduct curve at which a tangent is parallel to either the ordinate or abscissa axis. Within these isoclines the MPP's of both X_1 and X_2 are positive.

Two problems of economic choice exist within this area of rationality. The isoproduct contours indicate that a given output can be produced by alternative combinations of the two inputs. Which combinations to use becomes a problem of economic choice and the criteria employed in making the selection is the minimum cost combination.

This is determined by superimposing budget lines on the isoproduct map (Figure 2). These lines indicate the different combinations of the two inputs which can be purchased for a given outlay of funds. The optimum combination is indicated at the point of tangency between the isoproduct line and the budget line. (Proof that this is the minimum cost combination can be found in any of the suggested references.) A line connecting these points of tangency will indicate the optimum combinations as output is expanded, and is called the scale line or expansion path.

This brings us to the second of our problems of economic choice; that is, the optimum output to produce. Further production is profitable as long as the revenue from one further unit of production is greater than the cost of securing that greater output. Skipping the production function where output is a function of X_1 and X_2 combined according to the scale line and going direct to the related cost curves, maximum profits are secured when MC = P. Combining the inputs as dictated by the scale line, output is expanded until this point is reached.

Derivation of the cost curves. Of the traditional set of cost curves that is derived for the firm in the short run, only one is germane to the present analysis. Since in the short run it is to the producer's interest to carry production to the point where marginal cost equals price, his short run MC curve will also be his rational short-run supply curve relating price and quantity supplied. Thus, this cost curve is the fundamental curve for the present analysis.

The "short-run" is taken to be a period long enough to permit of any desired change of output technologically possible without altering the scale of plant, but which is not long enough to permit of any adjustment of scale of plant.

For this problem, the relevant length of run is one in which feed and its associated inputs are variable. (See Chapter II for a further discussion of this.) All other inputs are fixed and are part of the "plant". All costs to the firm can then arbitrarily be classified into two groups - those which are necessarily fixed in amount and whose magnitude delineate the scale of the plant, and those which are freely variable and change with changes in output. This latter group are variable in their aggregate amount as output varies, as well as in their amount per unit of product.

Marginal cost is defined as the additional costs necessary to produce one additional unit of output. As total fixed costs remain constant, only variable costs enter into marginal costs. Total variable costs are defined as the sum of the total variable costs necessary to secure a given output. Total variable costs divided by the respective output to give a per unit value is average variable costs. Marginal variable and marginal costs are synonomous.

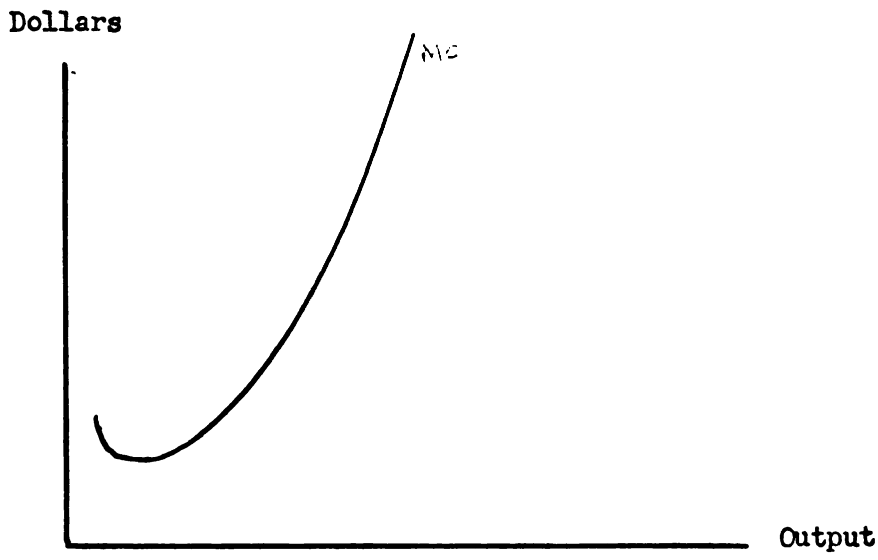

Figure 3. Marginal cost curve for the firm in the short run.

The marginal cost curve for a firm is illustrated in Figure 3. It is typically U-shaped as a result of the law of diminishing returns.[16]

Theoretical presentations often indicate that only variable costs are important in decision making once the commitments for fixed costs have been made. Such presentations indicate that production can be maintained in the short run so long as average variable costs are covered, and further, that losses are minimized by this continued operation.

However, if the price becomes so low that the earning power of the fixed asset becomes less than its salvage value, the fixed asset will be sold. This may well occur at a price that is still more than covering average variable costs. When this takes place, a longer length of run is entered into and the cost computations for the previous length of run are not applicable.

The supply curve for the firm, then, consists of the marginal cost curve of the firm above the level of the average variable costs, unless the earning power of the fixed assets become less than their salvage value. In this case, the short run supply curve does not extend down to the average variable cost curve, but stops at this point where the planning span involves a longer length of run.

The supply curve for the industry in a given length of run is simply the sum of the abscissa of the individual marginal cost (= individual supply) curves for that length of run.

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16 Ibid, pp. 75 - 76

<u>Discussion of the length of run considered and the respective characteristics of the dairy enterprise</u>. A large number of productive agents are used in the dairy enterprise. Various lengths of run[17] or planning spans can be identified by dividing these inputs into a fixed and variable classification. Typically, three lengths of run can be identified with respect to the dairy enterprise.

<u>The short run</u>. 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 combination in which roughage and concentrates are fed is variable, and in addition some other minor inputs and small portions of other inputs associated with the feeding level are variable.

<u>The intermediate length of run</u>. In a somewhat longer length of run, the dairyman can vary some of the factors fixed in the short run. This planning span is called the intermediate length of run, and within this span the dairyman may increase or decrease 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 variable. An upper limit on herd size is imposed by barn space.

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[17] A word of explanation relative to the concept of length of run is appropriate at this time. This is not strictly a time concept, but involves planning and the associated decisions with respect to varying the specified factors of production mentioned above. The length of run is determined by the planning span one is considering when commitments are made. If a variation in feeding level is contemplated, it is a short run phenomenon. If a variation in barn size is being considered, it is a long run phenomenon.

The long run. A still longer length of run can be conceived of in which all factors of production are variable. Buildings and land are variable in this length of run and conceivably management could be variable, for with the passing of time, the farmer could undergo a learning process and increase his managerial skill. Whether management could be increased in proportion to the other factors is debatable.

These are only three examples of an infinite number of lengths of run possible. They are rather arbitrary, but somewhat meaningful in referring to lengths of run in which farmers usually plan.

Length of run considered in this study. In this study, only the short run is selected for consideration. The level at which the cows are fed and the combination of roughage and concentrates is variable. That part of labor associated with the feeding level will be variable. Additional milk cans will be needed to handle the increased milk resulting from a higher level of feeding. A small amount of electricity will also be variable as the milking time increases and the volume of milk to cool is changed.

All other factors of production are assumed fixed. The size of herd is constant, and land is fixed. For the milk shed, the number of herds is fixed at 12,223.

Weaknesses and Advantages of the Proposed Method

Weaknesses of the proposed method. The proposed method of analysis has several innate weaknesses. One of these involves input prices and the problem of partial equilibrium analysis. It is assumed for purposes of the study that the price for each of the inputs remains constant, although for any of the inputs in the economy as a whole it is obvious that price is a function of the amount used. This problem is partially circumvented for items with a national market such as corn, oats, soybean oil meal, milk cans and salt, by the fact that we are dealing with the production in only one of the areas in which the commodity is produced in the total economy. The relationship between the price and the quantity used in the Detroit milk shed is probably slight, then, if it exists at all, because the use under consideration is only part of a much larger market.

The problem is more acute for those inputs that are fixed in supply either locally or on an individual farm basis, but variable within the individual farm between enterprises, such as labor, hay, silage and pasturage. Here the price very definitely is a function of the quantity used. This problem is partially solved by holding the quantity of silage and pasture used constant at all of the feeding levels. Labor and hay cannot be held constant as the level of feeding changes, though, so they must be given special treatment. A discussion of the method used is found in a later chapter.

A second weakness of the study is that it makes no direct allowance for events of an episodic nature. It is assumed that there are a definite number of producers, and that they continue to produce throughout the period under consideration. In reality many events will occur to eliminate some producers from the market, such as fires,

epidemic diseases, hail storms, wars and crop failures. These occurrences are of a random nature and are in no way connected with the market situation. Indirectly, events of this nature are taken into consideration when adjusting the final curve as discussed in Chapter IV.

A third weakness is the inherent lack of accuracy implied by any sampling process, in addition to the bias resulting from sampling a special group of the total population with a mail questionnaire. It was impossible to secure a list of addresses of all the producers in the Detroit market to which to send the questionnaire. The Michigan Milk Producers' Association were very cooperative, however, in allowing the author access to their address list, from which two 10 percent random samples were drawn. Members of the Association make up approximately 85 percent of the shippers in the shed, there probably being an upward bias in the sample toward the larger and more efficient producers as a result. This is indicated by the daily deliveries for each group in September of 1952. The members had an average daily delivery of 324.8 pounds as compared to 292.2 pounds for the non-members and 319.7 pounds average for the total shippers.

Another sample bias is the one that is indigenous to a mail questionnaire. Again it is probably only the larger, more efficient producers that respond, although we have no estimate of the descrepancy in this case. A 50 percent response was secured after sending one reminder letter.

A correction is made for these biases after the shape of the composite curve has been determined by shifting the entire curve laterally to force it through the actual production for the period of time being considered.

Advantages of the proposed method. An advantage of this study is that it is organized around a meaningful theoretical framework and is based on factual evidence derived from experiments, surveys, and time and motion studies. Theoretical and empirical procedures are teamed together for the attack on the problem. It considers the responses of the individual producer to price changes and aggregates them into the composite supply curve.

Another advantage that stems directly from the consideration of the individual producer is the increased validity of the aggregation process. The supply curve will not be restricted to a straight line relationship, nor will it be burdened with the deficiencies associated with aggregating regression coefficients. It will be a lateral summation of the individual supply responses, and as such, transcends many of the weaknesses of the traditional aggregation process.

The historical-statistical procedure presupposes that producers will react in the future much in the same way that they have in the past. This precludes the possibility of a changing technology, changing tastes, and changing alternative opportunities. The proposed method specifies that for the given cost structure, the supply response will be as indicated. Changing the cost structure will result in a different supply response. There is not a projection over a time period for which there is not supporting evidence as is done in the historical-statistical method. Wold and Jureen have pointed out the lack of validity involved in predicting from a regression coefficient beyond the limits of the data.[18]

This method considerably increases the accuracy over that achieved by Mighel and Black's process. Continuous responses are ascertained rather than just the three or four alternatives proposed in their study. This results in increased validity over the range of the supply curve. Increased accuracy also comes from having ten representative enterprises for each of which a marginal cost curve is computed. These curves are then weighted according to their respective occurrence in the milk shed. This is considerably more accurate than setting up one typical enterprise for which three or four alternative situations are budgeted.

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[18] Wold, H., and Jureen, L., Demand Analysis, John Wiley and Sons, Inc., New York, New York, 1953, p. 31.

CHAPTER III

THE COMPUTATION OF THE COST CURVES FOR THE REPRESENTATIVE DAIRY ENTERPRISES

As indicated in Chapter I and II, a marginal cost curve is required for each of ten representative dairy enterprises. This chapter describes (1) how the physical input-output data were secured and (2) the method of computing the marginal cost curves.

Determining the Physical Input-Output Relationships

Feed. For the length of run with which we are concerned, feed is the major variable factor of production. The input-output relationships used for deriving the cost figures in this study are based on a combination of secondary experimental data, survey data, and judgement.

Milk production in this length of run is generally conceived to be a function of varying quantities of roughage and concentrates and necessary changes in associated inputs such as labor, minor equipment, and electricity, combined with such fixed factors as the cow, the quality of her feed, the management ability of the farm operator, and the climate. If one abstracts from the changes in the associated inputs such as labor, minor equipment, electricity, the economic analysis for this length of run involves the traditional three-variable analysis referred to in Chapter II. 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 intake of a particular cow can be varied has two limitations. Physically, the total digestible nutrients intake must be at least enough to satisfy the maintenance requirements of the cow. Economically it must be at least enough to equate the average physical product and the marginal physical product. As a maximum the total digestible nutrient intake is limited by the concentrate limit of the cow. In an economic sense this would be where the marginal physical product has decreased to zero. The economizing principle is rationally applied within this range.

Cost curves are derived logically from the production function with the inputs combined as dictated by the scale line. The determination of the optimum combination of the two inputs, roughage and concentrates, present a special problem in the case of the dairy cow. Current thought among dairy specialists is that it is economical to fill a cow's stomach either with roughages or with roughages and concentrates.[1] Under the normal range of price relationships the price

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[1] In a rather new textbook, the following statement was found in a section discussing balancing rations: "The cows should be fed all the roughage that they will clean up" H. G. Henderson, Carl W. Larson, and Fred S. Putney, Dairy Cattle Feeding and Management, (third edition, New York, John Wiley and Sons, Inc., 1947), p. 123. Professor Morrison 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." Frank B. Morrison, Feed and Feeding (21st edition, Ithaca, New York, The Morrison Publishing Company, 1948), p. 678. This only refers to

of total digestible nutrients from roughage is such that the farmer can buy three pounds at an outlay which would buy only two pounds or less total digestible nutrients from concentrates. Under these conditions the price line probably touches its highest product contour at the roughage base line. A consideration of the current thought of the dairy specialists combined with the normal range of price relationships seems to imply that the scale line should go out the roughage axis until it reaches the stomach limit line. Thereafter, 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.

It was originally decided that a ration consisting of 100 percent roughage should be the lowest level of feeding to consider in the study. Although this assumption is later dropped for the higher quality cows, the assumption is used here for the sake of logical development. Conceptually, it would seem that additional milk production could be secured from this point on only at a higher marginal cost per unit, because a high cost feed, concentration, would be substituted for a low cost feed, hay. Cost computations are to be made for six levels of feeding ranging from 100 percent of the total digestible nutrients

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good quality roughage, but he indicates that if a cow is worth keeping at all, she is more profitable if fed liberally. The United States Department of Agriculture Technical Bulletin Number 815 on input-output relationships in milk production also utilizes this idea. In this extensive study, one of the two series of feeding experiments was made by feeding grain at specified rates in addition to all the roughage the cows would consume.

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 follow.

Feed input-output relationships were wanted for four quality cows. By converting the milk produced per cow as ascertained by the survey into four-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 in United States Department of Agriculture Technical Bulletin 815.[2] (The average annual production per cow figures that we acquired from the mail survey were assumed to be the result of a 1:4 rate of feeding - a usual rate recommended and followed over much of the state of Michigan.) These input-output relations were therefore taken as the basic data for this cost study.

Cows in the Detroit milk shed get their total digestible nutrients from a combination of concentrates, hay, pasture, and silage. To avoid the problem of pricing the inputs silage and pasture which are fixed for the farm, it was decided to hold these factors constant over the range of the feeding variations.[3] The level of feeding is raised by

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[2] Jensen, E., et al, Input-Output Relationships in Milk Production, Technical Bulletin Number 815, United States Department of Agriculture, Washington, D.C., May, 1942, p. 42.

[3] For most Detroit milk shed 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.

adjusting the amounts of hay downward and increasing the consumption of grain from the level at which the ration consists of 100 percent roughage. The total digestible nutrient intake can be increased only by increasing the amount of concentrates fed and reducing the quantity of hay fed under the conditions of the problem.

Experimental data were available to indicate approximately the proportions in which hay and grain substitute for each other along the stomach limit line. Such information is indicated by the manner in which total digestible nutrient intake increased as the level of grain feeding was raised in the experiments reported in United States Department of Agriculture Technical Bulletin 815.[4] In order to estimate this increase in total digestible nutrient intake as grain is substituted for hay along the stomach limit line, a smooth curve was fitted to the data in Bulletin 815[5] relating grain consumption and total digestible nutrients consumed per year for each quality of cow. These curves were then adjusted up or down for the difference in quality between the cows in this study and those in Bulletin 815.[6] See Figures 4, 5, 6 and 7.

As an example, using that quality of cow which had an annual average production of 5,133 pounds of milk at the 1:4 level of feeding

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[4] *Ibid*, p. 43.

[5] *Ibid*, p. 43.

[6] *Ibid*, p. 42.

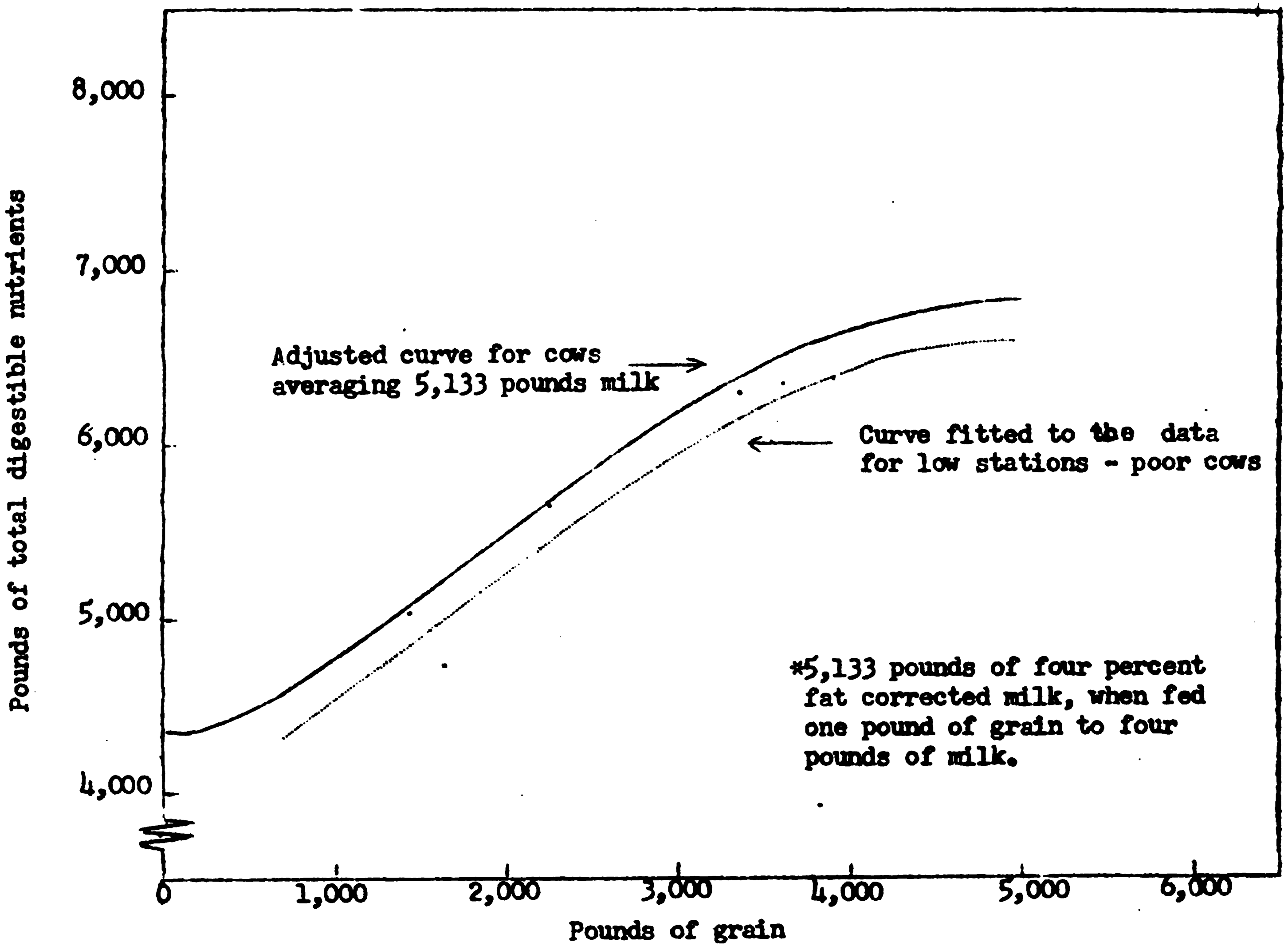

Figure 4. Grain-total digestible nutrient relationship for cows with a capacity of 5,133 pounds of milk*.

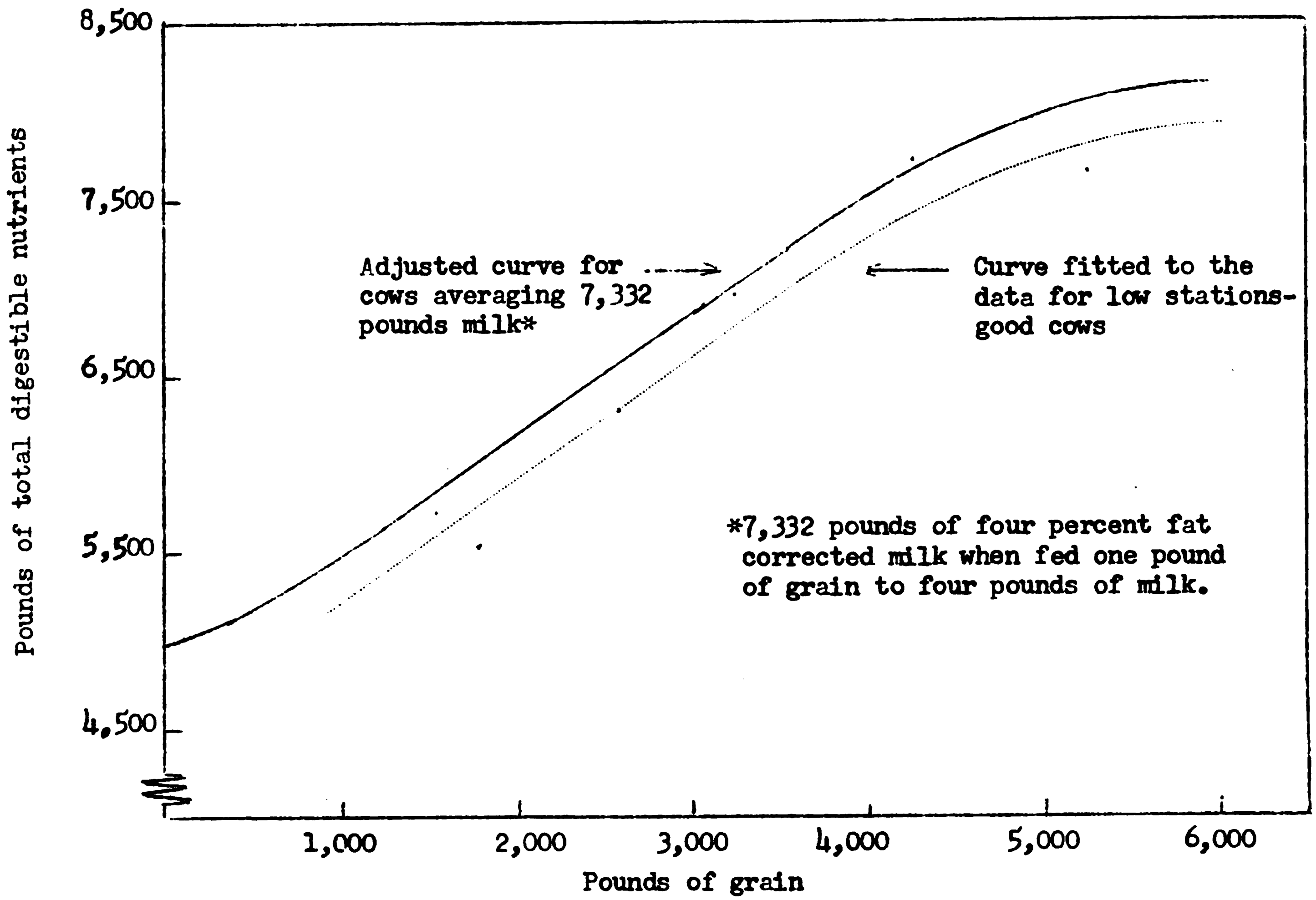

Figure 5. Grain - total digestible nutrient relationship for cows with a capacity of 7,332 pounds of milk*.

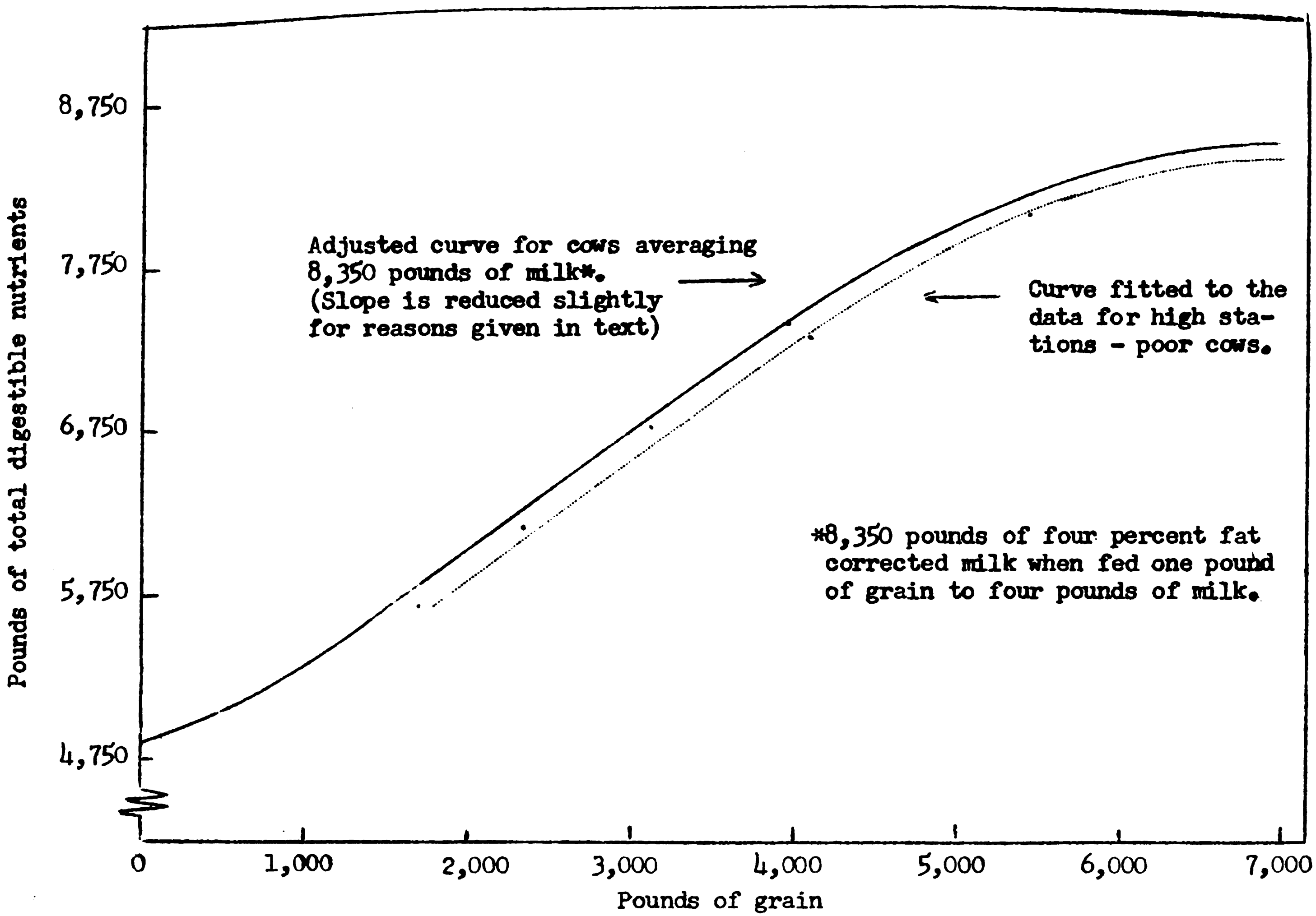

Figure 6. Grain - total digestible nutrient relationship for cows with a capacity of 8,350 pounds of milk*.

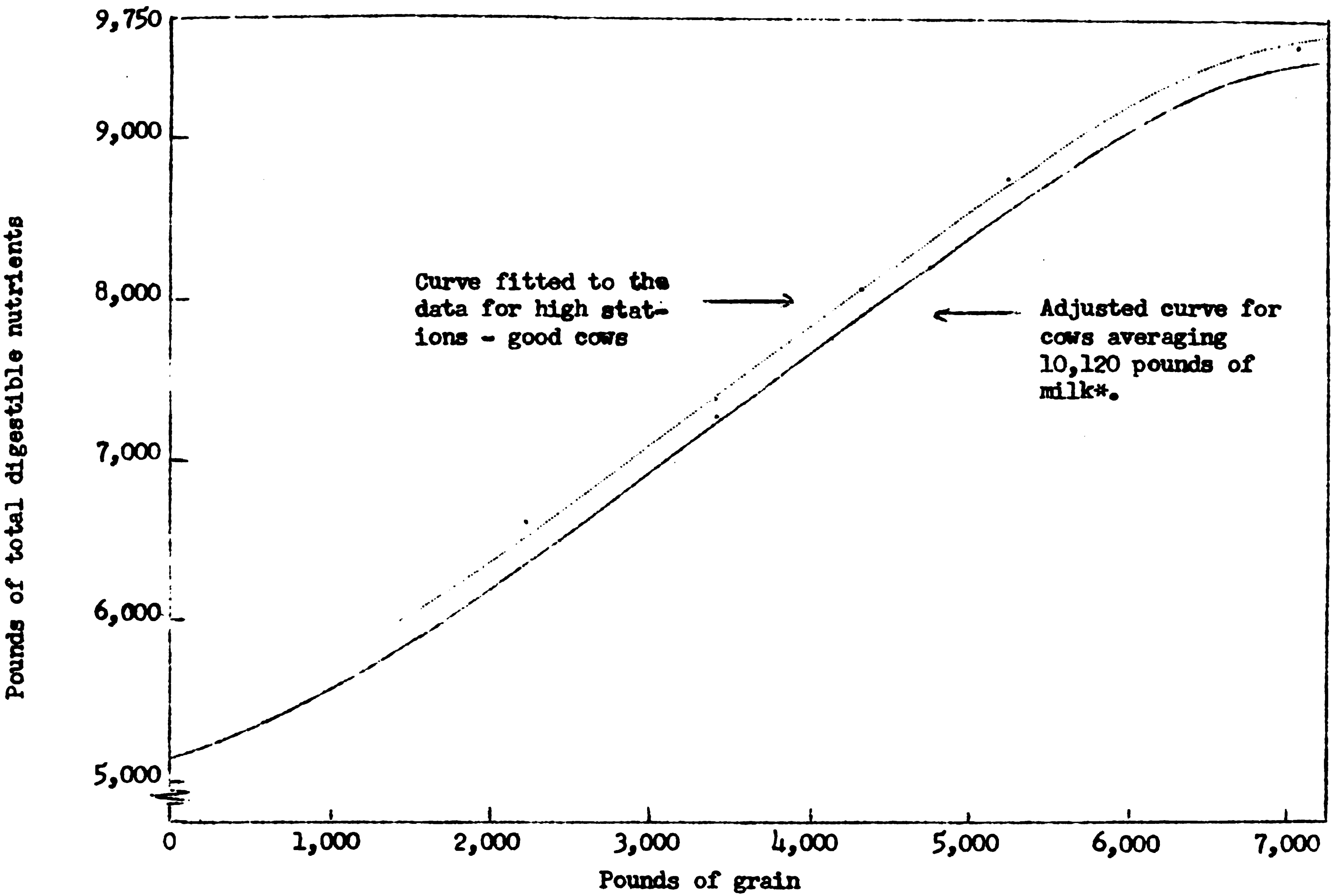

Figure 7. Grain - total digestible nutrient relationship for cows with a capacity of 10,120 pounds of milk*.

to correspond with the low stations poor cows,[7] was estimated that 1,283 pounds of grain would result in a total digestible nutrient intake of 4,977 pounds. This is found by reading from the input-output curve for low stations - poor cows, the total digestible nutrients necessary to produce 5,133 pounds of milk and adding to it the maintenance requirement for a 1,200 pound cow - of 3,394 pounds of total digestible nutrients.[8]

This rate of total digestible nutrient intake was plotted against its respective grain intake on the graph for that quality of cow. This point was found to be above the line fitted to the data reported in Technical Bulletin 815, so a second line was drawn through the point parallel to the first line. This was the curve from which the total digestible nutrient intake was estimated as grain is substituted for hay in the ration. This was done for each of the quality of cows. (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 curve represented the range covered in the experiment. An extension of the curve was needed to carry the relationship down to the level of feeding at which 100 percent of the nutrients are being supplied by roughage -- this tentatively being the

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[7] Ibid, pp. 42 - 43.

[8] Morrison, F. B., Feeds and Feeding, The Morrison Publishing Company, Ithaca, New York, 1950, p. 1147.

lowest level of feeding in the study. Experimental data indicate that cows fed no grain will produce approximately 80 percent as much milk as when fed at a 1:6 grain-milk ratio.[9] The curve was extended to the left until a level of grain feeding of 1:6 was reached. The total digestible nutrient needed to produce 80 percent as much milk and maintain the cow was ascertained, and the intersection point on the ordinate axis was then located. The curve from this point to the 1:6 point was drawn so that total digestible nutrients would be increasing at an increasing rate with beginning increments of grain. A study by Redman indicates a similar awareness of an extremely high rate of substitution of grain for hay for these initial increments of grain to a 100 percent roughage ration.[10]

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[9] Mosely, T. W., Stuart, Duncan, and Graves, R. R., Dairy Work at the Huntly, Montana, Field Stations, Huntly, Montana, 1918-1927, United States Department of Agriculture Technical Bulletin 116, 1929; Sherwood, D. H., and Dean, H. K., Feeding Alfalfa Hay Alone and With Concentrates to Dairy Cows, Oregon Agricultural Experiment Station Bulletin 380, 1940; Headley, F. B., The Economics of Feeding Alfalfa Hay and Grain to Holstein Cows, Nevada Agricultural Experiment Station Bulletin 140, 1935; Graves, R. R., Bateman, George Q., Shephard, J. B., and Caine, George B., Milk and Butterfat Production by Dairy Cows on Four Different Planes of Feeding, United States Department of Agriculture, Technical Bulletin 724, 1940.

[10] Redman, J. C., "Economic Consideration of Grain-Roughage Substitution in Feeding for Milk Production", unpublished Ph.D. thesis, University of Kentucky, 1951, p. 103. Published as a Journal Article "Economic Aspects of Feeding for Milk Production", Journal of Farm Economics, Volume XXXIV, August, 1952, pp. 333 - 345.

These relationships between concentrates and total digestible nutrient intake were then used to determine the amount of grain in the ration at each of the feeding levels for each of the four quality of cows. Hay was adjusted downward accordingly while pasture and silage were held constant. Input (feed) - output (milk) tables are given for each of the four quality of cows in Appendix B, Tables I, II, III, and IV.

The rate of substitution of grain for hay is quite variable over the range considered. For the initial increments from the 100 percent roughage ration, there was the aforementioned high rate of substitution of grain for hay. Then as additional grain is added, the rate of substitution of grain for hay approaches zero as grain consumption is increased with very little decrease in hay consumption, indicating an almost vertical stomach limit line. Still more grain added to the ration begins again to substitute for hay at successively higher rates until the stomach limit line becomes almost horizontal. This appears contrary to findings of Hoglund,[11] Morrison,[12] and Wells,[13] but it is

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[11] Hoglund, C. R. and Wright, K. T., Reducing Dairy Costs on Michigan Farms, Michigan Agricultural Experiment Station, East Lansing, Michigan and United States Department of Agriculture, Washington 1952, p. 17.

[12] *Op. cit.*, Morrison, p. 676.

[13] Wells, J. A., "A Technique for Synthesizing Cost of Production Data - With Special Reference to Dairy Enterprises in Green and Taylor Counties of Kentucky", unpublished Master's thesis, Department of Farm Economics, University of Kentucky, 1951, p. 38.

consistent with work done by Redman[14] at the University of Kentucky and part of the data presented in Technical Bulletin 815.[15]

Hoglund in his work at Michigan State College has used a constantly increasing rate of substitution along the stomach limit line ranging from .15 for the first increments of grain up to .99 for the last increments. This appears to be an inadequate allowance for the rate of substitution for the first increment of grain. Further, it does not reflect the low rate of substitution existing where the stomach limit line is almost vertical.

Morrison assumes a changing rate from between .6 to .8 while Wells uses a rate from between .5 and .7. Redman, though, in delineating the stomach limit line, found them to be shaped as suggested by this study. The data in Technical Bulletin 815 for different quality cows reflect the substitution rates ascertained earlier in this study. However, when lumping all the data together, the authors of Technical Bulletin 815 arrived at an "average" rate of substitution of between .5 and .7.

The results of this study are based on the experimental data presented in Technical Bulletin 815 for the different quality cows. When lumping all the cows together to get an "average" rate of substitution Jensen, et. al., no longer were dealing with a single

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[14] _Op. cit._, pp 100, 122.

[15] _Op. cit._, p. 43.

production function, but were combining segments of functions for a number of cows into an inter-cow function. The fallacious results that arise from combining points from unlike functions have been pointed out by Bronfenbrenner[16] and Reder.[17]

Other feed inputs must be considered also. Investigation showed that vitamins and minerals supplied in the ration were sufficient at all levels with the exception of salt. It became an associated variable with the feeding level, and the amount needed to be supplied at each feeding level for each of the quality cows is given in Appendix B, Table V. These amounts are based on recommendations of Morrison[18] of a minimum requirement of .75 ounce daily per 1000 pounds live weight, plus .3 ounce in addition for each 10 pounds of milk produced.

Labor. Certain portions of labor are associated with the level of feeding and hence must be included in the variable and marginal costs for this length of run. In computing these inputs, data were taken from cost studies conducted in the Detroit milk shed[19] and in addition from work simplification studies made at this and other institutions.[20]

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16 Bronfenbrenner, M., "Production Functions Cobb-Douglas, Interfirm, Intrafirm", Econometrica, Volume 12, January, 1944, pp 35 - 44.

17 Reder, M. W., "An Alternative Interpretation of the Cobb-Douglas Function", Econometrica, Volume 12, July-October, 1943, pp 259 - 264.

18 Op. cit., p. 683.

19 Unpublished data, Agricultural Experiment Station, Michigan State College, 1952.

20 Brown, L. H., "A Comparative Analysis of Stanchion and Milking Parlor Barns", Work Simplification News Letter, Purdue Work Simplification Laboratory, Issue No. 19 (Lafayette, Indiana: Agricultural Hall Annex),

From the cost study, base quantities were determined at the 1:4 level of grain feeding for each of the quality of cows under the given conditions of herd size and type of barn. These figures which were given in terms of 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 ascertained in work simplification studies.

Only certain portions of the labor are variable with the level of feeding. As a result the jobs were divided into those that vary with the level of feeding and those that do not vary with the level of feeding. Only those portions that are variable for this specific length of run are included in the computation of the cost curves.

Rates of doing the several jobs that vary with the feeding level were estimated for each of the sizes of herd and the different types of barns. These rates were based on a per hundred pounds of feed fed or per hundred pounds of milk handled -- whichever operation the job entailed. For the pen-type barn with an average herd size of 16.4

July, 1948, pp. 9 - 18; Lowry, B. H., "Labor, Equipment and Building Costs in Dairy Farming with Special Reference to Work Methods" (Unpublished Master's thesis, Department of Farm Economics, University of Kentucky, 1949), pp. 49 - 59, and 75 - 94; Wells, J. A., "A Technique for Synthesizing Cost of Production Data - With Special Reference to Dairy Enterprises in Green and Taylor Counties of Kentucky", (Unpublished Master's Thesis, Department of Farm Economics, University of Kentucky, 1951), p. 67; Brown, L. H., Cargill, B. F., and Bookhout, B. R., Pen-type Dairy Barns, Michigan Agricultural Experiment Station Special Bulletin 363, 1950, pp. 28 - 29.

cows, the rates of doing the jobs were quite similar to the rates for doing the same jobs in the stanchion barns for a herd size of 22.6 cows. The same rates were therefore used in each instance.

Using these rates, the labor input was estimated for each of the levels of feeding for each of the qualities of cow. The results are presented in Appendix Tables VI and XV along with the rates of doing the respective jobs for each of the herd sizes, presented in Appendix Table XVI.

These inputs are only estimates of the labor used on Detroit milk shed dairy farms. Labor used varies quite widely among farms and probably on the same farm in different seasons of the year. The results are thought to be fairly accurate, though, because the base quantities are determined by actual data taken from the Detroit milk shed farms.

Milk cans. As the level of feeding is raised and more milk is produced on an annual basis, additional milk cans are needed to handle the daily deliveries. Average daily deliveries were estimated at the various feeding levels for each of the representative enterprises and the additional 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 was estimated on the basis of a five year life for the cans. This charge was evenly distributed over the various feeding levels.

Electricity. As the level of feeding is raised and more milk is produced, additional electricity is used. This results from increased milking machine operation and milk cooling.

Electrical appliances on several typical dairy enterprises were metered by the Michigan State Agricultural Engineering Department as part of a demonstration in 1952. Although the rate varied considerably between different farms, these studies showed that additional milk could be cooled at the rate of .98 kilowatt hours per hundred pounds of milk. The electrical power used by the milking machine in milking an additional hundred pounds of milk could be done at the rate of .0836 kilowatt hours. The results of applying these rates to the additional milk produced at the higher levels of feeding is presented in Appendix Table XVII.

These averages may not be representative as power requirements vary considerably between conditions. The data do indicate, however, something of the magnitude of electricity costs, and as such costs make up such a small part of the total variable costs, rather large proportional errors would not significantly influence the marginal cost computations and the supply curve.

Feed grinding. As the level of feeding is raised another associated variable is the cost of grinding the additional concentrates. A large proportion of the producers in the Detroit milk shed have their feed ground either by taking it to a local elevator or by having it custom ground at the farm. Consequently, it seemed reasonable to use custom rates in establishing the charge.

A study on custom work in Michigan made by Vary[21] indicated that the most common charge for grinding feed was ten cents per bag. It is estimated that a bag holds approximately eighty pounds. The cost, based on this charge, at each feeding level for each of the different herds is presented in Appendix Table XVIII.

Manure credit. The manure of the dairy animal has value to the farmer and as such is a credit for the dairy enterprise. It acts to lower both the variable and marginal cost of producing milk as it is associated with the feeding level. The amount of fertilizer elements returned to the soil is determined partially by the composition of the feed fed to the animals and partially by the manner in which the manure is handled.

The composition of the hay used in this study was such that a hundred pounds of it contained 1.8115 pounds of nitrogen, .24 pounds of phosphorus, and 1.9697 pounds of potassium. A hundred pounds of the grain mixture contained 2.58 pounds of nitrogen, .346 pounds of phosphorus, and .64 pounds of potassium. These figures are based on the average composition of feed as indicated in Morrison's Feeds and Feeding.[22]

Because of the richness of milk in nitrogen and phosphorus, when dairy cows producing a good yield of milk are fed the usual types

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21 Vary, K. A., Rates for Custom Work in Michigan, 1952 and 1953, Extension Folder F-161, Michigan State College Cooperative Extension Service.

22 Morrison, Op. cit., pp 1086 - 1131.

of rations, they will 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, being about 86 percent.[23]

Morrison indicates that under proper management not over 25 to 30 percent of the nitrogen and practically none of the phosphorus and potassium are lost.[24] In this study, a 30 percent loss was assumed for nitrogen and a five percent loss for the phosphorus and potassium under the conditions of the stanchion barns. As somewhat more nitrogen can be saved with a pen-type barn, it was assumed that eighty percent of the nitrogen excreted could be returned to the fields.

In computing the manurial credit to the dairy enterprise, the amount of the fertilizer elements fed to the cows at each feeding level was estimated on the basis of the aforementioned data on feed composition. The amount excreted by the animal was estimated and from this the amount reaching the fields. Results are presented in Appendix Table XIX.

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 that help to dissolve otherwise insoluble plant foods, and the great number of various kinds of bacteria that it contains. While the value of these

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23 Ibid, p. 641.

24 Ibid, p. 648.

latter mentioned qualities is not measurable, it is assumed sufficient to offset the cost of spreading and hauling the manure. The total value of the fertilizer elements reaching the fields was therefore credited to the dairy enterprise.

Pricing of the Factors of Production

The inputs were valued at their on-farm prices. Due to their heterogeneous uses, differences in marketability, and different sources, prices were arrived at in several ways. A description of the method of pricing for each input follows.

Inputs with little or no seasonal variation in price or use. Milk cans, stock salt, nitrogen, phosphorus, potassium, electricity, and soybean oil meal have little or no seasonal variation in price, Consequently, a straight average of the average quarterly prices as secured from the Michigan Agricultural Statisticians office is used. These are at-farm quotations.

Inputs with seasonal variations in price and use. Both the use and value of feed grains and hay vary seasonally. In arriving at the annual average price, an allowance for this was made by taking average monthly prices and weighting them by months according to their estimated use in the dairy enterprise. For corn and oats, a nine percent weighting was used for October through April and a 7.4 percent weighting was used for May through September. For the shelled corn, seven cents per bushel was charged for shelling.

The average monthly prices for hay were weighted at 15 percent for November through March and 12.5 percent for October and April. It was assumed that little or no hay was fed through the remainder of the year.

Labor - an asset that is often fixed for the farm but variable between enterprises. The pricing of labor, as earlier mentioned, presents one of the more difficult problems of the study. For the individual Michigan farm, labor is often considered to be a fixed asset, which implies its earning power is less than opportunity cost and greater than its off-farm disposable value.[25] Under these conditions, the farm manager is motivated neither to buy more of it nor to market some of it in an off-farm alternative opportunity.

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 is changed and the amount of milk produced changes, the amount of labor varies and must be priced. However, as an asset that is often fixed for the farm as a whole, it can be priced at its earning power in dairy or in an alternative enterprise. If a firm is in a state of equilibrium, the labor input is allocated among enterprises so that MFC = MVP for each enterprise and its MFC in one enterprise will be its MVP in an alternative use. In order for one more unit of labor to be used in the dairy

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[25] Bradford, L. A., and Johnson, G. L., Farm Management Analysis, John Wiley and Sons, Inc., New York, 1953, p. 321.

enterprise, it must be paid at least the on-farm opportunity cost which is the MVP sacrificed by diverting it from an alternative enterprise. If there are no on-farm alternatives other than the dairy enterprise, an additional unit of labor applied to it can not be valued higher than the MVP of labor so long as labor is a fixed asset as previously defined.

Computations for dairy farms in Ingham County as made by Wagley[26] and modified by Johnson estimate the MVP of labor at 67 cents per day. As this study has been criticized for underestimating the earning power of labor, a comparison was made with data presented in the Farm Business Analysis report for Area 5[27] by Michigan State College and also with data from a study made by Paul Wilkes.[28] The results are indicated in Table VI.

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 the study made by Wilkes.

There is, however, a high degree of consistency among the different studies for gross income per PMWU and labor income per PMWU, the evidence suggesting that the Johnson-Wagley estimate of the MVP is not too low.

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[26] Wagley, R. V., "Marginal Productivities of Investments and Expenditures, Selected Ingham County Farms, 1952", unpublished Master's Thesis, Department of Agricultural Economics, Michigan State College, 1953.

[27] Farm Business Analysis Report for Area 5, Agricultural Experiment Station, Michigan State College, 1952.

[28] Wilkes, P., unpublished computations, Michigan State College, 1953.

TABLE VI

GROSS INCOME, LABOR INCOME, AND ESTIMATED MARGINAL VALUE PRODUCTIVITY OF LABOR ON SELECTED MICHIGAN FARMS, 1952

	Wagley	Area 5	Wilkes
	(Dollars)	(Dollars)	(Dollars)
Gross income/PMWU*	26.86**	22.18	25.47
Estimated MVP/day	.67	---	---
Labor income/PMWU	7.29#	5.56	6.22

SOURCE: Refer to footnotes 26, 27 and 28 this Chapter.

*Productive Man Work Unit.

**Gross income/day, actually $\frac{d(\text{gross income})}{d(\text{labor})}$

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

where the i's are inputs other than labor.

For purposes of this study, however, we would not be justified in pricing labor at a value of 67 cents per day. 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 MVP of labor is probably significantly higher than its MVP for the year as a whole. This would seem to justify our placing a higher value on it than the evidence would seem to indicate.

An estimate of fifty cents per hour is used, it being realized that there is little or no empirical evidence to substantiate such a value. It is considerably below the going wage rate, this being justified by the fixed nature of the labor asset and its low estimated earning power. It is above the value at the margin for the above given reason.

The prices used in computing the cost curves are found in Table XX, Appendix B.

Computation of the Cost Curves

The physical quantities of each of the inputs associated with that length of run in which feed is variable have been computed. Prices for each of these inputs to the farmer have been established from various sources.

As pointed out in Chapter II, marginal costs are determined by the cost of the inputs which can be varied within a specific length of run. Variable costs[29] are found by multiplying the input quantities by their respective prices at each feeding level. This gives the total cost of each input at each feeding level. These costs are then summed at each feeding level to determine the total variable costs[29] associated with the length of run in which feed and associated inputs are variable.

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[29] Less than total variable costs in some instances, but the difference is a constant and does not influence marginal costs for this length of run.

It was pointed out in an earlier section that the fertilizer elements returned to the farm in the form of manure were a credit to the dairy enterprise. The physical quantities of these nutrients at each feeding level are multiplied by their respective prices to determine their credit to the farm. The value of this credit is then subtracted from the total costs at each feeding level and the total variable costs chargeable to the dairy enterprise are determined.

The problem is to determine the marginal cost of producing an additional 100 pounds of milk. As the feeding level is raised changes occur in two factors. Total variable costs are increasing, and at the same time, milk production is increasing. Dividing the increase in total variable costs from one level of feeding to the next higher level by the increase in milk production, in hundreds of pounds, that resulted from those additional costs, gave the marginal cost per 100 pounds of milk. The resulting figure is an average marginal cost per hundred pounds of milk for going from one level of feeding to the next higher level. The variable and marginal costs at each level of feeding for each of the typical herds are presented in Appendix B, Tables XXI - XXX.

In drawing the curves, the milk production at each level of feeding was plotted on the horizontal axis. Midway between the quantity produced at each feeding level the average marginal cost of going from one level of feeding to the next higher level was plotted.

A smooth curve was fitted to these points for each of the typical herds. The results are presented in Figures 8 through 17.

For the lowest quality cows, the marginal cost curve is continually rising over the range plotted. For the other three quality of cows the marginal costs first decrease with heavier feeding levels and then increase. The significance of this is discussed in the next section.

For all the curves there is a considerable range over which the curves are only gradually rising. Beyond a certain level, however, the marginal cost of producing milk rapidly rises. For the higher quality cows, this range of rapidly rising marginal costs is not reached, even at the highest level of feeding. It was desired to know the marginal costs of producing milk up to a cost of six dollars per hundred, so the curves for these high quality of cows was extended up to this amount. As the extension was not very large in either of the three cases, it detracts little from the accuracy of the prediction curve.

It is significant to point out that for the length of run in which only feed and associated inputs are variable, herd size has very little impact on the marginal costs of producing milk. A discussion of the reasons for this is given in Chapter V.

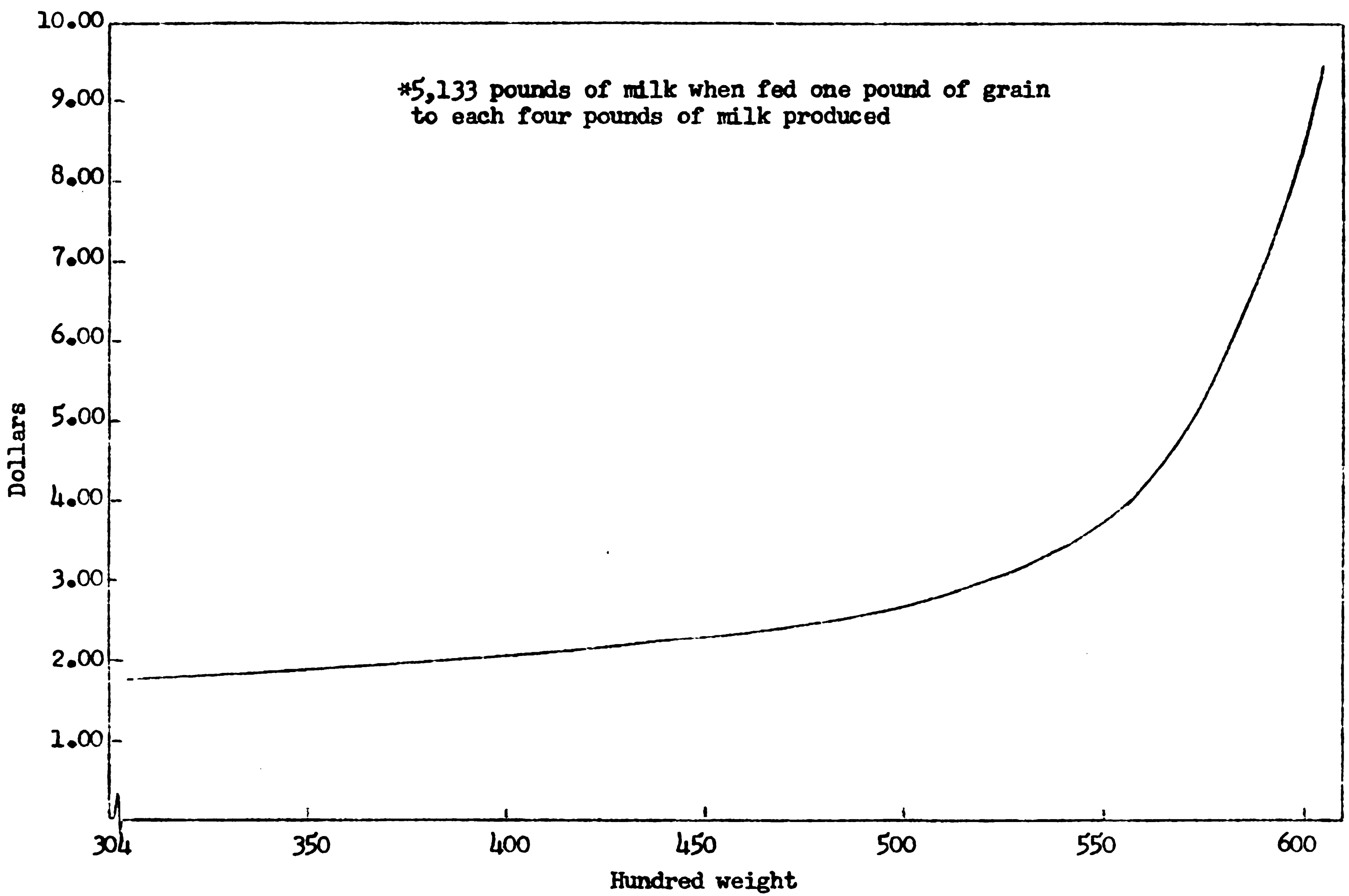

Figure 8. Marginal cost curve, 8.3 cow herds, producing 5,133 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

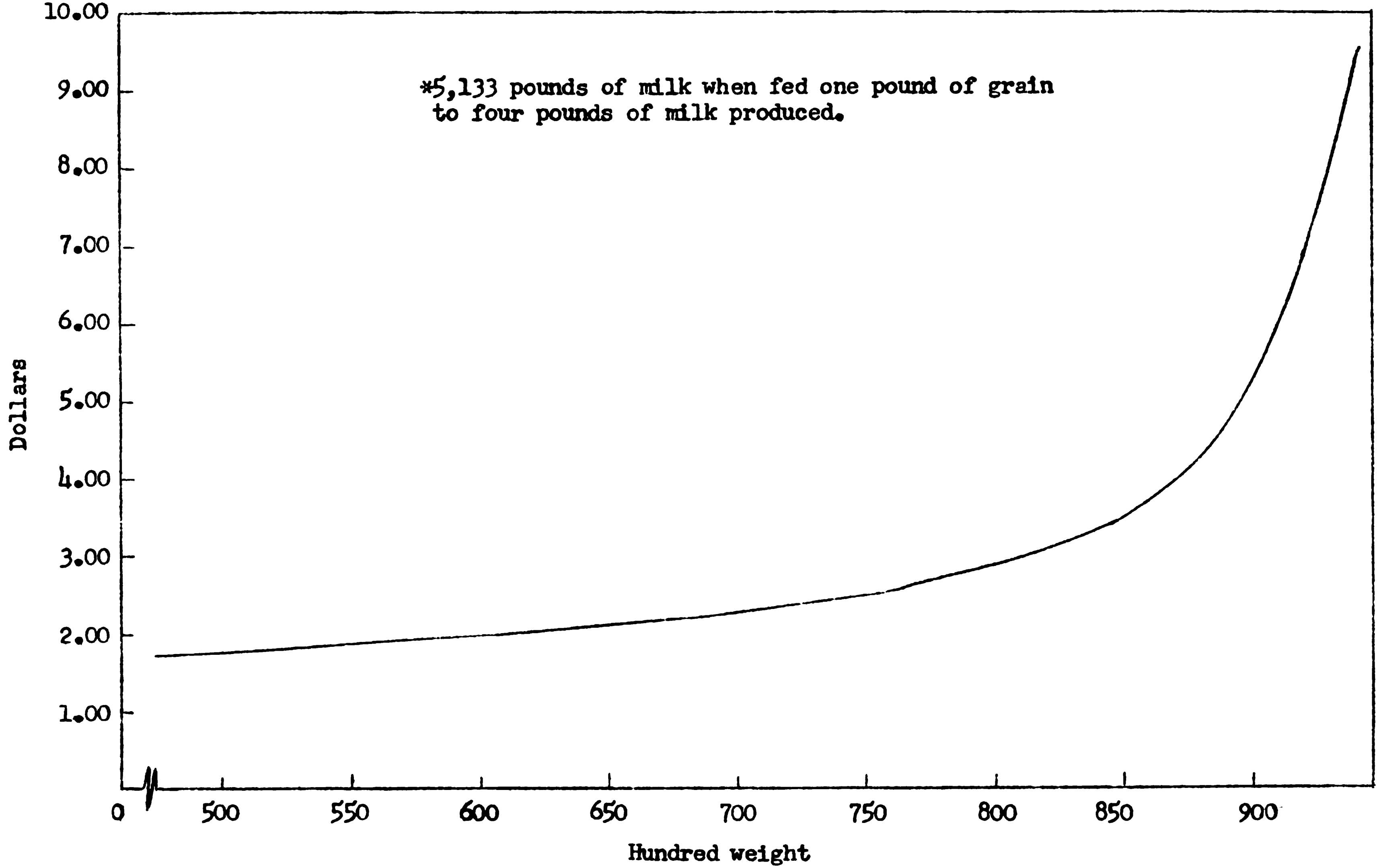

Figure 9. Marginal cost curve, 12.9 cow herds, producing 5,133 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

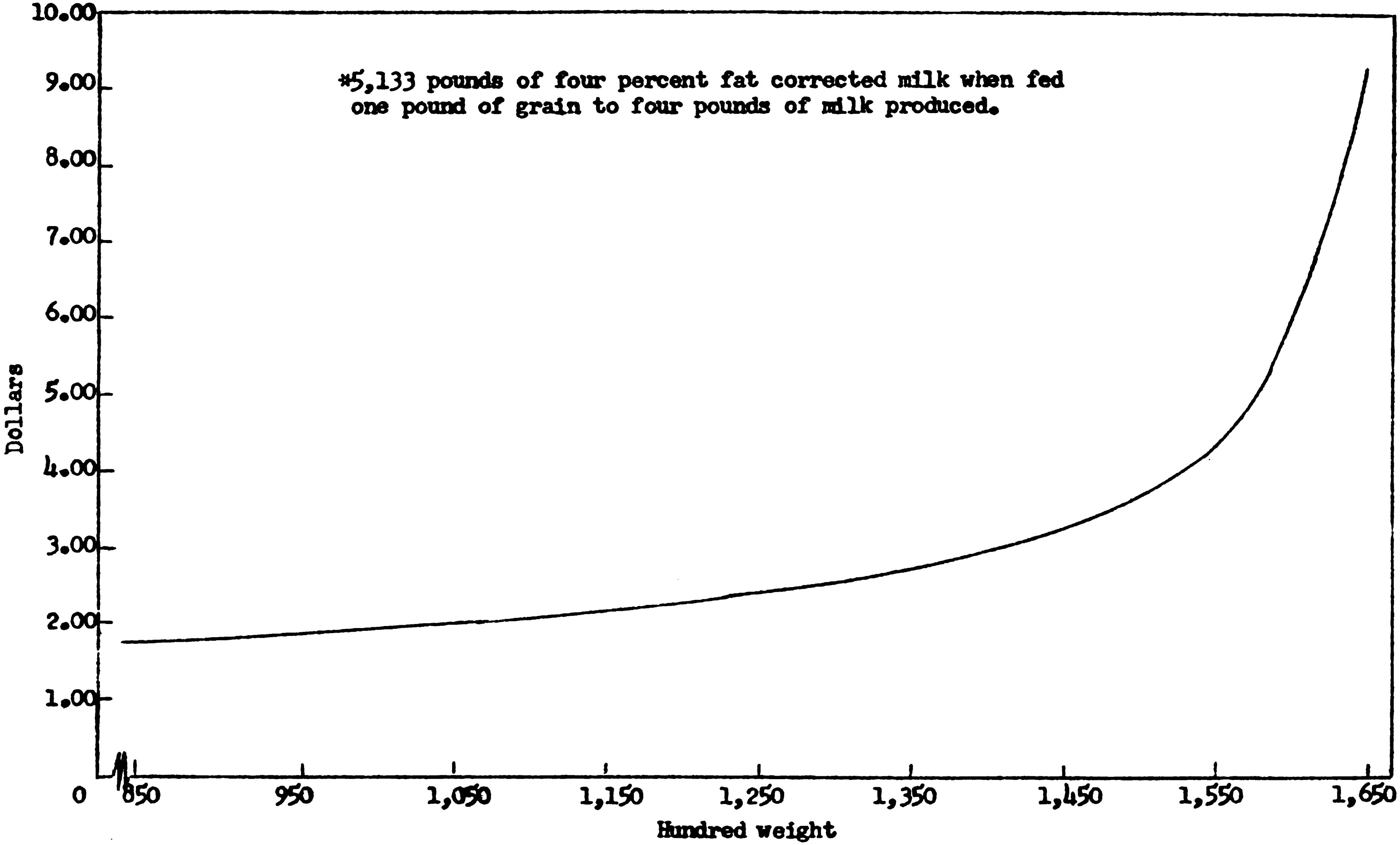

Figure 10. Marginal cost curve, 22.6 cow herds, producing 5,133 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

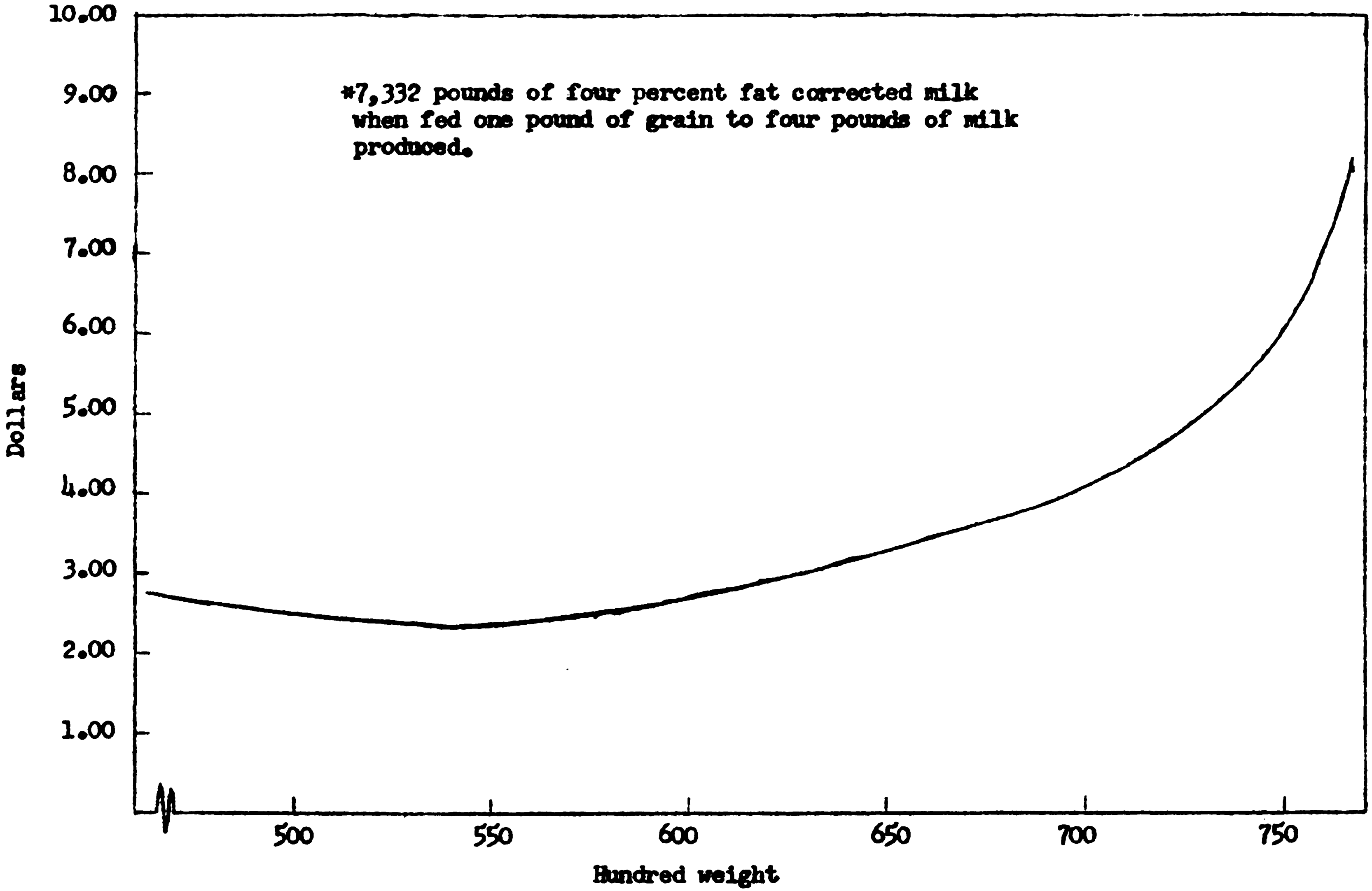

Figure 11. Marginal cost curve, 8.3 cow herds, producing 7,332 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952

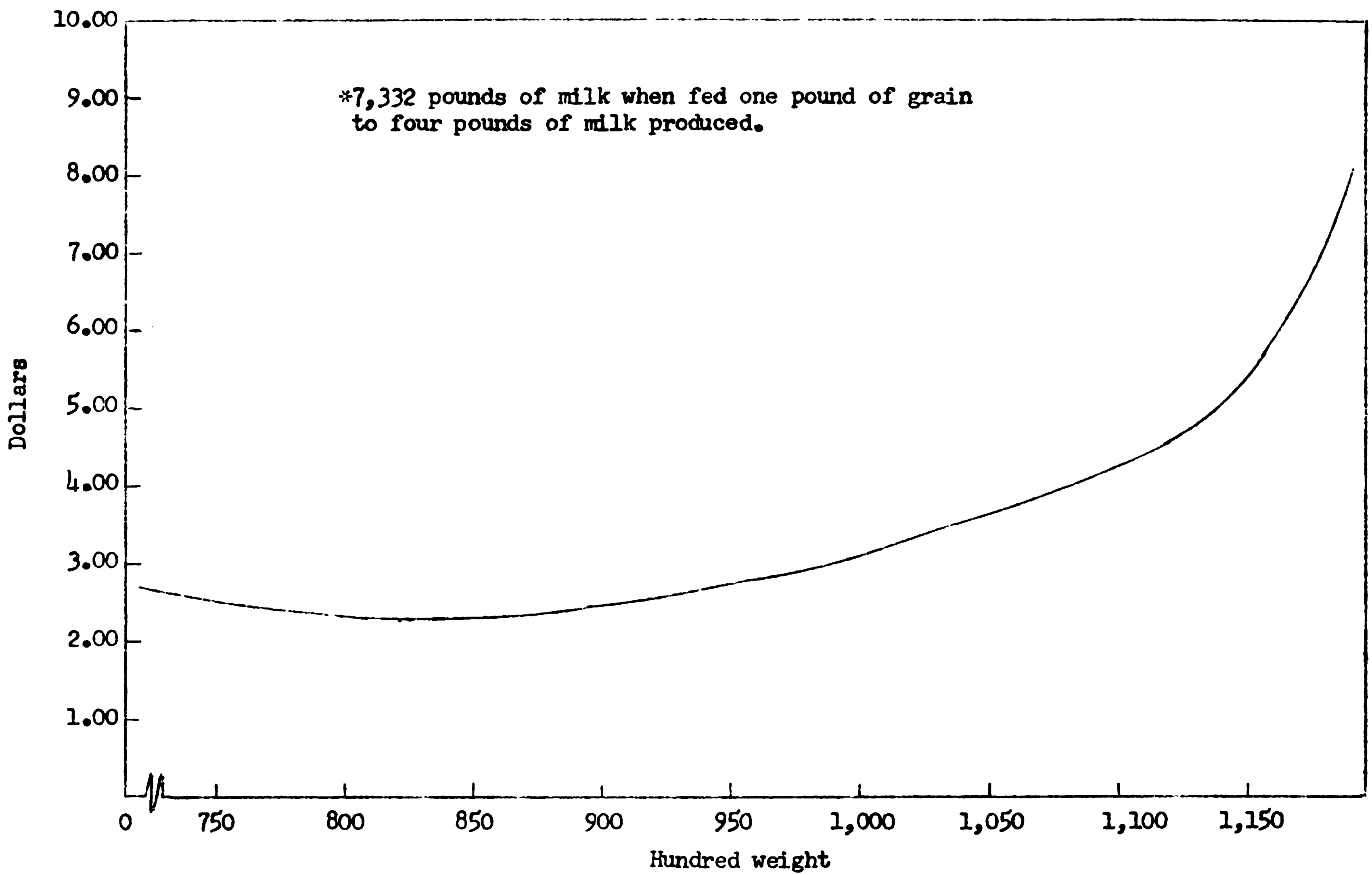

Figure 12. Marginal cost curve, 12.9 cow herd, producing 7,332 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

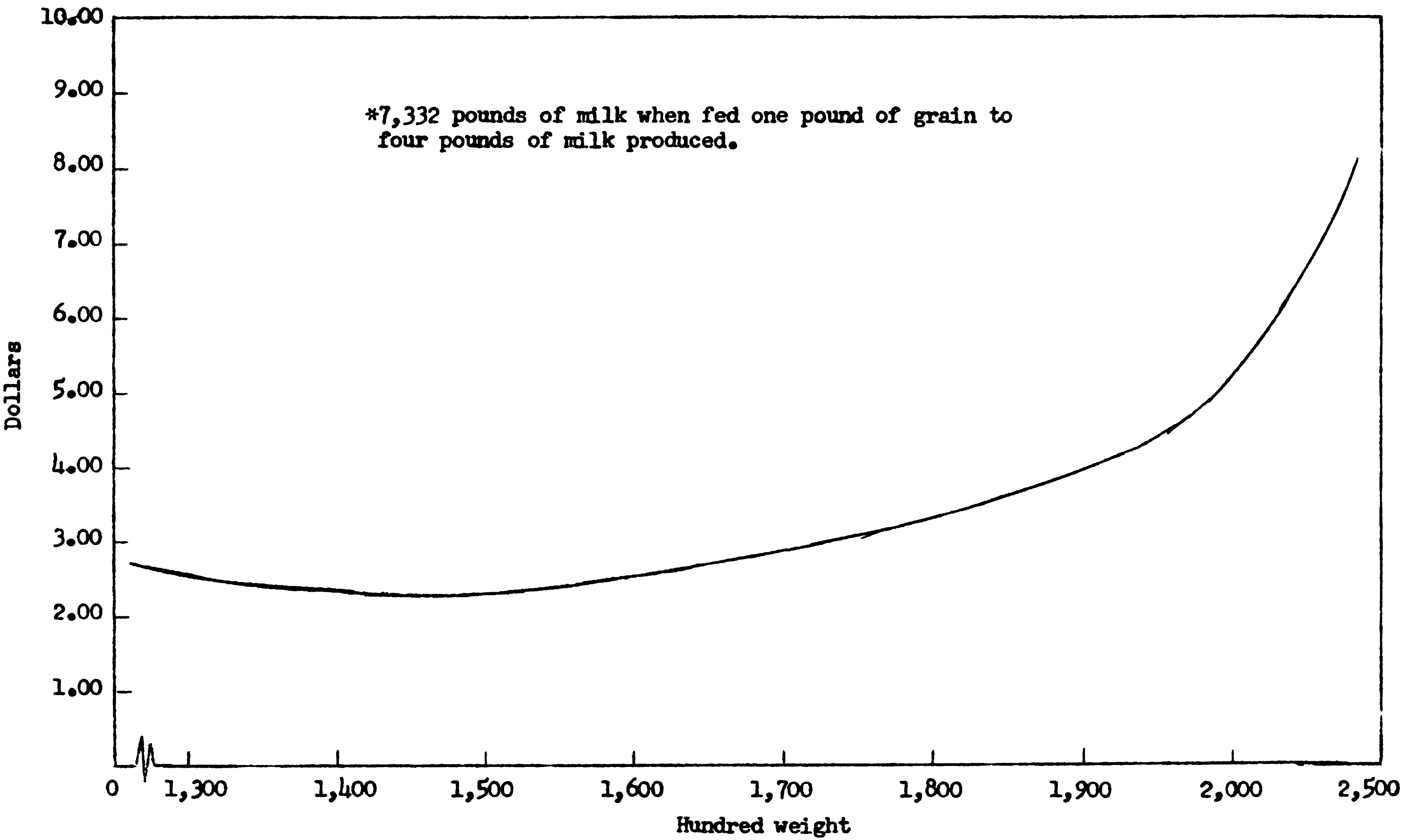

Figure 13. Marginal cost curve, 22.6 cow herds, producing 7,332 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

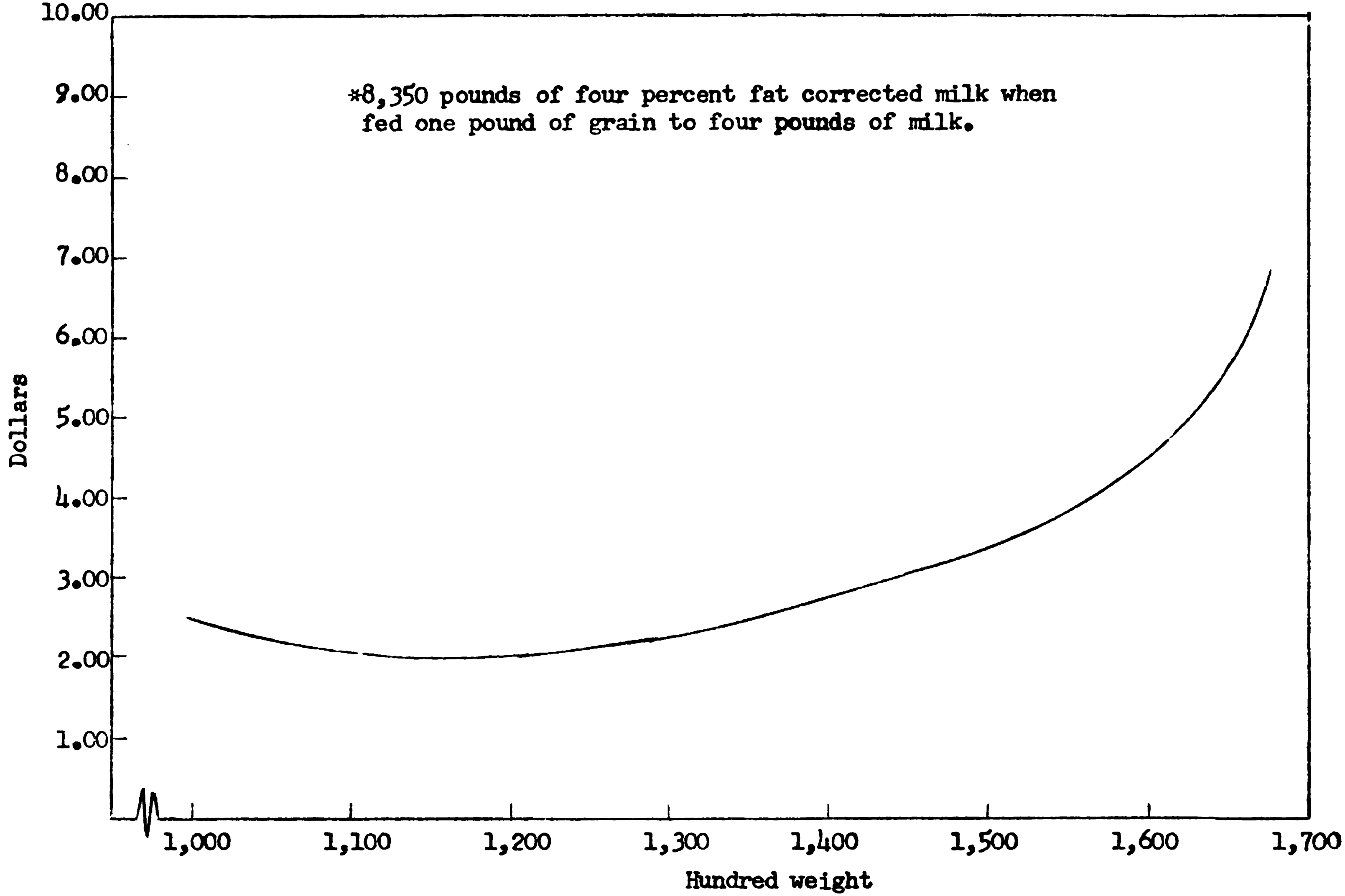

Figure 14. Marginal cost curve, 16.4 cow herds, producing 8,350 pounds of milk,* pen-type barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

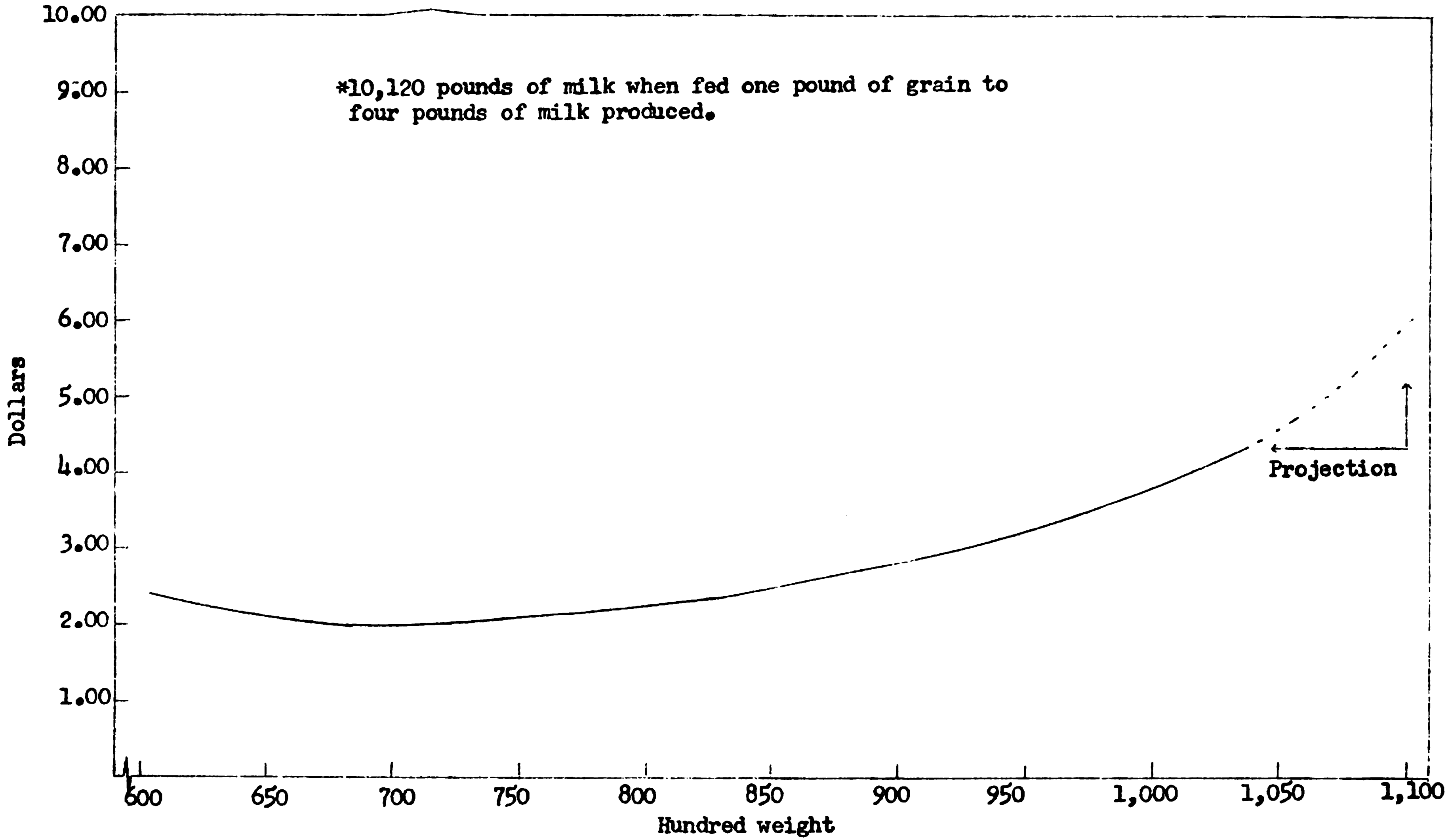

Figure 15. Marginal cost curve, 8.3 cow herds, producing 10,120 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

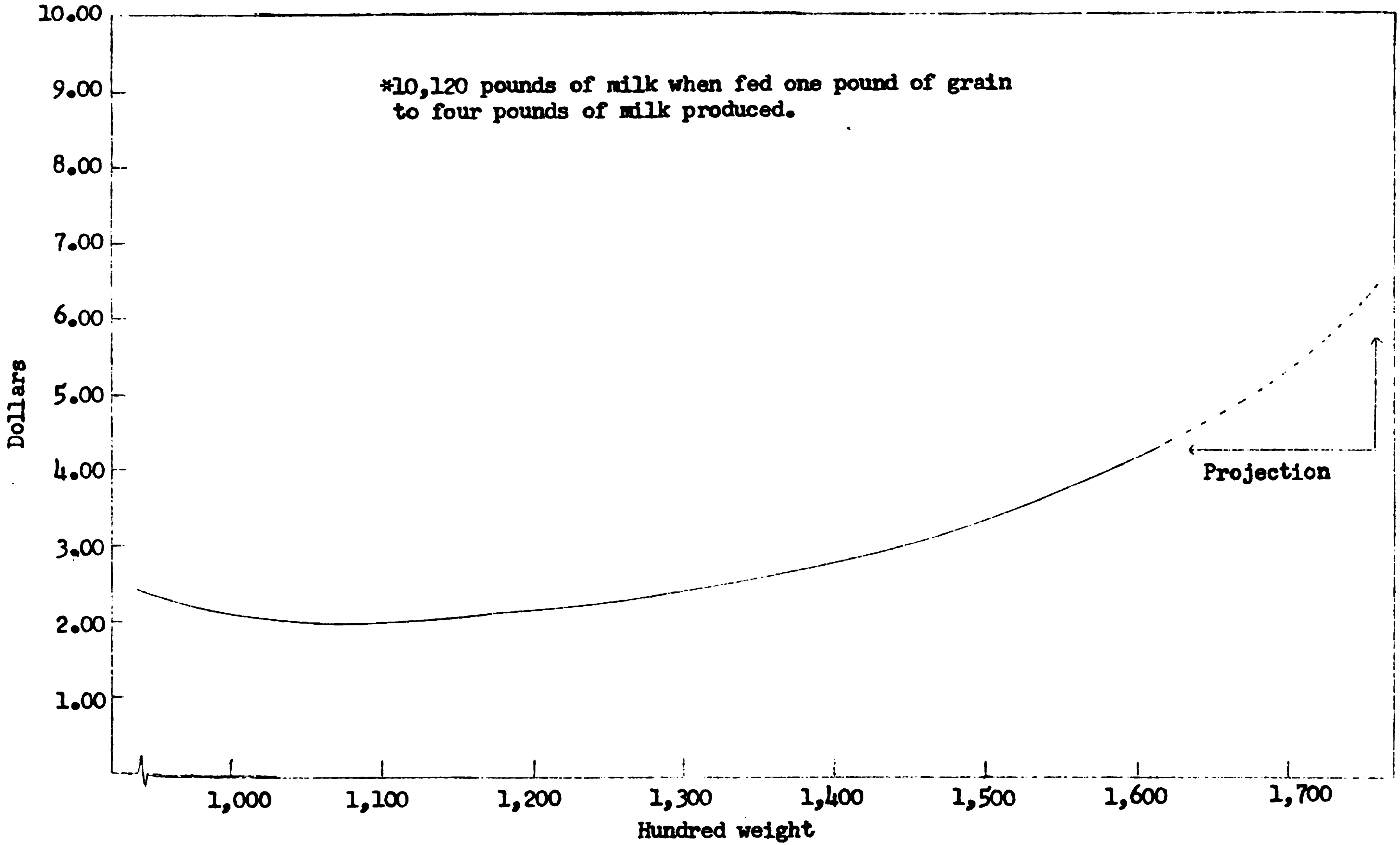

Figure 16. Marginal cost curve, 12.9 cow herds, producing 10,120 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

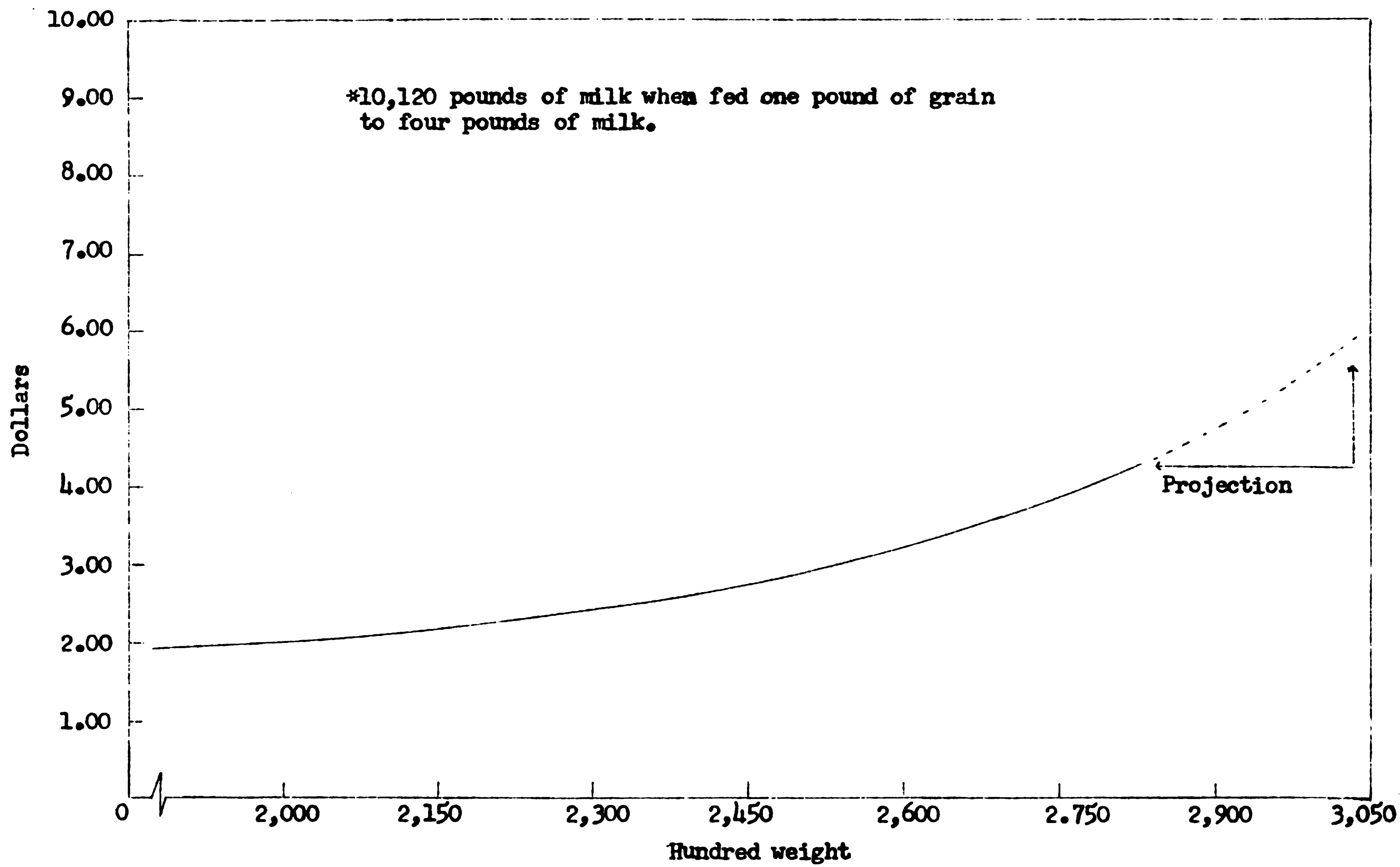

Figure 17. Marginal cost curve, 22.6 cow herds, producing 10,120 pounds of milk,* stanchion barns, Detroit milk shed, October 1, 1951 - September 30, 1952.

Economic Significance of These Curves for Purposes of Aggregating the Supply Curve

As was mentioned earlier, it was originally thought that the 100 percent roughage level of feeding would secure the lowest cost per hundred weight of producing the milk. Wells, in computing marginal cost curves for milk production over this same length of run in certain areas of Kentucky found this to be the case, and the feeding recommendations of the dairy specialists, as earlier mentioned, also seem to imply this.

In computing the curves this was found not to be the case for high quality cows. For the three high quality cows in this study, the marginal cost of producing additional milk actually decreased as the initial increments of grain were added along the stomach limit level to the 100 percent roughage ration. This indicates that for these qualities of cows, the scale line does not go out the roughage axis and up the stomach limit line, but actually leaves the roughage axis before reaching the stomach limit line for all roughage and meets the stomach limit line at some combination of grain and roughage. See Figure 18.

In searching the literature it was found that Redman achieved similar results in his studies at Kentucky.[30] The explanation for the phenomenon appears to be that the marginal physical product of total digestible nutrients is very high as the initial increments of grain replace large quantities of roughage.

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30 *Op. cit.*, p. 100, 122.

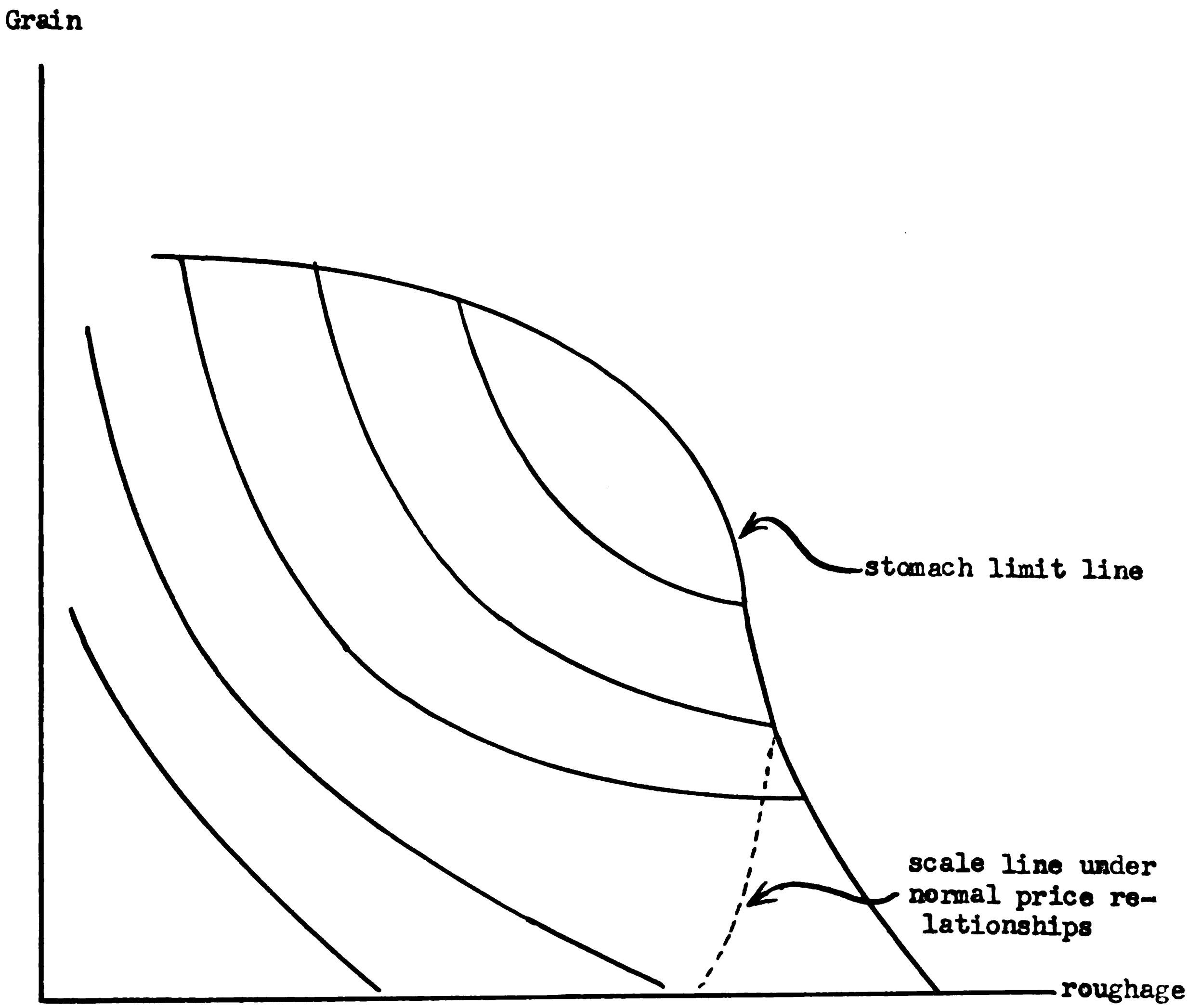

Figure 18. Production surface for the dairy cow.

Though the marginal factor cost at this time is increasing too, because as pointed out previously, a high cost source of digestible nutrients is being substituted for a low cost source, total digestible nutrients may increase very little. If marginal costs are found by dividing marginal factor cost by marginal physical product, the lower marginal cost, then results from a high marginal physical product of total digestible nutrients along the initial segment of the stomach limit line. However, marginal cost rises with further additions of grain to the ration because of the diminishing marginal physical productivity of total digestible nutrients as grain loses its ability to replace large quantities of roughage.

This ability to utilize grain in producing milk at a lower marginal cost appears to be related to the quality of the cow. For the lowest quality of cows in this study, the marginal cost was lowest at the 100 percent roughage level of feeding. Wells, in his study at Kentucky in which his marginal costs were lowest at the 100 percent roughage level of feeding had even lower quality cows, so this work is consistent with his results.

Selection of the Relevant Portions of the Marginal Cost Curves

To reiterate what has been written previously, the relevant portions of the marginal cost curves for each of the typical herds are the firms' rational short-run supply curves, indicating the quantity of milk they will supply at alternative prices. As the firm attempts to maximize profit it will adjust its output toward the point where marginal cost is equal to the price of the product. For each producer, changing prices call forth changing quantities of output, then and the firm's marginal cost curve indicates this relation between price and the quantity supplied by each firm - given the cost structure and input prices.

Determining the relevant portion of the marginal cost curve presents a special problem due to the unique shape of those curves identified with the three high qualities of cows. Static neo-marshallian theory commonly indicates 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. This appears to be logical and straight forward from an abstract theoretical standpoint but has to be further developed when applying theory to cost problems. An extension of theory has to be made in determining what portion of the marginal cost curve is the dairyman's rational supply curve and to cover conversion of fixed assets to variable assets.

For the three highest qualities of cows the marginal cost curve first drops and then rises, even though the data indicate that average variable costs are rising. As was pointed out in the previous section this is because the inputs were not combined according to the scale line over this lower range. If the curves had been recomputed with the inputs combined as dictated by the scale line, the marginal cost curve would have increased continually over the range of the computations along with the average variable costs.

Preliminary work by Denio Caul[31] here at Michigan State College indicates that if the price of milk drops below a minimum level on the marginal cost curve corresponding roughly to the point of difficulty on the stomach limit line, the cow's earning power becomes so low that she will be disposed of at salvage value.[32] The length of run in which herd size is variable is beyond the scope of this thesis. As stated previously, this is an analysis for that length of run in which feed is variable. Thus, to compute the supply response below this minimum price level would entail consideration of a longer length of run. Therefore, the composite supply curve will be computed only from that portion of the marginal cost curves of the firm that is to the right of the minimum level.

The minimum price for which a supply response can be ascertained for all of the ten herds is two dollars and forty cents. The composite supply curve will therefore be estimated over the range from two dollars and forty cents up to and including six dollars per hundredweight of milk.

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31 Caul, Denio, a tentative Master's thesis on estimating the value of various quality of cows.

32 This is based on a definition of a fixed asset as presented by Bradford and Johnson. Bradford, L. A. and Johnson, G. L., Farm Management Analysis, John Wiley and Sons, Inc., New York, p. 321. They state that market 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 its opportunity cost, 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 not within these limits, it is no longer fixed for the firm and becomes a variable asset.

CHAPTER IV

THE COMPUTATION AND EXPLANATION 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 ten typical enterprises is given in Table VII. This breakdown is based on the results of the mail questionnaire sent to the members of the Michigan Milk Producers' Association.

The estimated response of each of the ten typical enterprises at prices of two dollars and forty cents, two dollars and fifty cents and upward by fifty cent intervals to the six dollar level was multiplied by the number of similar enterprises in the milk shed. These results were then summed at each price level to get the composite response for the entire market area. The resultant supply curve is presented in Figure 19.

Adjusting the Composite Supply Curve

The shape of this supply curve, being based on the experimental production functions from the four qualities of cows and the relative importance of each quality of cow in the market, should be quite valid

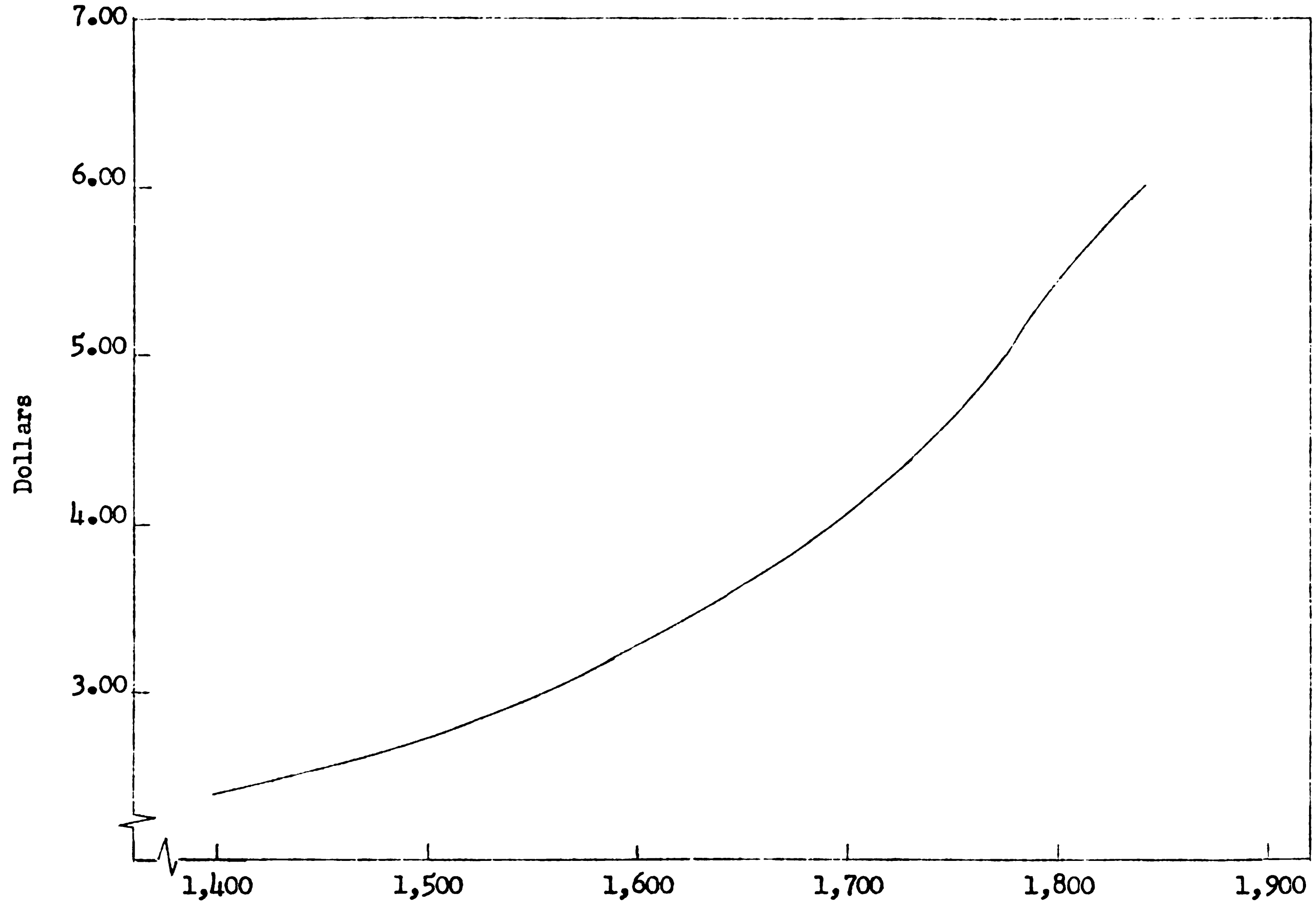

Figure 19. Supply curve for milk, based on mail questionnaire, four percent fat corrected milk, Detroit milk shed, October 1, 1951 - September 30, 1952.

TABLE VII

TYPES OF HERDS AND ESTIMATED NUMBER OF PRODUCERS OF EACH TYPE IN THE DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952

Number of milking cows in herd	Average production per cow in pounds*	Percent herds of this type are of total herds	Number of producers with this type of enterprise
Stanchion Barns			
8.3	5,331	12.755	1,559
8.3	7,332	11.426	1,397
8.3	10,120	9.477	1,158
12.9	5,331	8.592	1,050
12.9	7,332	10.629	1,299
12.9	10,120	10.452	1,278
22.6	5,331	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		100.00	12,223

*Four percent Fat Corrected Milk.

for four percent milk. To make use of the curve for predicting purposes, the shape of the curve must be altered by presenting it in terms of 3.68 percent milk and shifting it laterally to adjust for the bias toward large producers that resulted from sampling a special group of producers with a mail questionnaire. 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.

Adjusting the curve to present butterfat content. The input-output relationships used in deriving the individual marginal cost curves were in terms of four percent fat corrected milk. Data of the Michigan Milk Producers' Association indicated that for the fiscal year under consideration, the weighted average butterfat content of the milk produced was 3.68 percent butterfat. The production figures as ascertained from the mail questionnaire were therefore converted from 3.68 percent to four percent fat corrected milk for purposes of analysis. The composite curve as presented in the last section was in terms of milk with this fat content.

To be useful for predicting purposes the curve must be converted back to 3.68 percent milk. This was done by taking the quantity produced at each of the specified prices used in locating the curve, and multiplying that quantity by four percent. This gives the butterfat produced at each price, and the quantity of 3.68 percent milk can be determined by dividing the pounds of butterfat by .0368. The resulting curve is given in Figure 20.

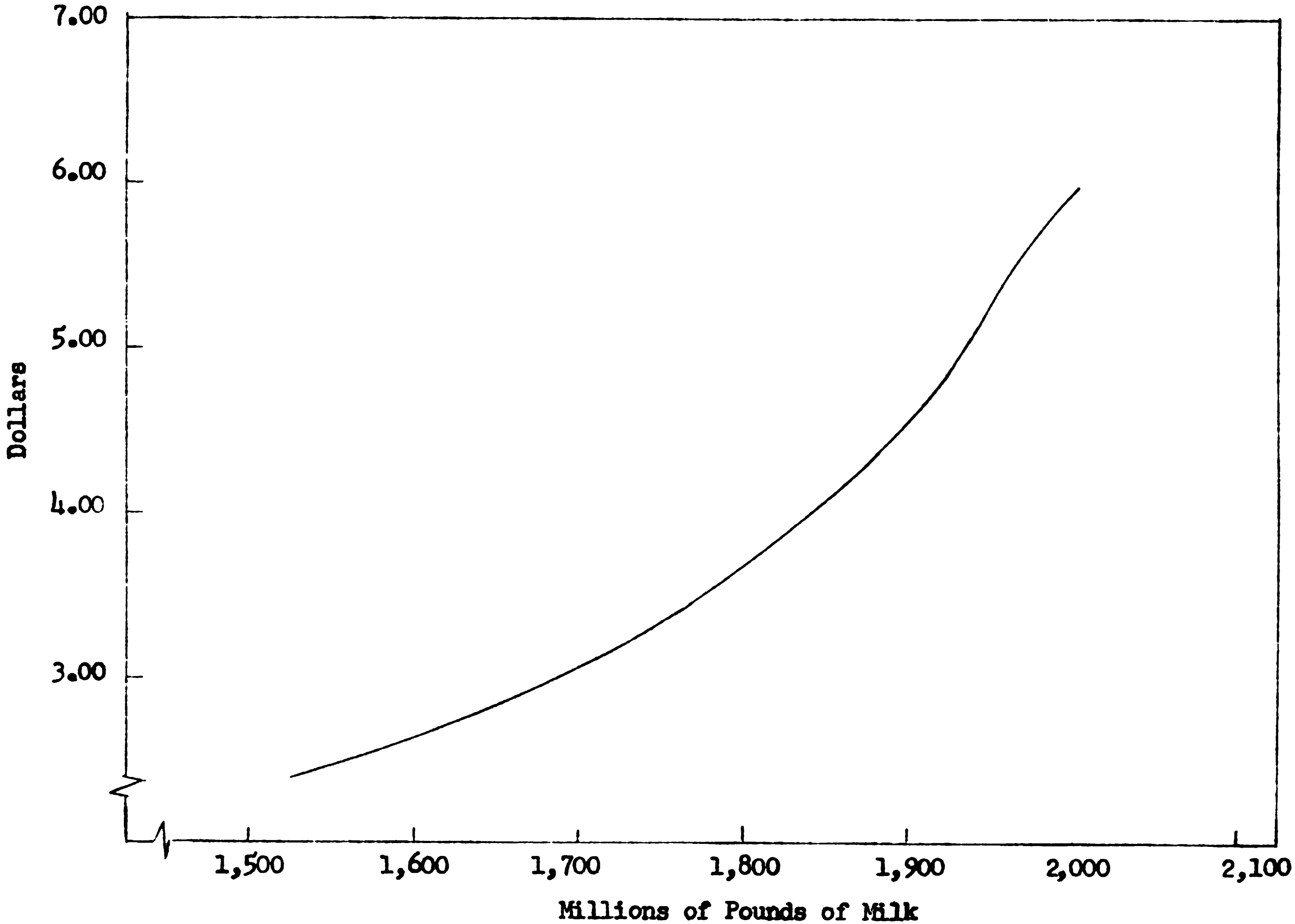

Figure 20. Supply curve for milk, based on mail questionnaire, corrected to 3.68 percent fat corrected milk, Detroit milk shed, October 1, 1951 - September 30, 1952.

The shape of this curve is valid for the year under consideration. If in the future the average butterfat content of the milk changes significantly, the curve can be converted to the new content. Changes in the average butterfat content of the milk are slow in being made, however, unless there is a change from one breed to another.

Shifting the curve to correct for bias. It was expected that the unadjusted curve would indicate an excess of production at each price due to the twofold bias resulting from taking a mail sample of a special group of producers. The respondents to any mail questionnaire 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 area.

The population used in drawing the sample was biased, too, as indicated in Chapter II. The questionnaire was sent only to members of the Michigan Milk Producers' Association. Members of this organization are probably larger and more efficient than the average producer in the area as indicated by their average daily delivery of 324.8 pounds as compared to 292.2 pounds for the non-members and 319.7 pounds average for the total shippers.

These two factors would cause production to be overestimated at each price level. No measure of the exact magnitude of these biases is available, but an alternate method of adjusting for them is presented below.

The shape of the curve as it is given in Figure 20 is probably quite valid, as pointed out earlier, because it is based on the

production functions and proportion each function contributes to the composite response. Therefore, the curve 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 preceeding the period[1] and shifting the curve laterally[2] to pass through this point. The result of doing this is given in Figure 21. This is the aggregate supply curve for fluid milk in the Detroit milk shed for the period from October 1, 1951 to September 30, 1952. It is based on the given cost structure and the given number of producers.

Adjusting the composite supply curve for year to year changes in number of cows, quality of cows, and input prices. Three adjustments should be made in using the curve for year to year prediction purposes. In the first place, the curve will shift vertically in response to a change in the cost structure on which the curve is based. If the variable costs of producing milk rise, the curve will move upward,

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

[2] 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.

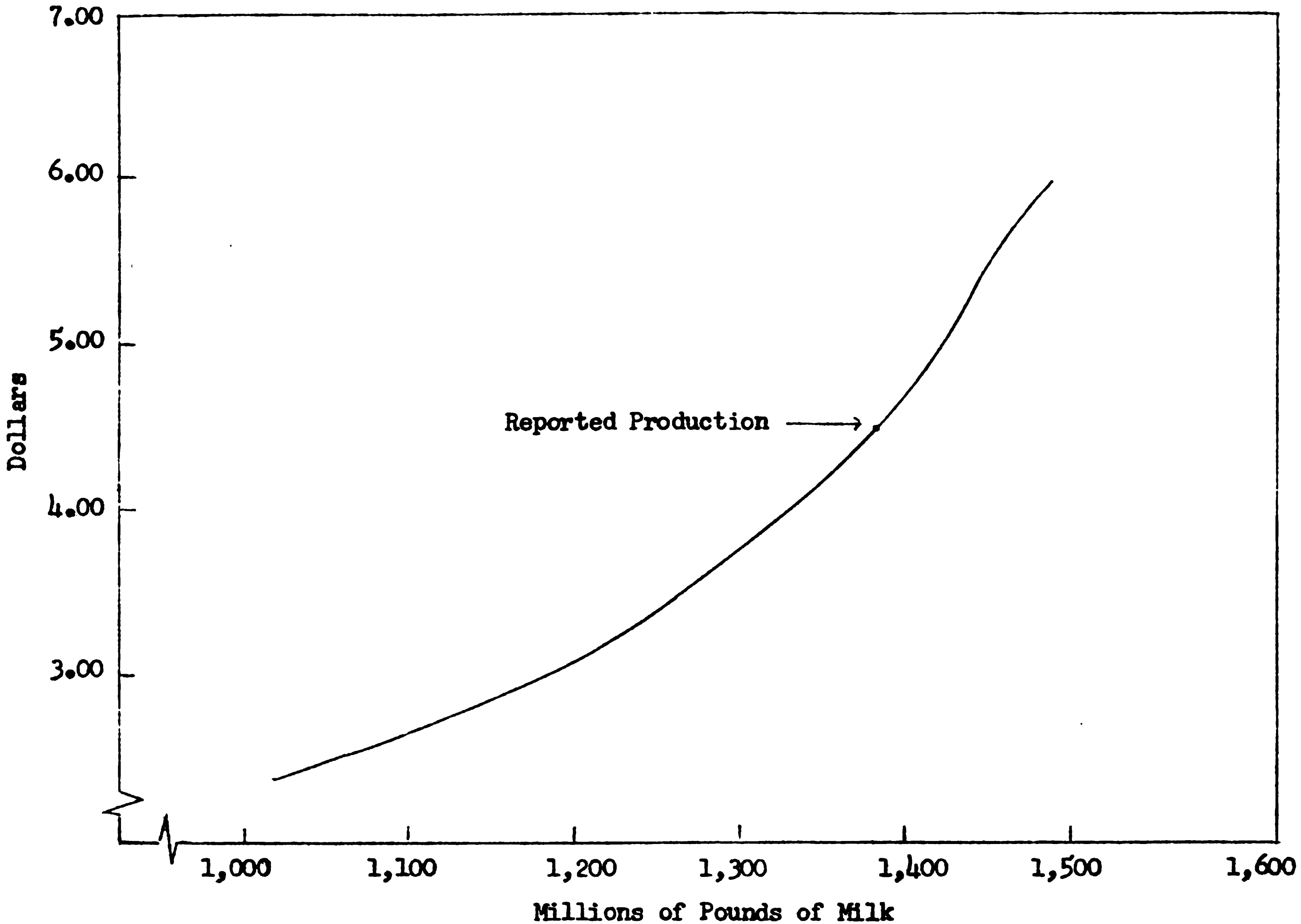

Figure 21. Supply curve for milk, 3.68 percent fat corrected milk, Detroit milk shed, October 1, 1951 - September 30, 1952.

indicating that less milk will be produced at each price. If the variable costs decrease, the curve will shift downward, indicating that more milk will be produced at each price.

The curve can be adjusted to some measure of the change in costs and reasonably accurate predictions made. Over the range of the individual cost curves included in the composite curve, concentrates make up the major portion of marginal costs. In addition to being the most important single cost, it is the cost item that is most likely to vary in price from year to year. As a result, the change in the cost of a hundred pounds of concentrates is a useful guide in deciding how much and in which directions (up or down, vertically) to shift the curve.

The percentage that concentrate cost is of the total variable costs at three points on the cost curve is indicated in Table VIII.

TABLE VIII

PERCENTAGE CONCENTRATE COST IS OF TOTAL VARIABLE COSTS AT THREE POINTS ON THE MARGINAL COST CURVES, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952

Marginal cost*	Percent concentrate cost is of total variable cost
2.50	58.22
4.00	71.38
5.50	75.73

*Dollars per hundredweight.

These percentages were found by straight line interpolation between points on the marginal cost curves for each of the representative enterprises. The percentages were then averaged by weighting the results for each kind of herd according to the relative importance of that kind of herd in the market. The results indicate that the curve does not shift parallel, but has a larger response to changing costs towards the high cost end than towards the low cost end.

The United States Department of Agriculture published estimates for the United States of the cost of a hundred pounds of concentrate.[3] For the period for which the supply curve is estimated, the cost of a hundred pounds of grain was three dollars and seventy four cents.[4] This is a more expensive ration than was used in making the computations but is readily available and, hence, serves as a practical basis for quickly computing the results of a change in input price.

To determine how much to shift the curve, the percentage change in cost per hundred pounds of the ration is multiplied by the percentage importance of the grain in the total costs at the several levels to establish the percentage change in cost. This percentage at each of the several levels is multiplied by the cost at that level and the result is the amount, in cents, that the curve has to be shifted at each of the three levels.

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[3] Rations Fed to Dairy Cows, United States Department of Agriculture, Bureau of Agricultural Economics, Washington, D. C.

[4] Ibid, January, 1953, p.2.

As an illustration, a prediction of the amount of milk produced in 1953 was made. The cost of a hundred pounds of grain ration dropped to three dollars and forth-three cents - an 8.28 percent decrease since 1952. Multiplying this by the relative importance of grain in the variable costs at two dollars and fifty cents, four dollars, and five dollars and fifty cent levels, it was found that the curve should be lowered 4.82 percent at the two dollar and fifty cent level, 5.91 percent at the four dollar level and 6.27 percent at the five dollar and fifty cent level. These involve shifts of 12 cents, 23 cents, and 34 cents respectively. These points are plotted and the curve shifted so as to be drawn through them. See Figure 22.

Using the average blend price of the previous year, 1952, it is estimated that the milk production will be 1,438 million pounds. This assumes that the producing ability of the cows has remained constant and that the number of producers and the size of the herds have remained constant. Thus, the estimate still must be adjusted to allow for changes in these three things to be accurate.

Milk production per cow has increased rather steadily over a long period of years.[5] Over the 8 year period from 1944 to 1952 the average production per cow in Michigan increased 2.50 percent per year. This change in production ability has varied from year to year, but for purposes of prediction, a trend may be used unless a more accurate figure is known. Judgment can be used in estimating what

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[5] Milk Production on Farms, Bureau of Agricultural Economics, United States Department of Agriculture, 1953.

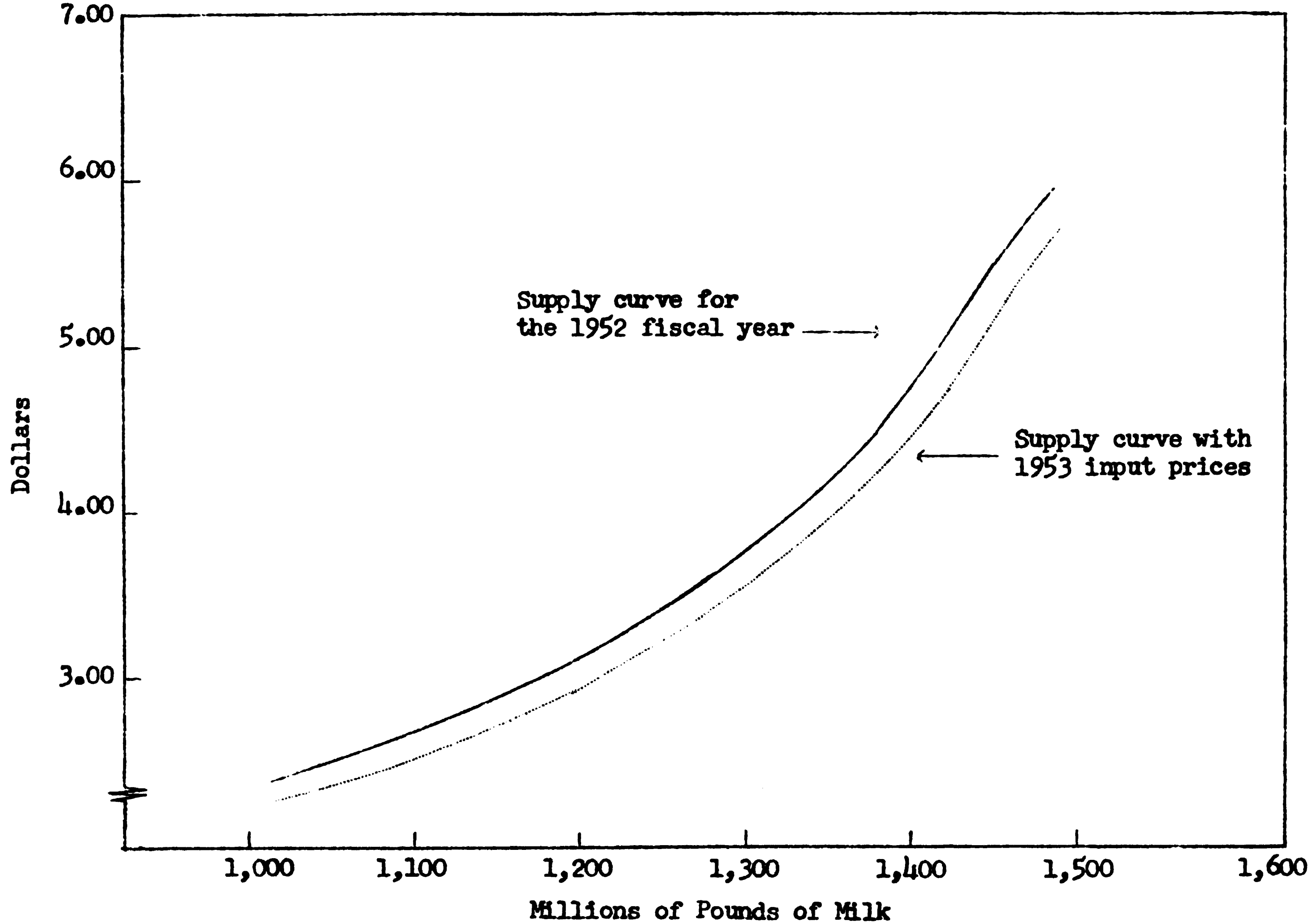

Figure 22. Supply curves for milk, 3.68 percent fat corrected milk, different levels of input prices, Detroit milk shed, 1951 - 1953.

this change will be from year to year if it varies considerably from this trend.

Multiplying 1,438 million by 2.50 percent indicates a thirty-six million increase in the estimate due to an increase in the production ability per cow. This is added to the 1,438 million pounds to secure an estimate of 1,474 million pounds.

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 two years old and over kept for milk, and the number of heifers one to two 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 6.15 percent.[6]

The number of heifers one to two years old being kept for milk cows increased 5.81 percent over the same period. It was decided to consider only half of this increase in the number of heifers as contributing to an increase in milk production because probably only about half of them will come into production in that period. Therefore, averaging these increases, it was estimated that the number of milk cows in the area increased by 6.03 percent during the period under consideration.

The estimate of 1,474 million pounds of milk based on an increased production capacity for the cows must be increased by this

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

amount, then, assuming the new cows are of the higher producing ability. The result is an estimated fluid milk production for 1953 of 1,563 million pounds. The curve is adjusted laterally to pass through this point. (A lateral movement is used because there is no change in input prices.) See Figure 23. Actual production for that period was 1,591 million pounds, giving an error of prediction of 1.76 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. Eighty-six and four tenths of this increase in production was predicted.

As further illustration, the production for 1951 was estimated at 1,337 million pounds by using the same kind of adjustments, except that the average capacity of the cows was increased from the 1951 base. (See adjusted curve in Figure 24.) Actual reported production for 1951 was 1,340 million pounds - a predicting error of .22 percent.

The decrease in production from 1952 back to 1951 was 3.3 percent. The direction of this change was predicted in addition to 93.5 of its magnitude. This is more accurate than the prediction for 1953 from a 1952 base.

As a word of caution, it should be pointed out that a high degree of accuracy cannot be expected year after year. Deviations of an unexplained nature do occur, and in addition, the factor used in adjusting the curve makes up around 75 percent, as a maximum, of the total variable costs. Wide variations in the prices of other inputs could affect the curve, the productive ability of the cows may change by a greater

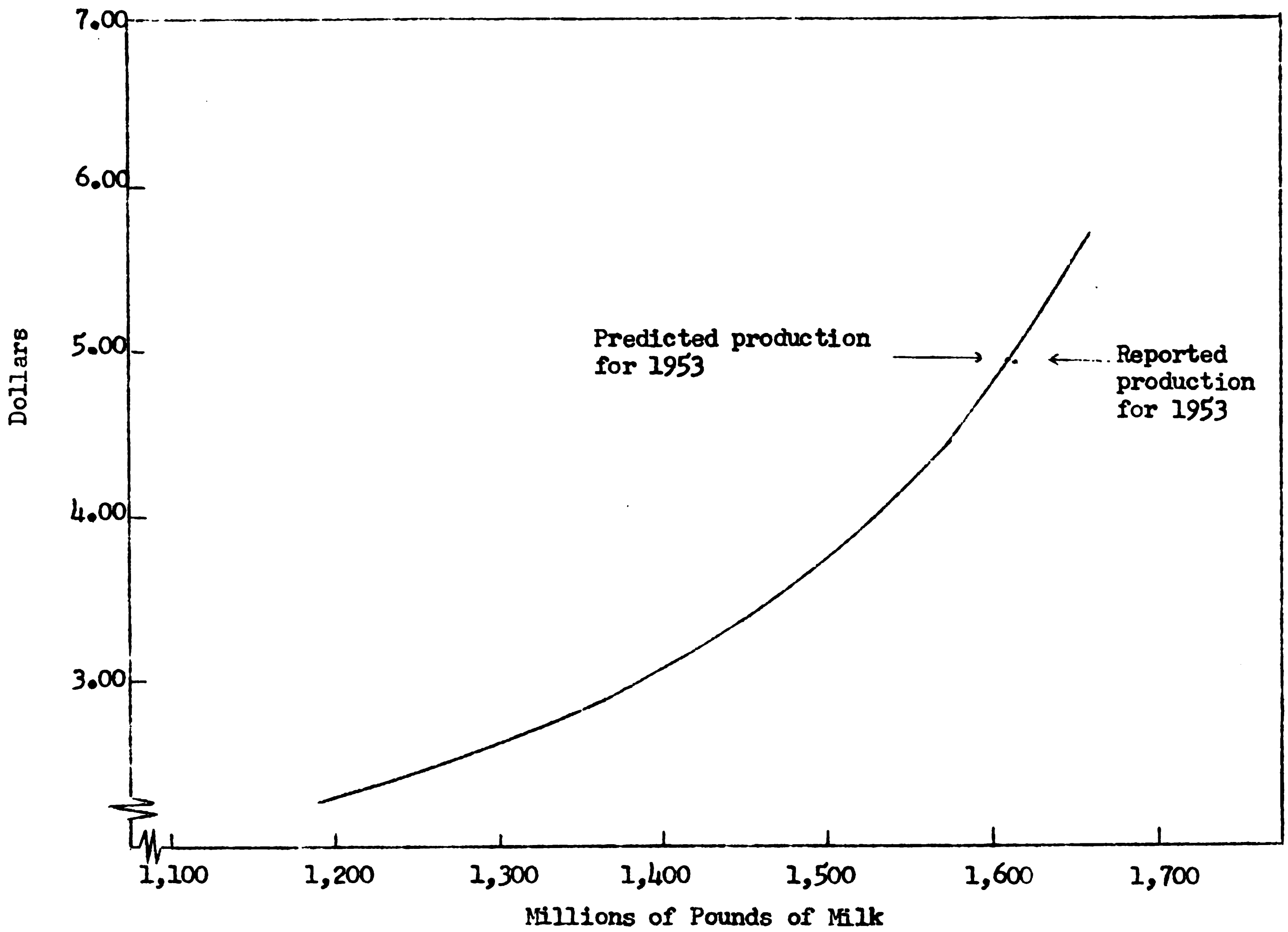

Figure 23. Supply curve for milk, 3.68 percent fat corrected milk, Detroit milk shed, 1953.

or less amount in response to unusual circumstances, and the weather may vary widely, causing the quality of the pasture to significantly influence the prediction in any one year. However, shifting the base continually from one year to the next would reduce the cumulative importance of these phenomenon by constantly correcting for them.

There is evidence to indicate that as the number of cows in the area decreases significantly, the prediction is less valid. An attempt to estimate the production in 1950, when there were about ten percent more cows in the area, on the basis of the 1951 - 1952 base resulted in an approximate error of ten percent. The estimated production was greater in magnitude than the quantity that was actually produced.

A possible explanation for this is that as the number of cows decreased, the low producers were culled, leaving only the higher producing cows, and significantly raising the average production per cow. As a result, the average production ability of the cow probably increased more than the 2.50 percent per year from 1950 to 1951.

As a check, the curve was adjusted to a 1950 base, and an attempt was made to predict the production in 1951. In this case the estimated production for 1951 was below the actual production by 9.4 percent. This indicates that the improvement in production was greater than expected, and had this been adjusted for, the prediction would have been more accurate.

Economic judgment of this and other factors must be considered when doing all outlook or predicting work. It is felt that if all

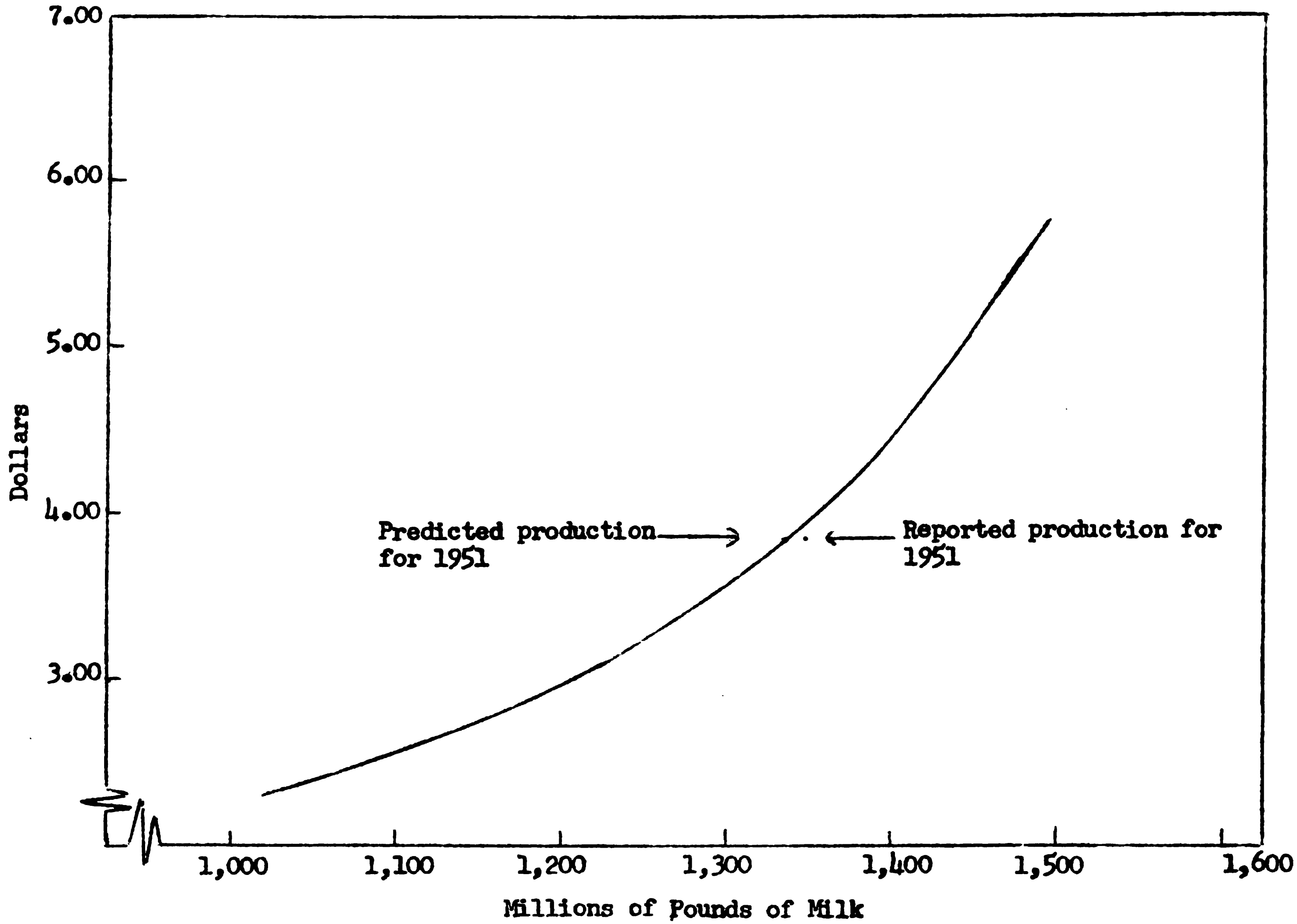

Figure 24. Supply curve for milk, 3.68 percent fat corrected milk, Detroit milk shed, 1951.

factors are considered, and that if the curve is annually adjusted for what is known about changes in production ability, number of cows, and changes in costs, reasonably accurate estimates can be obtained over a period of years. Several suggestions for additional research to improve the accuracy of predictions will be presented in the next chapter.

CHAPTER V

Significance and Implications of the Results

The results of this study are significant in three broad areas. In terms of a semi-macro type of analysis, the supply curve estimates have implications for the operation of price support programs and federal milk marketing orders. In terms of micro-analysis, the marginal cost data are potentially useful guides for the individual producer seeking to lower his costs in the face of a cost-price squeeze. Third and lastly - both the supply curve and marginal cost estimates are useful in analyzing the position of the milk producer in the Detroit area with respect to interregional competition.

The Semi-Macro Analysis

Controlling production for the operation of a price support program. Since World War II a price support program has been in existence. An apparent assumption behind a price support program is that the equilibrium price determined in a free market for a product is too low to provide the farmer with a "fair" income. Therefore, at times, the support prices are often established above the equilibrium level. On the basis of static Marshalliam economics, this results in malallocation of resources and over-production of the commodity as well as higher incomes for the producers concerned.

In the case of price supports for dairy products, large quantities of butter have been put in government storage and means of reducing these stocks have been sought. It has been suggested, as a remedy, that milk production be controlled by restricting herd sizes for the individual producer. This study indicates that production control based on this policy would be only partially effective in reducing the supply of milk. The supply curve indicates that for the short length of run in which feed is the only variable, milk production can be varied from 1,000 million pounds to 1,500 million pounds in the Detroit milk shed in response to price changes from two dollars and forty cents to six dollars per hundred weight. In addition, there is always the possibility of moving into the longer length of run in which the producer can shift from one production function to another by changing to a higher quality of cow. On many farms production could be doubled by the simple expedient of replacing the low quality cows with cows of high inherent producing ability.

Beyond the fact that production controls based on restricted herd size for the individual producer are ineffective in controlling milk production, is the danger of freezing herd sizes at inefficient levels. The cost studies by Caul[1] and Wells[2] indicate that increasing herd size is very effective in reducing average total costs.

Federal milk marketing orders. Producers in a fluid milk area have practically no bargaining power as individuals when dealing with

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[1] *Op. cit.*, Caul.

[2] *Op. cit.*, Wells.

milk handlers. Their problem is further complicated by the fact that all milk produced in a fluid milk shed is not used for fluid purposes. Some part, and the proportion varies with the season, is used for cream and manufactured products which bring a lower return than that used as fluid milk.

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 is quite responsive to price changes. Using the composite curve as a guide, the price necessary to call forth a given production from a given dairy cow population can be estimated. Procedures for adjusting for year to year changes in cow population, inherent production ability, and input prices are also available.

Such estimates can reduce the economic waste resulting when resources are guided 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 the aggregative well-being in the economy by maximizing consumer satisfactions and producer incomes within a given distribution of wants, preferences, and desires.

Interregional competition. Most factors influencing the location of production can be lumped under the two headings of supply and demand. This study has dealt with some of the factors under the former heading.

When considering supply, all of the things that affect the production costs and the quantities of milk that farmers will produce at each price should be included. The composite supply curve for the area gives an indication of the quantity response, while the marginal cost curves for the firms give an indication of some of the factors affecting cost of production. They do not give the entire cost situation, though, for only variable costs are included in marginal costs.

That production costs are important in determining the location of production can be illustrated by the production of process milk in Michigan and Kentucky for distribution in New York and New Orleans. Milk is produced this distance from market only because it can be produced and put on the New York and New Orleans markets at a lower average cost per unit than production areas closer to the markets can. This may be because of the low opportunity costs for the production resources rather than a specific efficiency of production. Nevertheless, the milk has to be put on the market at a lower cost than competing areas can in order for these distant areas to stay in production.

The milk producers in the Detroit milk shed probably will not have to deal with other areas putting fluid milk on the Detroit market cheaper than they can. Their problem will be to deal with processed milk producers in neighboring states who can put processed milk on the distant markets, such as New York and New Orleans, at a lower cost than the Michigan producer can. Once these distant markets are gone for the local producers their only alternative is to sell their milk on the Detroit market - unless they go into alternative production opportunities.

To the extent that this excess milk is put on the Detroit market with an unchanged demand pattern, the blend price will be lowered, reducing the income of the producers already in the market.

This pressure to lower prices in the Detroit market is partly counter-balanced by an increasing demand in the Detroit area for fluid milk. This market is growing, and as a result, attracting processed milk producers in the shed to change over to fluid milk production.

Processed milk and fluid milk are produced under different cost structures. Fluid milk costs more per hundred weight to produce than processed milk. It is produced in the near proximity of large markets because of its bulky nature and the high cost of transporting it from the farm to the city. Neighboring areas, even though they may be able to produce the milk cheaper, cannot compete on the Detroit market for fluid milk because of the high transportation costs.

In the production of process milk, transportation costs are considerably reduced because the milk is processed close to the farm and a less bulky product is shipped to the market. It is in this area that local producers are likely to meet the most competition, directly and indirectly, particularly with respect to distant markets such as New York and New Orleans.

In order accurately to estimate the competitive position of the farmers in this area, supply curves for other areas must be compared with the one from this area. However, partial information about the relative position of producers in an area can be estimated from its supply curve alone.

With the cost structure and input prices as they existed during the 1952 fiscal year, producers in the Detroit milk shed could compete profitably with other areas down to a cost of production of two dollars and forty cents per hundred weight. For instance, if producers in Kentucky could put fluid milk on the Detroit market at a cost of three dollars when Detroit producers were getting three dollars and fifty cents, the producers in the local area could continue operation by cutting back production so as to reduce their marginal costs. They would then be able to meet the Kentucky competition.

If other areas could put the milk on the Detroit market at a lower cost than two dollars and forty cents per hundred weight, some of the producers in the Detroit milk shed would no longer be able to compete, even in the short run, with the quality of cows, input prices, and cost structure existing in 1952. They would have to either cease production or reorganize their operation with respect to quality of cows. A discussion of the needed adjustments will be presented in the next section.

It should be pointed out that the ability of farmers in the Michigan area to compete with neighboring areas, particularly to the south, hinges on the low opportunity costs for the fixed assets in the area. Dairy farming requires an abundance of forage production. Climatic and soil conditions in Michigan are such that over much of the state forage production is the only alternative. This becomes a fixed asset for the farm due to the low opportunity cost, and the only way the farmer can profitably utilize it is to produce milk or beef. At the present time dairy seems to have a comparative advantage over beef herds due to the extensive type of operation required with beef. Most farms are small and beef herds would not supply a large enough source of income.

The farmer's flexibility is decreased even more after he has committed himself in longer lengths of run to such things as specialized dairy barns and equipment. These factors, combined with the distance of industry, combine to lower the opportunity cost of labor, too. It becomes a fixed asset, then, and milk production is the only way of utilizing it.

Opportunities for alternative uses of the resources may arise in the future, and if milk can be put on the Detroit market at a lower cost from neighboring areas, research may be required to develop these alternatives or to raise the earning power of the resources in their present use. For the present, though, milk is produced in the Michigan area not so much because it has a comparative advantage, but because by producing milk the resources are utilized so as to minimize their comparative disadvantage.

The Micro Analysis

The contribution that this study makes to farm management involves the marginal cost of producing milk by the firm and how it is affected by the quality of the cow. This section presents a discussion of the alternatives open to the individual producer if it is desired to lower the marginal costs of production.

The nature of the individual marginal cost curves indicate that one way of lowering costs is to shift to higher quality cows. With the given cost structure, the marginal cost of producing milk can be reduced to one dollar and ninety-two cents per hundred weight by producing milk with cows that average 10,120 pounds of four percent fat corrected milk when fed one pound of grain to four pounds of milk.

The data also indicates that so long as the producer has to cover only variable costs, size of herd does not greatly affect the ability of farmers to withstand competition from other areas. Wells[3] found similar results in his cost study at Kentucky, but by computing costs for longer lengths of run, he found that when the planning span was long enough to require the covering of average total costs, the small herds became vulnerable first.

The explanation seems to be 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 it has no effect on the marginal cost of production. In longer lengths of run in which the entire saving in labor per cow can be considered as herd size is variable, it does give the larger producer a competitive advantage.

Logically, it would seem that as neighboring areas were able to put milk on the Detroit market at a lower cost, the producers with the low quality of cow would be squeezed out of production first. However, due to the nature of the cost curves for the lowest quality

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[3] Op. cit., Wells, p. 52.

of cow considered, producers with this kind of cows have two alternatives.

So long as their marginal value productivity does not become less than salvage value, they can cut back production and produce at a lower marginal cost. When doing this, the aforementioned work of Caul indicates they no longer cover fixed costs, but in the short run they need only cover variable costs so long as the capitalized value of the marginal value productivity of the cow plus her discounted salvage value is greater than her present salvage value.

As a second alternative, it may be that the marginal value productivity of the cow would become less than her salvage value when production is cut back. If this happens, the longer length of run in which herd size is variable is entered into and the producer sells the cow to stop his losses on her. However, he may be able to resume profitable production of milk by replacing the low quality cows with high quality cows.

In considering cost-price squeezes, it is not known exactly at what price the producers with the lowest quality of cow would be unable to compete, for this price depends to a considerable extent on the disposal value of the cow. However, logically it would seem that these producers will be the first to either drop out of milk production entirely or replace their low quality cows with higher quality cows.

For the individual producer, converting to higher quality cows is often impossible due to lack of resources. In this case they will shift to alternate income opportunities or else begin to mark down the income of some of their other assets. Caul's work indicates producers with 7,332 pound cows could produce profitably in the short run at 1952 costs, as long as the price for milk is above two dollars and thirty cents per hundred weight. If the price drops below this, they logically dispose of their cows and go into alternative income opportunities or else replace their cows with higher quality cows. If these producers are unable to replace their cows with higher quality cows and have no alternative production opportunities, they, too, may write down the income to their fixed factors and continue to produce. In this case, they would follow the scale line to get lower marginal costs than computed for this study by reducing the feeding level to less than stomach capacity. No indication of their production response or costs at these levels of the stomach limit line is given in this study because adequate experimental data are unavailable.

Within the limits of this study, the next lowest marginal cost of production can be secured by going to the cow with an inherent production ability of 8,350 pounds of four percent fat-corrected milk. The costs for this quality of cow were computed on the basis of a pen type barn, but since labor appears to be insignificant at the minimum points on the marginal cost curves, the quality of the cow is the deciding factor in lowering the marginal costs of producing the milk. The data indicate that under the given conditions, producers with this quality of cow could reduce marginal costs to a minimum of one dollar and ninety-eight cents per hundred weight by reducing the level of grain feeding and could continue to produce in the short run as long as price was above this level.

If competition drives price down lower yet, the producer has the same alternatives he had with the lower quality cows. By shifting to cows of a still higher production ability of 10,120 pounds of four percent fat-corredted milk, the marginal costs can be reduced to a minimum of one dollar and ninety-two cents per hundred weight. If he is unable to shift to cows of this higher quality, he too can lower the return to his fixed factors and feed at less than the stomach limit with the lower quality cows.

If the milk can be put on the Detroit market for a lower marginal cost than this, it will no longer be profitable for milk to be produced in the Detroit milk shed under the given cost conditions. New technology will have to lower the cost of production if continued production is desirable or the producers will have to write down the income to their fixed factors. In the meantime, other sources of income may have become more profitable.

Suggestions for Additional Research

Problems encountered in the course of this study have pointed up the need for additional research in several areas. A discussion of these proposals follows.

Input-output studies. The inability to compute the costs with inputs combined as dictated by the scale line below certain minimum levels pointed up the need for this kind of research. Studies are needed to delineate isoproduct lines with grain and roughage as variable inputs for several qualities of cows. Then when the scale line no longer follows the stomach limit line, the optimum combinations can be estimated by price relationships. The need for research of this nature has also been pointed out in a report prepared by the North Central Farm Management Research Committee.[4]

Cost computations for other lengths of run. Studies are needed to determine the various costs when herd size is variable and when barn size is variable. Combining these studies with the present one would permit the compilation of a general treatise on the economics of milk production in Michigan. Studies of this nature may indicate ways of increasing the earning power of assets that are fixed on many farms in the area. (At the present time Ed Jones, here at Michigan State College, is studying the entry and exit of firms from the market.)

Adjustments to risk and uncertainty. A knowledge of the way farmers react to changing conditions will enable more accurate predictions to be made for outlook purposes. This study shows that even in short lengths of run the farmer has considerable flexibility in adjusting his output to changing conditions. The extent to which farmers base their present operations on future expectations will determine whether production will be above or below the predicted amount.

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[4] Feed-Milk Relationships in Dairying, a report prepared by the North Central Farm Management Research Committee, January, 1954.

(Albert Halter and Glenn Johnson, here at Michigan State College, are currently working in cooperation with the North Central Farm Management Research Committee on a study to determine how farmers react in the face of risks and uncertainty.)

How do producers enter and leave the market. Difficulty was encountered in predicting future production when there was a sudden change in the number of cows in the area. A study is needed to determine the extent to which the average production per cow is raised by the culling effect of reducing the cow population. The answer lies partly in the data presented herein, and partly in determining at what level it is no longer profitable to keep a cow. The material in this thesis is inadequate to accurately estimate the change, but it does indicate that the low producers are the first to be culled. (It was pointed out previously that a study is currently under way to find a partial solution to this problem.)

Converting the curve to an aggregate index. If the individual cost items could be converted to indexes, and an aggregate index based on these individual indices could be developed, the outlook work could be greatly expedited, and possibly made more accurate by including the changes in all cost items.

Uses of the Data Synthesized in this Thesis

The data synthesized in this study have use in five broad areas:

1. The input-output relationships are useful in cost studies of practically any nature.
2. Improving the effectiveness of production controls.
3. Improving the effectiveness of milk marketing orders.
4. Estimating the position of local producers with respect to interregional competition.
5. Studies such as Caul's in which he is estimating the value of various quality cows under changing conditions.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to estimate a supply curve for fluid milk in the Detroit milk shed for the length of run in which only feed and its associated inputs are variable. This was accomplished by synthesizing the short run marginal cost curves for typical firms in the industry and aggregating these curves into an aggregate short run supply curve.

A mail survey was taken of the producers in the milk shed 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 classified so as to have ten typical herds representing production conditions in the area.

A marginal cost curve was computed for each of these ten herds by using a budget process and utilizing various sources of secondary data. In the short run, milk production for the farm is varied by changing the level of feeding, which involves the substitution of grain for roughage. The basic input-output relationship for constructing the marginal cost curves considers 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 must be considered also. The relevant relationship involved not only feed, then, but feed and its associated variable inputs.

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

From this information the marginal cost of producing an additional hundred pounds of milk was determined by dividing the change in variable costs from one level of feeding to the next 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. When these costs are plotted and a smooth curve fitted to them, the curve does give an estimate of the marginal cost of each unit of output.

From the marginal cost curve for each of the typical herds, the quantity of milk each producer would supply at prices ranging from two dollars and forty cents per hundred to six dollars per hundred 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 typical herds and the resulting production at each price was summed to get the aggregate supply response for all of the producers in the Detroit shed.

The shape of this supply curve has important policy implications, but its value could be increased immeasurably if the curve could be used to predict milk production from one year to the next. A change in input prices, a change in the number of milk cows, and a change in the average production per cow are the three most important variables causing the curve to become out of date. Adjusting the curve from year to year to allow for changes in these variables makes the supply curve quite usable for predicting year to year changes in milk production.

A consideration of both the individual marginal cost curves and the aggregate supply curve leads to the following general conclusions:

1. In the length of run in which only feed and associated inputs are variable, the production of fluid milk can be varied from 1,000 million pounds to 1,500 million pounds in response to price changes from two dollars and forty cents per hundred to six dollars per hundred.

2. Production controls based on restricting the herd size of the individual producer will be only partially effective in controlling the production of fluid milk.

3. The production of fluid milk can be regulated by adjusting the price of milk and the cost of the inputs used in producing it.

4. From a farm management standpoint, the marginal cost of producing milk can be significantly lowered by keeping high quality cows.

5. Producers in the Detroit milk shed can cut back on the level of feeding and reduce marginal costs in the face of a cost-price squeeze so long as the discounted capitalized value of the marginal value productivity stream of the cow in milk production plus the discounted

salvage value of the cow when discarded in the future does not become less than her present salvage value.

6. Producers do operate in a rational manner and adjust their production in response to price relationships. This is indicated by the ability to accurately predict the production of milk from the supply curve.

7. From a methodological aspect, the study shows that traditional economic theory can be combined with results of primary experimental work and modifications of the theory to solve practical problems.

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APPENDIX A

MICHIGAN STATE COLLEGE

East Lansing

Department of Agricultural Economics

Dear Producer:

In connection with a research project at the Michigan Agricultural Experiment Station, it is very important that we have some simple information about your dairy operation. This information will be used to help determine the potential supply of milk from the Detroit milk shed.

Enclosed is a self-addressed, stamped card on which you can conveniently check the information requested.

Your cooperation will be appreciated and will contribute to the productivity of your experiment station.

Sincerely,

George E. Schuh
Graduate Assistant
Michigan State College

GES/tn

During the period Oct. 1, 1951 to Sept. 30, 1952.

Did you have a pen-type barn ________
or a stanchion-type barn ________

What was the average number of cows you were milking during this period?

If it is convenient for you, we would like to know the total pounds of milk produced on your farm between Oct. 1, 1951 and Sept. 30, 1952 ______________ lbs.

If this information is not available, send the card back with the other information requested. It in itself is quite valuable.

MICHIGAN STATE COLLEGE

East Lansing

rtment of Agricultural Economics July 23, 1953

Dear Producer:

Several weeks ago you received a letter requesting some information that would contribute to the work of your experiment station. Some of the replies have been slow in coming in.

In case you have lost or misplaced the reply card, we are enclosing another card. If you have not mailed in your reply, we would greatly appreciate your doing so, now.

Appreciatively yours,

George E. Schuh

GES/tn
Enc.

APPENDIX B

TABLE I

ANNUAL FEED INPUTS AND MILK PRODUCTION OF DAIRY COWS, PRODUCTION ABILITY - 5,133 POUNDS OF MILK,[1] FED AT DIFFERENT LEVELS, 305 DAY LACTATION PERIOD, PREDOMINANTLY HOLSTEIN COWS,[2] AVERAGE HAY AND PASTURE FOR THE AREA, 1200 POUND COWS,[3] FOUR PERCENT FAT-CORRECTED MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.[4]

Level of feeding: TDN[5] from roughage	Level of feeding: Total TDN consumed	TDN for Milk Production[6]	Hay[7] TDN	Hay[7] Weight	Grain[8] TDN	Grain[8] Weight	Milk Production
Percent	Pounds						
100	4342	948	1646	3578	0	0	3289
90	4500	1106	1354	2943	450	600	4055
80	5012	1618	1313	2854	1003	1337	5222
70	5725	2331	1311	2850	1718	2~~8~~90 ?	6277
60	6455	3061	1171	2546	2588	3450	7166
50	6795	3401	705	1532	3394	4525	7416

SOURCE: Synthesized from data reported in U.S.D.A. Technical Bulletin No. 815.

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

[2] Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

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

[4] Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying fourteen pounds of total digestible nutrients a day and 50 days supplying four pounds of total digestible nutrients a day for a total of 1600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent blue grass.

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 1096 nutrients.

[5] Total digestible nutrients

[6] Total digestible nutrients supplied by rations minus maintenance requirement.

[7] 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.

[8] 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.

TABLE II

ANNUAL FEED INPUTS AND MILK PRODUCTION OF DAIRY COWS, PRODUCTION ABILITY - 7,332 POUNDS OF MILK,[1] FED AT DIFFERENT LEVELS, 305 DAY LACTATION PERIOD, PREDOMINANTLY HOLSTEIN COWS,[2] AVERAGE HAY AND PASTURE FOR THE AREA, 1,200 POUND COWS,[3] FOUR PERCENT FAT-CORRECTED MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.[4]

Level of feeding		TDN for Milk Production[6]	Hay[7]		Grain[8]		Milk Production
TDN[5] from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent	Pounds						
100	4991	1597	2295	4989	0	0	5222
90	5375	1981	2139	4650	540	720	5945
80	6010	2616	2114	4596	1200	1600	7112
70	6740	3346	2019	4389	2025	2700	8166
60	7560	4166	1842	4004	3022	4030	9027
50	8090	4696	1353	2939	4042	5390	9416

SOURCE: Synthesized from data reported in U.S.D.A. Technical Bulletin No. 815.

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

[2] Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

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

[4] Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying fourteen pounds of total digestible nutrients a day and 50 days supplying four pounds of total digestible nutrients a day for a total of 1600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent blue grass.

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[8] 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.

TABLE III

ANNUAL FEED INPUTS AND MILK PRODUCTION OF DAIRY COWS, PRODUCTION ABILITY - 8,350 POUNDS OF MILK,[1] FED AT DIFFERENT LEVELS, 305 DAY LACTATION PERIOD, PREDOMINANTLY HOLSTEIN COWS,[2] AVERAGE HAY AND PASTURE FOR THE AREA, 1,200 POUND COWS,[3] FOUR PERCENT FAT-CORRECTED MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.[4]

Level of feeding		TDN for Milk Production[6]	Hay[7]		Grain[8]		Milk Production
TDN[5] from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent	Pounds						
100	4866	1472	2170	4717	0	0	5732
90	5150	1756	1939	4215	515	687	6444
80	5712	2318	1872	4070	1144	1525	7667
70	6470	2076	1834	3986	1940	2587	8888
60	7450	4056	1773	3854	2981	3975	9945
50	8276	4882	1436	3121	4144	5525	10,527

SOURCE: Synthesized from data reported in U.S.D.A. Technical Bulletin No. 815.

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

[2] Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

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

[4] Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying fourteen pounds of total digestible nutrients a day and 50 days supplying four pounds of total digestible nutrients a day for a total of 1600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa, 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent blue grass.
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 1096 nutrients.

[5] Total digestible nutrients.

[6] Total digestible nutrients supplied by rations minus maintenance requirement.

[7] 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.

[8] 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.

TABLE IV

ANNUAL FEED INPUTS AND MILK PRODUCTION OF DAIRY COWS, PRODUCTION ABILITY - 10,120 POUNDS OF MILK,[1] FED AT DIFFERENT LEVELS, 305 DAY LACTATION PERIOD, PREDOMINANTLY HOLSTEIN COWS,[2] AVERAGE HAY AND PASTURE FOR THE AREA, 1,200 POUND COWS,[3] FOUR PERCENT FAT-CORRECTED MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.[4]

Level of feeding		TDN for Milk Production[6]	Hay[7]		Grain[8]		Milk Production
TDN[5] from roughage	Total TDN consumed		TDN	Weight	TDN	Weight	
Percent	Pounds						
100	5172	1778	2476	5382	0	0	6888
90	5422	2028	2182	4743	544	725	7611
80	5955	2561	2069	4498	1190	1587	8888
70	6700	3306	1998	4343	2006	2675	10,333
60	7775	4381	1967	4376	3112	4150	11,862
50	9110	5716	1858	4039	4556	6075	13,166

SOURCE: Synthesized from data reported in U.S.D.A. Technical Bulletin No. 815.

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

[2] Guernseys, Jerseys, Aryshire, Red Polled, and mixed breeds are present.

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

[4] Pasture and silage were held constant over all feeding levels.

a. Pasture consisted of 100 days supplying fourteen pounds of total digestible nutrients a day and 50 days supplying four pounds of total digestible nutrients a day and for a total of 1600 total digestible nutrients. The average pasture mixture was 24 percent alfalfa. 16 percent red clover, 45 percent brome, 6 percent timothy, and 9 percent blue grass.

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 1096 nutrients.

[5] Total digestible nutrients.

[6] Total digestible nutrients supplied by rations minus maintenance requirement.

[7] 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.

[8] 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.

TABLE V

SALT[1] USED PER COW ANNUALLY AT DIFFERENT FEEDING LEVELS, FOUR QUALITY OF COWS, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Feeding level (percent TDN from roughage)	Average Production Capacity of Cow: 5133 pounds[2]	7332 pounds[2]	8350 pounds[2]	10,120 pounds[2]
	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

1 These amounts are based on a requirement of .75 ounce of salt daily per 1000 pound live weight, plus .3 ounce in addition for each 10 pounds of milk produced. Morrison, F. B., Feeds and Feeding, The Morrison Publishing Company, Ithaca, New York, 1950.

2 These quantities are the production per cow when fed at the rate of one pound of grain to four pounds of milk.

TABLE VI

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 8.3 COW HERD, STANCHION BARN, AVERAGING 5,133 [1] POUNDS OF MILK, DETROIT MILK SHED OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level[2]					
	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	17.72	17.72	17.72	17.72	17.72	17.72
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
Preparing equipment	9.61	9.61	9.61	9.61	9.61	9.61
Pouring up milk and handling	1.34	1.34	1.34	1.34	1.34	1.34
Total of this section	94.32	94.32	94.32	94.32	94.32	94.32
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	0	.24	.60	.93	1.21	1.29
Pouring up milk and handling	0	.53	.78	1.79	2.64	2.88
Milking machine operation	0	.38	1.08	1.71	2.24	2.26
Idle time and waiting	1.24	1.01	.66	.34	.07	0
Total of this section	5.98	8.00	10.15	13.38	16.58	18.25
Total all together	100.30	102.32	104.47	107.70	110.90	112.57

SOURCE: Synthesized from data secured from sources indicated in footnote 20 Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE VII

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 8.3 COW HERD, STANCHION BARN, AVERAGING 7,332 [1] POUNDS OF MILK, DETROIT MILK SHED OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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	17.72	17.72	17.72	17.72	17.72	17.72
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
Preparing equipment	9.61	9.61	9.61	9.61	9.61	9.61
Pouring up milk and handling	1.34	1.34	1.34	1.34	1.34	1.34
Total of this section	94.32	94.32	94.32	94.32	94.32	94.32
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	0	.23	.60	.93	1.20	1.32
Pouring up milk and handling	0	.69	1.80	2.81	3.63	4.00
Milking machine operation	0	.37	1.07	1.70	2.22	2.45
Idle time and waiting	1.29	1.07	.72	.40	.28	0
Total of this section	6.58	9.02	12.30	15.70	19.25	21.53
Total all together	102.27	104.71	107.99	111.39	114.94	117.22

SOURCE: Synthesized from data secured from sources indicated in footnote 20 chapter III

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE VIII

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 8.3 COW HERD, STANCHION BARN, AVERAGING 10,120 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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	17.72	17.72	17.72	17.72	17.72	17.72
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
Preparing equipment	9.61	9.61	9.61	9.61	9.61	9.61
Pouring up milk and handling	1.34	1.34	1.34	1.34	1.34	1.34
Total of this section	94.32	94.32	94.32	94.32	94.32	94.32
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	0	.23	.63	1.09	1.57	1.98
Pouring up milk and handling	0	.69	1.91	3.29	4.75	6.00
Milking machine operation	0	.33	.53	1.39	2.31	3.09
Idle time and waiting	1.66	1.44	1.06	.63	.18	0
Total of this section	7.11	9.57	12.35	16.37	21.21	26.59
Total all together	104.92	107.38	110.16	114.18	119.02	124.40

SOURCE: Synthesized from data secured from sources indicated in footnote 20 Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE IX

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 12.9 COW HERD, AVERAGING 5,133 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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	15.90	15.90	15.90	15.90	15.90	15.90
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
Preparing equipment	8.81	8.81	8.81	8.81	8.81	8.81
Pouring up milk and handling	1.07	1.07	1.07	1.07	1.07	1.07
Total of this section	84.72	84.72	84.72	84.72	84.72	84.72
Jobs that vary with feeding level:						
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	0	.18	.47	.70	.91	1.65
Pouring up milk and handling	0	.19	.73	1.68	2.48	2.71
Milking machine operation	0	.43	1.07	1.02	1.65	2.14
Idle time and waiting	1.00	.82	.54	.28	.06	0
Total of this section	5.27	7.00	9.30	11.26	13.91	16.20
Total all together	89.99	91.72	94.00	96.61	99.12	101.06

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE X

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 12.9 COW HERD, AVERAGING 7,332 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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 preparatien	15.90	15.90	15.90	15.90	15.90	15.90
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
Preparing equipment	8.81	8.81	8.81	8.81	8.81	8.81
Pouring of milk and handling	1.07	1.07	1.07	1.07	1.07	1.07
Total of this section	84.72	84.72	84.72	84.72	84.72	84.72
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	0	.17	.30	.55	.73	.84
Pouring up milk and handling	0	.65	1.70	2.84	3.61	3.96
Milking machine operation	0	.38	.96	1.49	1.92	2.11
Idle time and waiting	1.22	1.00	.65	.33	.21	0
Total of this section	5.96	8.30	10.98	13.77	16.42	18.05
Total all together	92.01	94.35	97.03	99.82	102.49	104.10

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE XI

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 12.9 COW HERD, AVERAGING 10,120[1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level[2]					
	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	15.90	15.90	15.90	15.90	15.90	15.90
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
Preparing equipment	8.81	8.81	8.81	8.81	8.81	8.81
Pouring of milk and handling	1.07	1.07	1.07	1.07	1.07	1.07
Total of this section	84.72	84.72	84.72	84.72	84.72	84.72
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	0	.17	.47	.81	1.17	1.48
Pouring up milk and handling	0	.65	1.80	3.10	4.40	5.64
Milking machine operation	0	.37	.75	1.18	1.64	2.03
Idle time and waiting	1.26	1.12	.86	.57	.27	0
Total of this section	6.12	8.62	11.16	14.13	17.62	21.41
Total all together	93.93	96.42	98.96	101.93	105.49	109.21

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE XII

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 22.6 COW HERD, STANCHION BARN, AVERAGING 5,331 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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	14.30	14.30	14.30	14.30	14.30	14.30
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
Preparing equipment	7.97	7.97	7.97	7.97	7.97	7.97
Pouring of milk and handling	1.02	1.02	1.02	1.02	1.02	1.02
Total of this section	76.25	76.25	76.25	76.25	76.25	76.25
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	0	.15	.38	.59	.77	.82
Pouring up milk and handling	0	.20	.54	1.43	2.18	2.39
Milking machine operation	0	.46	1.04	1.57	2.01	2.13
Idle time and waiting	.86	.71	.48	.29	.11	0
Total of this section	4.80	6.64	8.61	10.73	12.90	13.92
Total all together	81.05	82.89	84.86	86.98	89.15	90.17

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE XIII

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, STANCHION BARN, 22.6 COW HERD AVERAGING 7,332 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952

Jobs	Feeding Level [2]					
	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	14.30	14.30	14.30	14.30	14.30	14.30
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
Preparing equipment	7.97	7.97	7.97	7.97	7.97	7.97
Pouring of milk and handling	1.02	1.02	1.02	1.02	1.02	1.02
Total of this section	76.25	76.25	76.25	76.25	76.25	76.25
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	0	.16	.37	.58	.75	.83
Pouring up milk and handling	0	.61	1.59	2.47	3.19	3.51
Milking machine operation	0	.29	.87	1.40	1.83	2.02
Idle time and waiting	.94	.80	.57	.32	.15	0
Total of this section	5.15	7.45	10.04	12.35	14.53	16.11
Total all together	82.33	84.61	87.22	89.53	91.71	93.29

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE XIV

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 22.6 COW HERD, STANCHION BARN, AVERAGING 10,120 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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	14.30	14.30	14.30	14.30	14.30	14.30
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
Preparing equipment	8.71	8.71	8.71	8.71	8.71	8.71
Pouring of milk and handling	2.85	2.85	2.85	2.85	2.85	2.85
Total of this section	78.82	78.82	78.82	78.82	78.82	78.82
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	0	.14	.39	.68	.98	1.20
Pouring up milk and handling	0	.71	1.79	3.05	4.34	5.27
Milking machine operation	0	.27	.65	1.08	1.54	1.93
Idle time and waiting	1.21	1.07	.81	.52	.22	0
Total of this section	5.51	7.99	10.26	12.90	15.97	18.97
Total all together	84.33	86.81	89.08	91.68	94.75	97.75

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE XV

LABOR REQUIREMENTS, HOURS PER COW PER YEAR, 16.4 COW HERD, PEN TYPE BARN, AVERAGING 8,350 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Jobs	Feeding Level [2]					
	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	10.33	10.33	10.33	10.33	10.33	10.33
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
Preparing equipment	7.96	7.96	7.96	7.96	7.96	7.96
Pouring of milk and handling	1.32	1.32	1.32	1.32	1.32	1.32
Total of this section	63.10	63.10	63.10	63.10	63.10	63.10
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	0	.14	.38	.43	.84	.96
Pouring up milk and handling	0	.38	1.01	2.04	2.93	3.42
Milking machine operation	0	.29	.78	1.27	1.69	1.92
Idle time and waiting	1.07	.93	.69	.44	.23	0
Total of this section	4.30	7.66	9.51	11.77	14.50	16.35
Total all together	67.40	70.75	72.61	75.07	77.60	79.45

SOURCE: Synthesized from data secured from sources indicated in footnote 20, Chapter III.

1 Four percent fat-corrected milk when fed one pound of grain to four pounds of milk.

2 Percent of total digestible nutrients from roughage.

TABLE XVI

SOME LABOR REQUIREMENTS FOR JOBS VARYING WITH FEEDING LEVEL, STANCHION BARN,[1] HOURS PER COW PER YEAR, DIFFERENT HERD SIZES, DETROIT MILK SHED, 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 in footnote 20, Chapter III.

1 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.

TABLE XVII

ELECTRICITY INPUTS[1], VARIABLE WITH FEEDING LEVEL, VARIOUS TYPES OF HERDS, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Type of herd: Herd Size and type of barn	Capacity of cow	Feeding Level 100	90	80	70	60	50
cows	pounds	kilowatt hours					
Stanchion barn							
8.3	5,331	---	67.61	103.03	93.13	78.48	22.07
8.3	7,332	---	63.83	103.03	93.04	76.00	34.34
8.3	10,121	---	63.83	112.73	127.57	134.98	115.11
12.9	5,331	---	105.10	160.11	144.75	121.98	34.30
12.9	7,332	---	99.19	160.12	144.61	118.13	53.38
12.9	10,121	---	99.20	175.21	198.26	209.79	178.90
22.6	5,331	---	184.13	280.51	253.59	213.70	60.09
22.6	7,332	---	173.79	280.51	253.35	206.96	93.51
22.6	10,121	---	173.79	306.96	347.34	367.53	313.46
Pen-type barn							
16.4	8,350	---	124.19	213.33	212.98	184.37	101.52

SOURCE: Synthesized from data secured from experiments conducted at Michigan State College, 1952.

1 Based on .98 kilowatt hours to cool a hundred pounds of milk and .0836 kilowatt hours to operate milking machine to milk a hundred pounds of milk.

TABLE XVII

FEED GRINDING CHARGES[1], VARIABLE WITH FEEDING LEVEL, VARIOUS TYPES OF HERDS, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Herd size and type of barn	Type of Herd Capacity of cow	Feeding Level 100	90	80	70	60	50
cows	pounds	Dollars					
Stanchion Barn							
8.3	5,221	---	4.93	11.10	19.01	28.64	37.56
8.3	7,332	0--	7.74	17.25	29.54	44.50	58.37
8.3	10,121	---	13.56	30.22	51.75	77.97	102.26
12.9	5,331	---	5.98	13.28	22.41	33.45	44.74
12.9	7,332	---	9.29	20.64	34.83	51.99	69.53
12.9	10,121	---	16.27	36.16	61.02	91.08	121.81
22.6	5,331	---	6.02	13.17	22.20	34.44	50.42
22.6	7,332	---	9.35	20.47	34.51	53.54	78.37
22.6	10,121	---	16.38	35.87	60.46	93.79	137.30
Pen-type Barns							
16.3	8,350	---	11.27	25.01	42.43	65.19	90.61

SOURCE: Synthesized from secondary data.

[1] Based on a ten cent charge for grinding an 80 pound bag of grain.

TABLE XIX

FERTILIZER ELEMENTS REACHING FIELDS FROM MANURE, VARIOUS QUALITY COWS, DETROIT MILK SHED, 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., Feeds and Feeding, The Morrison Publishing Company, Ithaca, New York, 1950.

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

TABLE XX

PRICES USED IN THIS THESIS

Item	Unit	Price
Shelled corn[3]	70 pounds	$1.69
Corn and cob[2]	70 pounds	1.62
Oats[2]	32 pounds	.83
Soybean oil meal[1]	100 pounds	5.58
Grain ration[4]	100 pounds	3.04
Milk cans[1]	10 gallon can	10.62
Stock salt[1]	100 pounds	1.42
Hay[5]	100 pounds	1.06
Nitrogen[1]	pound	.13
Phosphorous[1]	pound	.09
Potassium[1]	pound	.06
Shelling corn[6]	bushel	.07
Crushing corn[6]	bag	.10
Electricity[1]	killowatt hour	.028
Labor[7]	hour	.50

1 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.

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

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

4 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.

5 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.

6 Based on usual custom charges in Michigan; Vary, K.A., "Rates for Custom Work in Michigan, 1952 and1953," Extension Folder F-161, M.S.C. Cooperative Extension Service.

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

TABLE XXI

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 8.3 COW HERD, STANCHION BARN, AVERAGE 5,133 [1] POUNDS OF MILK, DETROIT MILK SHED, 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
Feed grinding	------	4.98	11.10	19.01	28.64	37.56
Electricity	------	1.89	2.88	2.61	2.20	.62
Hay	314.79	258.93	251.09	250.74	224.00	134.79
Labor	24.82	33.20	42.12	55.52	68.80	75.74
Milk cans	------	.85	.85	.85	.85	.85
Salt	3.14	3.31	3.57	3.80	4.00	4.05
Total variable cost	342.75	454.55	648.96	910.34	1,198.99	1,395.37
Manure credit	64.78	63.85	75.23	91.93	106.81	107.41
Net variable costs	277.97	390.70	573.73	818.41	1,092.18	1,287.96
Marginal cost per hundred weight	------	1.77	1.89	2.79	3.71	9.44

SOURCE: Synthesized from secondary data computed in this thesis.

[1] 5,133 pounds fat-corrected milk when fed one pound of grain to four pounds of milk.

TABLE XXII

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 12.9 COW HERD, STANCHION BARN, AVERAGE 5,133 [1] POUNDS OF MILK, DETROIT MILK SHED, 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	1172.55 898.05	1,352.95	1,774.51
Feed grinding	------	7.74	17.25	29.54	44.50	58.37
Electricity	------	2.94	4.48	4.05	3.42	.96
Hay	489.25	402.43	390.26	389.27	348.14	209.49
Labor	33.99	45.15	59.98	72.62	89.72	104.49
Milk cans	------	1.70	1.70	1.70	1.70	1.70
Salt	4.88	5.15	5.55	5.91	6.22	6.30
Total variable cost	582.12	700.41	1,003.53	1,401.58	1,846.65	2,155.82
Manure Credit	100.69	99.23	116.92	142.88	166.00	166.94
Net variable costs	427.42	601.18	886.61	1,258.70	1,689.65	1,988.88
Marginal cost per hundred weight	------	1.758	1.90	2.73	3.68	9.56

SOURCE: Synthesized from secondary data computed in this thesis.

[1] 5,133 pounds fat-corrected milk when fed one pound of grain to four pounds of milk.

TABLE XXIII

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 22.6 COW HERD, STANCHION BARN, AVERAGE 5,133 [1] POUNDS OF MILK, DETROIT MILK SHED, 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
Feed Grinding	------	13.56	30.22	51.75	77.97	102.26
Electricity	------	5.16	7.85	7.10	5.98	1.68
Hay	857.15	705.03	683.70	682.75	609.92	367.00
Labor	54.24	75.03	97.30	121.25	145.77	157.30
Milk cans	------	2.55	2.55	2.55	2.55	2.55
Salt	8.56	9.02	9.72	10.36	10.89	11.04
Total variable cost	919.95	1,222.57	1,749.91	2,449.08	3,223.37	3,750.69
Manure credit	176.39	173.85	204.83	250.32	290.71	292.48
Net variable costs	743.56	1,048.72	1,545.08	2,198.76	2,932.66	3,458.21
Marginal cost per hundred weight	------	1.76	1.88	2.74	3.65	9.30

SOURCE: Synthesized from secondary data computed in this thesis.

[1] 5,133 pounds fat-corrected milk when fed one pound of grain for four pounds of milk.

TABLE XXIV

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 8.3 COW HERD, STANCHION BARN, AVERAGE 7,332 [1] POUNDS OF MILK, DETROIT MILK SHED, 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
Feed grinding	------	5.98	13.28	22.41	33.45	44.74
Electricity	------	1.79	2.88	2.60	2.13	.96
Hay	439.35	409.11	404.36	386.15	352.27	258.58
Labor	27.30	37.44	51.04	65.16	79.89	89.35
Milk cans	------	.85	.85	.85	.85	.85
Salt	3.57	3.73	3.99	4.22	4.41	4.50
Total variable cost	470.22	640.63	880.11	1,162.65	1,489.85	1,758.98
Manure credit	90.33	96.87	111.39	127.01	143.86	148.12
Net variable costs	379.89	543.76	768.72	1,035.64	1,346.39	1,610.86
Marginal cost per hundred weight	------	2.73	2.32	3.05	4.35	8.19

SOURCE: Synthesized from secondary data computed in this thesis.

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

TABLE XXV

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 12.9 COW HERD, STANCHION BARN, AVERAGE 7,332 [1] POUNDS MILK, DETROIT MILK SHED, 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
Feed grinding	------	9.29	20.64	34.83	51.99	69.53
Electricity	------	2.76	4.48	4.05	3.31	1.49
Hay	682.19	[illegible]35.84	628.45	600.15	547.51	401.88
Labor	38.44	53.54	70.82	88.82	105.91	116.42
Milk cans	------	.85	.85	.85	.85	.85
Salt	5.55	5.79	6.20	6.56	6.85	6.99
Total variable cost	726.18	990.45	1,358.90	1,794.09	2,296.82	2,710.90
Manure credit	140.38	150.56	173.12	197.41	222.97	230.22
Net variable costs	585.80	839.89	1,185.78	1,596.68	2,073.85	2,480.68
Marginal cost per hundred weight	------	2.72	2.30	3.02	4.30	8.10

SOURCE: Synthesized from secondary data computed in this thesis.

[1] 7,332 pounds fat-corrected milk when fed one pound of grain to four pounds of milk.

TABLE XXVI

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 22.6 COW HERD, STANCHION BARN, AVERAGE 7,332 [1] POUNDS OF MILK, DETROIT MILK SHED, 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
Feed grinding	------	16.27	36.16	61.02	91.08	121.81
Electricity	------	4.87	7.85	7.09	5.79	2.62
Hay	1,195.16	1,113.95	1,1101.02	1,051.42	939.19	704.06
Labor	58.20	84.18	113.45	139.56	164.19	182.04
Milk cans	------	2.55	2.55	2.55	2.55	2.55
Salt	9.72	10.16	10.86	11.49	12.00	12.25
Total variable cost	1,263.08	1,726.65	2,371.15	3,128.14	4,003.57	4,728.47
Manure credit	245.94	263.78	303.30	345.85	390.65	403.33
Net variable costs	1,017.14	1,462.87	2,067.85	2,782.29	3,612.92	4,325.14
Marginal cost per hundred weight	------	2.73	2.29	3.00	4.27	8.10

SOURCE: Synthesized from secondary data computed in this thesis.

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

TABLE XXVII

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 16.4 COW HERD, PEN TYPE BARN, AVERAGE 8,350 [1] POUNDS OF MILK, DETROIT MILK SHED, 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	------	3.48	5.97	5.96	5.16	2.84
Hay	820.00	732.74	707.53	692.92	669.98	542.55
Labor	35.26	62.81	77.98	96.52	118.90	134.07
Milk cans	------	2.55	2.55	2.55	2.55	2.55
Salt	7.28	7.59	8.12	8.65	9.12	9.37
Total variable cost	862.54	162.96	1,587.46	2,138.81	2,852.68	3,536.53
Manure credit	181.51	188.73	215.53	253.33	301.92	333.61
Net variable costs	681.03	974.23	1,371.93	1,885.48	2,550.76	3,202.92
Marginal cost per hundred weight	------	2.51	1.98	2.56	3.84	6.83

SOURCE: Synthesized from secondary data computed in this thesis.

1 8,350 pounds fat corrected milk when fed one pound of grain to four pounds of milk.

TABLE XXVIII

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 8.3 COW HERD, STANCHION BARN, AVERAGE 10,120 [1] POUNDS OF MILK, DETROIT MILK SHED, 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
Feed grinding	------	6.02	13.17	22.20	34.44	50.42
Electricity	------	1.79	3.16	3.57	3.78	3.22
Hay	473.51	417.29	395.73	382.10	376.20	355.35
Labor	29.50	39.72	51.25	67.94	88.02	110.35
Milk cans	------	1.70	1.70	1.70	1.70	1.70
Salt	3.94	4.10	4.37	4.70	5.03	5.33
Total variable cost	506.95	653.57	869.81	1,157.15	1,556.30	2,059.20
Manure credit	97.43	98.65	109.39	125.74	150.50	180.10
Net variable costs	409.52	554.92	760.42	1,031.41	1,405.80	1,879.10
Marginal cost per hundred weight	------	2.42	1.94	2.26	2.95	4.37

SOURCE: Synthesized from secondary data computed in this thesis.

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

TABLE XXIX

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 12.9 COW HERD, STANCHION BARN, AVERAGE 10,120 [1] POUNDS OF MILK, DETROIT MILK SHED, OCTOBER 1, 1951 - SEPTEMBER 30, 1952.

Variable Inputs	Feeding Level (Percent of TDN Supplied by Roughate)					
	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	------	2.78	4.90	5.55	5.87	5.01
Hay	735.94	648.56	615.05	593.86	584.70	552.29
Labor	39.48	55.60	71.98	91.14	113.65	138.10
Milk cans	------	2.55	2.44	2.55	2.55	2.55
Salt	6.12	6.37	6.80	7.31	7.83	8.28
Total variable cost	781.54	1,009.51	1,344.10	1,783.96	2,395.60	3,166.99
Manure credit	151.44	153.32	170.01	195.43	233.91	279.92
Net variable costs	630.10	856.19	1,174.09	1,588.53	2,161.69	2,887.08
Marginal cost per hundred weight	------	2.42	1.93	2.22	2.91	4.31

SOURCE: Synthesized from secondary data computed in this thesis.

[1] 10,120 pounds fat corrected milk when fed one pound of grain to four pounds of milk.

TABLE XXX

VARIABLE COSTS, FEED AND ASSOCIATED INPUTS VARIABLE, 22.6 COW HERD, STANCHION BARN, AVERAGE 10,120 [1] POUNDS MILK, DETROIT MILK SHED, 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	1,837.85	2,851.22	4,173.77
Feed grinding	------	. 16.38	35.87	60.46	93.79	137.30
Electricity	------	4.87	8.59	9.72	10.29	8.78
Hay	1,289.31	1,136.24	1,077.54	1,040 .41	1,024.36	967.58
Labor	62.26	90.28	115.94	145.77	180.46	214.36
Milk cans	------	4.25	4.25	4.25	4.25	4.25
Salt	10.72	11.16	11.92	12.80	13.72	14.50
Total variable cost	1,362.29	1,761.28	2,344.44	3,111.24	4,178.09	5,520.54
Manure credit	265.32	268.59	297.85	342.38	409.81	490.39
Net variable costs	1,096.97	1,492.69	2,046.59	2,768.86	3,768.28	5,030.15
Marginal cost per hundred weight	------	2.42	1.919	2.212	2.90	4.28

SOURCE: Synthesized from secondary data computed in this thesis.

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