THE EFFECTS OF U.S. DAIRY REGULATIONS ON HERD IMPROVEMENT ACTIVITIES

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Applied Economics

MONTANA STATE UNIVERSITY
Bozeman, Montana

October 1987

APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGMENTS

I would like to express my appreciation to my committee members, Dr. Bruce Beattie, and Dr. Michael Frank for their support during the course of this thesis. Special acknowledgment goes to my committee chairman, Dr. Jeffrey T. LaFrance, without whose patience and guidance this project would not have been accomplished.

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ABSTRACT

In order to assure an adequate supply of milk and increase dairy producers' incomes, the U.S. Government, through the Federal dairy regulations, has increased the price of milk received by farmers above that which would prevail under a competitive pricing system. In response to the higher price of milk, dairy producers have increased the total amount of milk they supply. Investigation of these responses and the factors causing them provides information about the impacts and effectiveness of the U.S. dairy regulations.

This study examines two aspects of dairy producers' responses to the dairy regulations. These are: (1) What is the relationship between profit incentives created by the dairy program and farmers' decisions to improve the productivity of dairy herds through herd quality testing activities? and (2) Have the short run profits created by the dairy regulations been capitalized into the market prices of replacement dairy cattle?

The results of the investigation suggest that there is no significant relationship between dairy profitability, as defined in the research, and the level of participation in Dairy Herd Improvement Association testing of dairy cattle. Further, the profitability created by the dairy program appears to be completely capitalized into the prices of dairy cattle implying that, in the long run, economic profits to dairy producers are zero. Consequently, the dairy regulations appear to have little impact on the adoption of herd improvement activities. However, the U.S. Government efforts to achieve the goals of the regulations are largely frustrated by the competitive nature of the production sector in the U.S. dairy industry.

CHAPTER 1

INTRODUCTION

Introduction

This study is an analysis of responses of the U.S. dairy industry to Federal regulation of the dairy market. Specifically, the study will address the nature of the rate of adoption of dairy herd improvement testing, and the impacts of the regulations on fluctuations in the market pricing of dairy cattle. Previous work has attempted to estimate dynamic supply and demand response relationships in the milk markets and the various costs and benefits from the Federal dairy regulations. This approach has developed from the pioneering work of Gaumnitz and Reed which formed the basis for the structure of the milk regulation, to the more recent, simulation framework of LaFrance and de Gorter. This study will further the research of LaFrance and de Gorter to investigate questions which have received little or no attention in the previous literature. While employing the econometric foundation of LaFrance and de Gorter, this project will extend the research to empirically investigate dairy farmers' responses to incentives created by Federal regulation of the dairy markets by improving the quality of their herds and bidding up the market price of replacement dairy cattle.

Statement of the Problem

Federal regulation of the Grade A production sector of the U.S. dairy industry has existed since the Great Depression. Originally the regulations were instituted to: 1) provide for "orderly marketing" of milk; 2) assure an adequate supply of milk throughout the year; and 3) raise dairy farmers' incomes. A further criterion stated that any regulatory decisions must be in the public interest [American Agricultural Economics Association Task Force].

In attempting to fulfill these goals, the dairy industry regulations, in the form of federal and state marketing orders and classified pricing schemes, have increased the price of milk received by farmers above that which would prevail in a competitive marketplace. Farmers have responded to this higher price with increased milk output from larger dairy herds, more intensive input use, and improved production efficiency. Consumers have also responded to the artificially high prices for fluid milk products through decreased consumption of these products. Consequently, surpluses have resulted from this divergence between what dairy producers supply and what consumers want to buy. The Commodity Credit Corporation (CCC) of the U.S. Department of Agriculture (USDA) purchases surplus milk products at announced prices and indirectly supports the prices of raw Grade B and surplus Grade A milk.

The economic costs of the dairy industry regulations and the resulting surplus of dairy commodities are substantial. These costs, including direct government expenses as well as lost economic surpluses caused by higher consumer prices and lower consumer purchases, have been estimated to be between $430 and $590 million per year (in 1980 dollars) [LaFrance and de Gorter]. The level of these economic costs is, to a great extent, dependent on the level of milk supplied by farmers and the resulting commodity surpluses generated. In order to fully understand the costs and economic impacts of the U.S. dairy support programs, one must investigate the supply response of dairy farmers to the production incentives created by the regulatory programs.

The productive capacity of milk production in a given herd can be increased by culling low producing animals from the herd and replacing them with better cows. Information about an animal's milk producing characteristics can be obtained through dairy testing programs such as those offered by the Dairy Herd Improvement Association (DHIA). By participating in such a testing program, a farmer learns which animals are genetically poorer and should be culled. These cows are then replaced with more productive animals which should have genetically superior offspring. In this way, the total productivity of the herd will be increased. A farmer not participating in a testing program might not gain this additional information about his herd.

A farmer's decision to participate in DHIA testing and herd improvement is similar to a decision to adopt a technological improvement to a production process. Dairy farmers were expected to respond to the higher, supported milk prices by adopting the available technology of herd improvement activities. This response further increases the supply of milk and the consequent surplus of milk products. An analysis of how and why farmers adopt the technological improvement of DHIA testing should provide insight into production incentives created by the dairy program regulations.

Finally, in a competitive industry, economic theory asserts that long run profits equal zero. This occurs because firms can freely enter or exit the industry in response to short run profits or losses. When short run profits are available, new firms attempt to enter the industry and existing firms attempt to expand to reap a share of the short run excess revenue. When this occurs in an industry with a relatively fixed stock of production assets, such as dairy cattle, the firms bid with each other for the additional assets they desire. This bidding drives up the market prices and values of dairy cattle, capitalizing the additional profits.

In the production sector of the dairy industry, few barriers to entry exist and the U.S. dairy regulations have appeared to create available rents with the supported milk prices. Thus farmers were expected to bid for available, replacement dairy cattle to gather a share of the available profits. An investigation of the relationship between the level of profitability in the dairy industry and fluctuations in the market prices of replacement dairy cattle was expected to confirm this assertion and provide additional evidence of the competitive nature of dairy production and the effectiveness of the U.S. dairy regulations.

This paper will investigate two aspects of farmers' production responses to the dairy programs. The questions of particular interest are: (1) What is the relationship between the profit incentives created by the dairy programs and farmers' decisions to improve the productivity of dairy herds through participation in herd improvement and testing activities? and (2) Have those increased revenues been dissipated into the market prices of replacement dairy cattle due to the competitive nature of the dairy industry?

Outline of the Thesis

The next chapter of this thesis presents a review of the literature concerning the nature of technological adoption and innovation, and various aspects of the U.S. dairy industry and its regulation. The third chapter contains the theoretical development of the dynamic supply and demand models employed in this research project and outlines the investigations of the rate of adoption of DHIA activities and fluctuation of the market prices of dairy cattle. The fourth chapter discusses and summarizes the empirical results derived in the research. The first section of the fourth chapter summarizes the estimated instruments used in the final portions of the research. The second section discusses the findings of the investigation of participation in the Dairy Herd Improvement Association. The third section presents the results concerning the relationship between profitability and the prices of replacement dairy cattle in the long run. The final chapter summarizes the main results and conclusions of the study and discusses possible implications for further research.

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter surveys previous research relating to the adoption of technological improvements in an industry, and to various aspects of the dairy industry and regulatory programs. The list of references cited in this review is not complete. However, it does contain those works considered by the author to be important to the development and motivation of this project.

The literature review is divided into four sections. The first section presents arguments concerning the adoption of technological improvements or innovations to production processes and the incentives which motivate these adoptions. Further, this section suggests certain functional forms appropriate for the modelling of such technological adoption. The second section summarizes several works addressing various questions of interest emanating from the regulation of the U.S. dairy industry. The first part of this section reviews early research on whose findings the dairy legislations are based. The second portion of this section addresses studies which suggest possible econometric models of the supply and demand sectors of the U.S. dairy industry used to research questions arising from the regulations. The last portion of this section reviews research of the capitalization of dairy program rents. The third section discusses possible functional forms for milk production functions. The final section relates possible questions of interest not investigated in the prior literature.

Studies of Technological Adoption

Griliches investigated the adoption of hybrid corn over open-pollinated varieties by farmers. The research determined that the rate of adoption of hybrid corn followed an S-shaped curve. Adoption was slow in the very early years with only a few innovative farmers using the technology. Over time, many other producers observed the benefits of planting hybrids rather than the older varieties, and the rate of adoption increased significantly. Finally, as the planting of hybrids approached an equilibrium level of use, the rate of adoption of the new technology slowed once again. To approximate this S-shape, Griliches fitted a transformation of the logistic function to the data. The logistic function is specified

$$(1) \quad P=k/[1+e^{-(a+bt)}],$$

where P is the percentage of corn acres planted with hybrid varieties, k is a ceiling value, t is time, and a and b are parameters.

The research found that the earliest origins, quickest acceptance rates, and highest ceilings occurred where the profitability from adopting the technology was the greatest. Griliches measured profitability with pre-hybrid yield per acre and average acres per farm as variables. Specifically, the use of hybrid corn started in Iowa and

Illinois and over time, spread to the entirety of the corn growing region of the United States.

Dixon, in a 1980 follow-up to Griliches' 1957 article, reestimated the Griliches model with the additional data available and takes issue with some of the original findings. In the original work ceiling values were specified a priori and were, in many instances, less than 1.0, where the ceiling is equal to the total population. In the intervening years between the two studies, hybrid varieties had completely replaced the open-pollinated seeds. To account for this, Dixon updated the parameter estimates using the same model but with all of the ceiling values set at 1.0. The great majority of the revised estimates of the slope or rate of acceptance parameters were less than Griliches' original figures due to the higher ceiling values and the long tails exhibited by such diffusion curves.

Dixon also found that a significant number of states exhibited a skewed rather than a symmetric growth curve. The logistic function used by Griliches is forced to be symmetric about one half of the ceiling value. To allow for asymmetry, Dixon specified a Gompertz function for the model estimation. The Gompertz function is specified

(2) $P=k(\alpha^{\beta^{t}})$,

where P is the percentage of acres planted with hybrid varieties, k is the ceiling value, t is again time, and α and β are parameters. The differential and rate of growth equations for the Gompertz are

(3) $dP/dt=P\ln(\beta)(\ln(P/k))$,

(4) $dP/dt\cdot(1/P)=\ln(\beta)[\ln(P) - \ln(k)]$,

where the logarithm of the exponentiated parameter β performs a similar role to the b coefficient in Griliches' logistic specification in that it determines the rate at which P approaches the ceiling value. Dixon found only four of 31 states for which the logistic function performed better than the Gompertz. Given the additional flexibility of the Gompertz function it may well be better than the logistic function for the types of technological adoption and diffusion questions of interest here.

Dixon further investigated Griliches' claim that a large portion of the variability in the rate of acceptance across states is explained by the profitability measures, pre-hybrid yield per acre, and average acres per farm. Using his parameter estimates in a regression of acceptance rates on the profitability variables, Dixon was unable to refute Griliches' original findings.

A third discussion of technological adoption and diffusion was undertaken by Mansfield. In his paper Mansfield investigated certain factors determining how rapidly the use of a new technique spreads from one firm to another. Specifically, he presented a model explaining differences in the rate of imitation among innovations and firms. He estimated the model with data on three innovations in each of four different industries, bituminous coal, iron and steel, brewing, and railroads.

Mansfield's hypothesis asserted that the proportion of firms adopting an innovation in a given period of time is a function of: 1) the proportion of firms which had already adopted the innovation by that period; 2) the profitability of the innovation; 3) the size of the investment necessary to implement the improvement; and 4) other unspecified variables such as risk aversion in an industry, more keenly competitive markets, financial health and stability of an industry, and industry attitudes toward innovation. Mansfield, like Griliches, used a logistic function to estimate the parameters of the S-shaped adoption path.

Mansfield further hypothesized that the slope or rate of acceptance parameter is linearly related to the profitability of the innovation and the size of the investment required to adopt it. When tested, both the profitability and investment parameters were of the appropriate sign and significantly different from zero.

Another appropriate functional specification, though not directly fitted to a question of technological adoption, is presented by Taylor. Taylor used a transformation of the hyperbolic tangent function to approximate any S-shaped curve. The hyperbolic tangent is specified

$$(5) \qquad \tanh(x) = (e^{x} - e^{-x})/(e^{x} + e^{-x}),$$

where $-\infty<x<\infty$ and the function has range (-1.0, +1.0). Taylor transformed the function such that it was bounded by 0.0 and 1.0 but retained the S-shaped characteristic. His transformation is

(6) $F(x) = .5 + .5[(e^{x} - e^{-x})/(e^{x} + e^{-x})]$.

Given this specification, the hyperbolic tangent reduces to the logistic function, particularly

(7) $F(x) = e^{2x}/(1 + e^{2x})$.

This research project employed the logistic specification for the estimation of the DHIA adoption path. The specified model was

(8) $F(x) = e^{P(x)}/(1 + e^{P(x)})$,

where the polynomial P(x) is free to achieve the best fit to the data. It was expected a priori that the polynomial would include terms with even powers. This allowed the estimated curve to exhibit some asymmetry.

Studies of the U.S. Dairy Regulations

Numerous studies have been done on the various aspects of the dairy industry and its regulatory program. Approximately half of the works in the literature are policy studies with emphasis placed on examining the effects on dairy markets of alternative policy decisions or altering the current regulatory structure. The rest of the post-World War II research are nonpolicy studies, primarily concerned with estimating supply and demand response relationships [Dahlgran 1981]. In this study, those works which derived econometric models of the U.S. dairy industry and investigate aspects of the questions of interest here are emphasized.

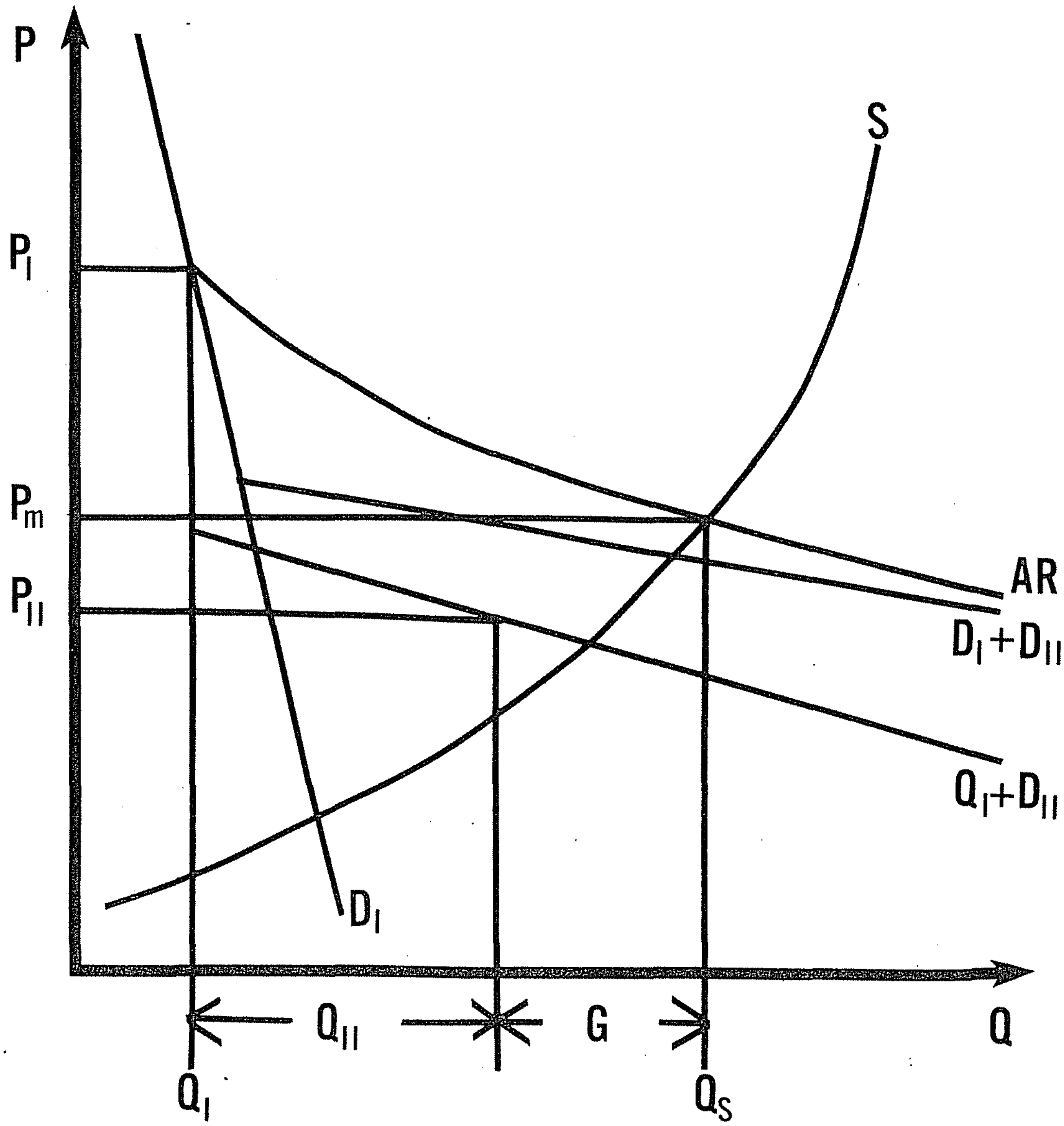
Basis for the U.S. Dairy Regulations

The study which formed the basis for the original dairy support legislation in 1937 was conducted by Gaumnitz and Reed. In the research the authors analyzed milk cooperative market power before 1937 and developed a model to show how a monopolistic price discrimination system such as the consequent classified pricing of milk could stabilize and enhance producer incomes given a fixed level of the farm supply of milk.

The demand for milk basically has two forms, for fresh fluid milk products, or for manufactured milk products such as butter, cheese, and nonfat dry milk. Fluid milk is highly perishable, bulky, and costly to transport. Consequently the demand for milk used in fresh products is considerably less elastic than that for manufactured dairy products which are easier to store and less costly to transport. The basic element in Gaumnitz and Reed's model is that the price could be raised for fluid uses of milk where the marginal revenue is relatively low and demand is relatively inelastic. The remainder of the milk supplied is diverted into manufacturing uses where marginal revenue is higher. This principle underlies the milk marketing orders as legislated in the Agricultural Adjustment Act of 1937. The current classified pricing mechanism is presented in Figure 1.

In the illustration, P_I and P_{II} are the observed Class I milk price and the announced Class II support price, respectively. The intersection of the Class I and Class II prices with the respective private demand schedules imply Q_I and Q_{II}, the quantities of Class I and Class II milk consumed by the private sector. The average revenue

Figure 1. Classified Pricing Mechanism for Milk



D_I = private demand for Class I milk
$D_I + D_{II}$ = horizontal summation of Class I and Class II milk demands
$Q_I + D_{II}$ = quantity of Class I milk consumed + Class II demand
Q_{II} = quantity of Class II milk consumed
Q_s = quantity of milk supplied
G = fluid milk equivalent of government purchases of surplus milk products
S = total supply of milk
P_I = Class I milk price
P_{II} = announced support price for Class II milk
P_m = average price received by farmers for all milk
AR = average farm revenue

curve (AR) consists of the set of averages of the Class I and Class II milk prices, weighted by the amount of milk used in each class of consumption. The intersection of the total milk supply (S) and the average revenue schedule determines the average price received by farmers for all milk (P_m) and the total amount of milk delivered (Q_s). Government purchases (G) is the difference between the total delivery of milk and total private consumption ($Q_I + Q_{II}$).

Econometric Models of the Dairy Industry

LaFrance and de Gorter provide an example of policy research using a simulation approach. The dairy industry model derived in this study forms the foundations for the research in this thesis and therefore will be reviewed in detail.

The authors econometrically derive a model involving both the supply and demand sides of the U.S. dairy industry and estimate the annual costs of the dairy program regulations. The specified model was a recursive system of equations with elements for Class I (fluid consumption) and Class II (manufacturing consumption) milk prices and private demands; net commercial removals of milk and dairy products; the average price received by farmers for all milk delivered; output of milk per cow; the aggregate U.S. dairy herd; and the total supply of milk.

Prices and quantities for the Class I and Class II milk markets were simulated under unregulated, competitive conditions from 1965 to 1980. The authors then compared the simulation results with the historical price and quantity data. Using this comparison, the authors calculated the costs of the program in terms of higher milk prices paid by consumers and lost economic surplus due to reduced consumption of milk in response to the artificially high fluid prices. Annual costs of the dairy program were determined as the sum of the calculated net economic losses and the actual net expenditures of the government necessary to administer and operate the dairy program. These outlays include expenditures by the CCC to purchase surplus dairy products, less the value of domestic CCC donations, plus storage and administration costs.

LaFrance and de Gorter estimated total costs of the U.S. dairy regulations to be between $430 and $590 million per year from 1965 to 1980 (in 1980 dollars). The range in the cost estimates is due to varying choices in the measurements of the surplus figures. The lower estimate results from an ex ante measurement of consumer and producer surplus, that is, assuming that the dairy program had been operating and had already affected the supply and demand schedules in previous years. The higher calculation results from an ex post measurement which assumes that competition had prevailed in the preceding years. The authors also calculated a long run cost figure for the program of $560 million. They determined this to be a reasonable middle ground between the other two estimates.

The model used by LaFrance and de Gorter, and its consequent results, appear to be fairly robust for several reasons. First, the dairy program cost estimates calculated by the authors compare quite favorably with other studies [Buxton, Buxton and Hammond, Dahlgran 1980, Heien, and Ippolito and Masson]. Further, the simulation of the competitive equilibrium situation appeared to result in a dynamically stable equilibrium. The authors tested this by simulating the model under the assumption that the dairy program had been terminated each year from 1953 to 1965. Each of these simulations resulted in equal or very nearly equal competitive price and quantity figures for each year from 1965 to 1980, revealing the long-run stability of the U.S. dairy market.

Hein specified and estimated an econometric model of the U.S. dairy industry to measure the effects of the Federal dairy support and classified pricing regulations on consumer prices of dairy products over the period 1949-1974. He used the resulting price changes as a cost of living index to estimate the social costs and consumer losses due to these programs. Hein's model of the dairy industry is divided into three main sectors.

The first sector is a farm level supply response relationship where total milk supplied is a function of the inputs grain and hay fed, dairy herd inventory figures, and time, to account for gradual technical change and improvements. The dairy herd response relationship is a dynamic system where changes in the dairy herd figures are influenced by the price of milk received, past inventory figures, and the opportunity cost of keeping dairy animals in production as measured by the market price of slaughter animals. This relationship does not, however, explicitly account for the present value of any long term profitability streams such as future milk production or income derived from the offspring of an animal.

The second sector of the model is composed of retail demand equations for the six major dairy products: fluid milk, butter, cheese, frozen dairy products, nonfat dry milk, and evaporated and condensed milk. In the model, the quantity demanded of each product is a function of its own price, prices of substitutes, the overall price level, and lagged dependent variables to account for persistence effects such as habit formation.

Last, the retail prices of these six products are specified as functions of the price paid for milk, and the wage rates for processing and distribution activities. The supply and demand sectors of the model are linked by the identity where the quantity of milk and dairy products supplied must equal private consumption plus U.S. government and military purchases, changes in private stocks held, and net exports.

Hein calculated the total social cost of the dairy support regulations over the period 1949-1974 to be $15.011 billion, or an average of $577.0 million per year. This total cost estimate is made up of three components. The first is $7.048 billion in direct government expenditures such as CCC purchases of surplus dairy commodities and program administration costs. The second element of the social cost is $3.405 billion, determined by the model to be the consumer welfare losses due to elevated prices and reduced consumption of dairy products. The cost of the classified pricing system and the Federal marketing orders, the last component of the total social cost, was calculated to be an additional $4.558 billion.

Salathe, Price, and Gadson present the structure, parameter estimates, and validation statistics for the dairy sector submodel contained in the USDA Food and Agricultural Policy Simulator. The model the authors developed was used to examine and simulate the adjustments in the supply and demand schedules of the U.S. dairy industry resulting from a reduction of the dairy support level from 75% to 65% of parity in 1981.

The dairy sector submodel is a simultaneous system of equations to endogeneously estimate dairy herd inventory figures; total milk production; farm level milk prices; fluid milk consumption; and the supply, price, and consumption of butter, cheese, nonfat dry milk, evaporated and condensed milk, and frozen dairy products. The authors estimated the levels of government purchases of surplus dairy products necessary to support milk prices at their predetermined levels. Using the parameter estimates generated by the model Salathe, Price, and Gadson predict the impacts of reducing the dairy support level.

The simulated reduction in the price supports to 65% of parity resulted in predicted decreases in the farm level price of milk of $.11/cwt in 1981, $.83/cwt in 1982, $1.26/cwt in 1983. By 1985, the aggregate dairy herd was expected to decrease by .22 million head and the total output of milk to fall by 3.0 billion pounds. Finally, necessary USDA purchases of surplus commodities would fall by $820 million and farmer cash receipts would decrease by $1.8 billion in 1983.

Investigation of Capitalization of Dairy Program Rents

Masson and Eisenstat investigated the effects of the dairy regulations in terms of the three goals for which the classified pricing system was enacted. Again, these goals are: 1) to raise dairy farmers' incomes; 2) to assure an adequate supply of milk throughout the year; and 3) to provide for an orderly market.

The authors used the Gaumnitz and Reed model of price discrimination to investigate how well the regulations have achieved the goals enunciated in the initial legislation. Further, the authors assumed a static equilibrium in the total dairy market and explore the questions of interest under two supply scenerios, a perfectly inelastic supply schedule and a positively sloped supply curve.

The results of the research, under either scenerio, suggested that the dairy regulations set farm level prices higher than that necessary to meet the first two goals. Masson and Eisenstat found that a substantial amount of the increased producer incomes are dissipated through land markets into higher landowner rents. They also determined that the support programs are set up so larger farmers and landowners receive a greater benefit than smaller producers. Further, the authors cite large surpluses of manufactured dairy products as an indication that farm level prices of milk are higher than necessary to achieve the adequate supply stipulation.

Finally, disorderly marketing in the 1930's meant lockouts, disruptive violence, and milk withholding actions. For the dairy markets of today this goal is somewhat obsolete. Therefore, the authors concluded that the classified pricing system could be completely eliminated without violating the goals of the dairy program.

Suggested Forms of the Milk Production Function

Numerous researchers have investigated the production function for milk to estimate a supply response. All of the studies reviewed employed a quadratic specification of the production function with linear and quadratic terms in the inputs grain and hay plus various other factors. The general specification used is

$$(9) \qquad Y = \alpha + \beta_1 g + \beta_2 h + \beta_3 g^2 + \beta_4 h^2 + \beta_5 g \cdot h + \cdots,$$

where Y is the output of milk, g is the input grain fed, h is the input hay fed, and $\cdots$ are the other factors varying among researchers [see, e.g. Heady, Jacobson, Schnittker, and Bloom; Heady, Madden, Jacobson, and Freeman; Hoover, Kelly, Ward, Feyerman, and Chaddha; Paris, Malossni, Pilla, and Romita; and LaFrance and de Gorter]. The research here, follows the pertinent literature and employs a quadratic form of the production function to model the output of milk.

Questions of Interest Arising in the Literature

Several points of interest were evident in the prior literature on technological adoption and innovation and the various aspects of the dairy program to motivate this research project. Particularly, the adoption of a technological improvement, such as herd improvement testing, should follow some S-shaped path. Further, the rate of adoption of a new technology was expected to depend on several factors such as expected profitability from the improvement, the size of the investment required to install it, the number of firms already using the innovation, and various, other unspecified factors.

The literature concerning the effects of the dairy support regulations and the classified pricing system analyzes an extensive range of questions, though primarily addressing the response relationships of the dairy supply and demand and deriving estimates of the various social costs and benefits incurred due to the legislation. There are however, other questions of particular interest which were not investigated or were explored only briefly in the course of, or as an extension of the primary research.

The first of these questions involves determining the factors influencing the rate of adoption of a technological improvement in the U.S. dairy industry. In this case, the technological improvement was herd quality testing. Both Hein and Salathe, Price, and Gadson employed a time trend as an explanatory variable to account for higher quality animals and improved management practices. This merely attempted to explain a portion of the variations in the level of milk output due to technological improvements. No literature reviewed explicitly researched the factors affecting farmers decisions to improve the productive capacity of their herds. Such an investigation is necessary to determine the rates of adoption of such improvements and to better understand the forces and incentives inducing dairy farmers to undertake such investments.

Another question which has yet to be fully analyzed involves determining the forms of dissipation of the short run profitability created by the Federal dairy regulations. Masson and Eisenstat concluded that attempts to achieve the goal of raising dairy farmers' incomes increased the price of land used in dairy production. In other words, the rents from the dairy regulation were capitalized into land values. Thus landowners, not necessarily dairy farmers themselves, were the final recipients of the benefits of the dairy program. While the research failed to refute this claim, there are other, even more specialized assets in the production of milk, namely the dairy cow itself. Land always has a number of good alternative uses such as tilling for crop production, or pasturing other types of livestock. A dairy cow, however, has few good alternative uses. Thus one expects that any short run rents or profits to be capitalized into the prices of replacement dairy cows even more quickly than into land values. Investigation of a relationship between program created rents and fluctuations in replacement cow prices is absent from the literature.

This research project builds an econometric model of the U.S. dairy industry following LaFrance and de Gorter and investigates the incentives created by the Federal dairy price support program and milk marketing orders. The research will address and empirically test two basic questions of interest. These are: (1) How do dairy farmers respond to incentives created by the dairy support program by attempting to improve their herds with quality testing? and (2) How does the dairy program impact the driving forces behind fluctuations in the price of a specialized asset, in this case, a dairy cow? The next chapter outlines the theoretical development of the empirical models employed in this research and describes the nature and construction of the data used to estimate the economic relationships.

CHAPTER 3

THE CONCEPTUAL MODEL AND DATA SOURCES

Dynamic Model of the U.S. Dairy Industry

The model that is employed in this research project has a recursive structure. The foundation for the model is a milk output per cow production function. This yield per cow equation is specified as a quadratic function where milk output is determined by the inputs grain and concentrated feed per cow (g), hay and roughage fed per cow (h), and participation in herd improvement activities (DHIA). DHIA is measured by the proportion of total cows on DHIA testing programs three years previously. The DHIA regressor is lagged three years to reflect the period for a tested animal to produce a calf and that heifer maturing into milk production. Specifically the equation is

$$(10)\qquad Y_t = \alpha_0 + \beta_1 DHIA_{t-3} + \beta_2 g_t + \beta_3 h_t + 1/2(\gamma_1 DHIA_{t-3}{}^2 + 2\gamma_2 DHIA_{t-3} \bullet g_t + 2\gamma_3 DHIA_{t-3} \bullet h_t + \gamma_4 g_t^2 + 2\gamma_5 g_t \bullet h_t + \gamma_6 h_t^2),$$

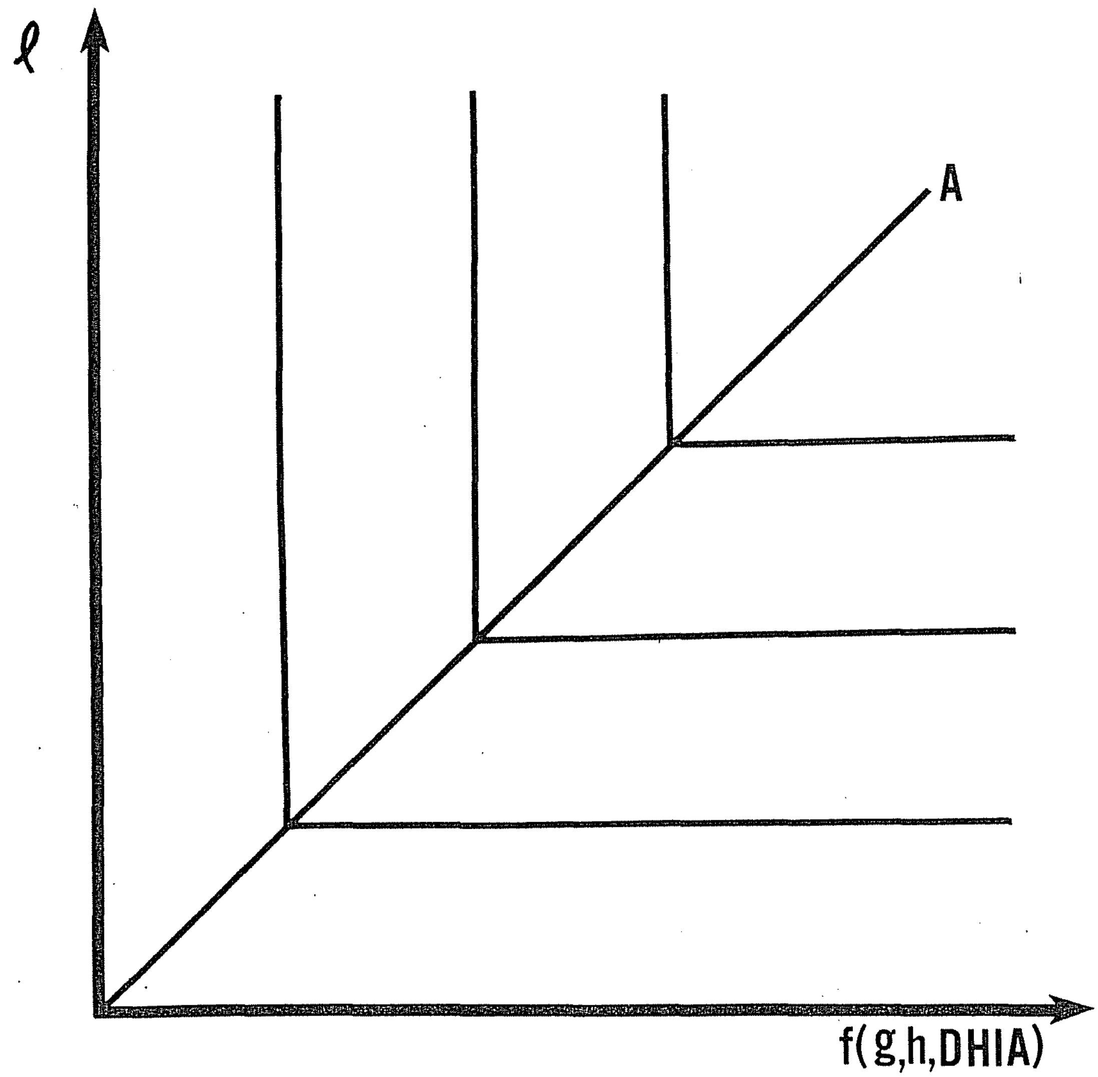
where the α_i, β_i, and γ_i are parameters. This specification results in closed form expressions for the factor demand functions and prior research suggests that it tends to fit the data well. It was assumed to be strictly concave in g and h, having the desirable properties of a well-behaved production function such as diminishing marginal productivities of the inputs, which results in finite solutions for the choice variables.

However, since the amount of hay and roughage fed per cow is not monitored in usual dairy feeding practices and is not a directly observable variable, one must use this quadratic production function to derive a reduced form supply equation where output is a function of input prices rather than input levels. The inputs grain and hay, as well as labor which does not explicitly appear in the production function, are employed in some complementary fashion. In prior research complete nonsubstitutability between all three inputs was assumed [LaFrance and de Gorter]. In this study, that constraint was relaxed so that the nonsubstitutability between grain and hay was not initially imposed. However, labor will still be assumed to combine with grain and hay, as well as the fourth factor, DHIA participation, in fixed proportions from a translated origin. The relationship between labor and the other factors is specified as

$$(11) \quad \ell_t \geq \alpha_{0,\ell} + \alpha_{1,\ell} g_t + \alpha_{2,\ell} h_t + \alpha_{3,\ell} DHIA_{t-3},$$

where all of the inputs are measured in units per cow. This relationship is illustrated in Figure 2 where labor and a bundle of the other inputs grain, hay, and DHIA participation are necessarily combined in fixed proportions along the production function for milk. This states that for each level of the inputs grain, hay, and DHIA, there will be some fixed, positive level of labor necessary to be combined with the other inputs for the production of milk.

Figure 2. Fixed Proportion Relationship between Milk Production Inputs



ℓ = labor per cow
f(g, h, DHIA) = assumed bundle of other milk production factors
A = set of least cost labor/other factor combinations

An individual dairy farmer is assumed to maximize profits. Particularly, the farmer maximizes the objective function

$$(12) \qquad \pi_t = P_m y_t - P_g g_t - P_h h_t - P_\ell \ell_t$$

subject to the constraints imposed by the production function (10) and the complementarity of the inputs (11). P_m is the average farm price of milk, P_g is the price per hundredweight of grain and concentrated feed, P_h is the price per ton of hay and roughage, and P_ℓ is the average farm wage.

Maximization of the profit per cow equation (12), implies a minimization of cost and factor usage. This forces the relationship between labor and the other inputs (11) to assume a strict equality. Substituting in the complementary amounts of labor necessary to combine with each of the other factors in the profit function (12) implies

$$(13) \qquad \pi_t = P_m \cdot y_t - (P_g + \alpha_{1,\ell} P_\ell) g_t - (P_h + \alpha_{2,\ell} P_\ell) h_t - (\alpha_{0,\ell} + \alpha_{3,\ell} DHIA_{t-3}) P_\ell .$$

Maximization of (13) and simultaneously solving the first order conditions for the inputs grain and hay results in the factor demand equations for those inputs

$$(14) \qquad g^* = \theta_1 [((P_g + \alpha_{1,\ell} P_\ell)/P_m) - \beta_2 - \gamma_2 DHIA_{t-3}] - \theta_2 [((P_h + \alpha_{2,\ell} P_\ell)/P_m) - \beta_3 - \gamma_3 DHIA_{t-3}],$$

$$(15) \qquad h^* = \theta_2 [((P_g + \alpha_{1,\ell} P_\ell)/P_m) - \beta_2 - \gamma_2 DHIA_{t-3}] + \theta_3 [((P_h + \alpha_{2,\ell} P_\ell)/P_m) - \beta_3 - \gamma_3 DHIA_{t-3}],$$

where

$$\theta_1 = \gamma_6/(\gamma_4\gamma_6 - \gamma_5^2),$$

$$\theta_2 = -\gamma_5/(\gamma_4\gamma_6 - \gamma_5^2),$$

$$\theta_3 = \gamma_4/(\gamma_4\gamma_6 - \gamma_5^2),$$

and the optimal level of use for each factor is a function of the deflated prices of the inputs and the level of DHIA participation. Assuming that these equations have been derived from the profit maximization hypothesis and that the structural production function, $y = f(g_t, h_t, DHIA_{t-3})$ is strictly concave, certain properties of factor demand equations are implied. These are: (1) equations (14) and (15) are homogeneous of degree zero in prices; (2) they are negatively sloped, that is, the first derivative of each demand equation with respect to own price is less than zero. This occurs if γ_4 and γ_6 are less than zero and $\gamma_4\gamma_6 - \gamma_5^2 > 0$; and (3) cross price symmetry exists, the partial derivative of a given factor demand equation with respect to the price of the other factor equals the partial derivative of the other factor demand equations with respect to the given factor price, particularly, $\partial g^*/\partial P_h = \partial h^*/\partial P_g = \theta_2 = -\gamma_5/(\gamma_4\gamma_6 - \gamma_5^2)$.

Substitution of the optimal input levels (14) and (15) into the initial production function (10) results in a reduced form output per cow equation, which is a product supply function in classical economic production theory, where milk produced per cow is a function of the output price, the factor prices, and DHIA participation. This function is specified

(16) $y_t^* = \psi_0 + \psi_1 DHIA_{t-3} + \psi_2 DHIA_{t-3}^2 + \theta_1[(P_g + \alpha_{1,\ell}P_\ell)/P_m]^2 + \theta_2 [(P_g + \alpha_{1,\ell}P_\ell)/P_m][(P_h + \alpha_{2,\ell}P_\ell)/P_m] + \theta_3[(P_h + \alpha_{2,\ell}P_\ell)/P_m]^2,$

where

$$\psi_0 = \alpha_0 - (\beta_2^2\gamma_6 - 2\beta_2\beta_3\gamma_5 + \beta_3^2\gamma_4)/[2(\gamma_4\gamma_6 - \gamma_5^2)],$$

$$\psi_1 = \beta_1 - [\beta_2\gamma_2\gamma_6 - (\beta_2\gamma_3 + \beta_3\gamma_2)\gamma_5 + \beta_3\gamma_3\gamma_4]/(\gamma_4\gamma_6 - \gamma_5^2),$$

$$\psi_2 = \gamma_1 - (\gamma_2^2\gamma_6 - 2\gamma_2\gamma_3\gamma_5 + \gamma_3^2\gamma_4)/[2(\gamma_4\gamma_6 - \gamma_5^2)].$$

From (11), the relationship between the inputs, $\alpha_{1,\ell}$ and $\alpha_{2,\ell}$ are constrained to be non-negative. The assumption of the strict concavity of the production function (10) imposes constraints on θ_1, θ_2, and θ_3. Specifically, $\theta_1 < 0$, $\theta_3 < 0$, and $\theta_1\theta_3 > \theta_2^2$. The parameters for the final reduced form yield equation are redefined to assure satisfaction of a weak inequality form of these restrictions. The coefficients are redefined as

(17a) $\theta_1 = -\varphi^2_{1,y}$,

(17b) $2\theta_2 = \varphi_{2,y}$,

(17c) $\theta_3 = -(\varphi^2_{2,y} + \varphi^2_{3,y})/\varphi^2_{1,y}$,

(17d) $\alpha_{1,\ell} = \varphi^2_{4,y}$,

(17e) $\alpha_{2,\ell} = \varphi^2_{5,y}$.

Substitution of these new coefficients into the reduced form yield per cow equation (16) results in the final estimable form of the yield equation. This reduced form yield equation, which is nonlinear in the parameters, is

$$(18) \quad y^* = \psi_0 + \psi_1 DHIA_{t-3} + \psi_2 DHIA^2_{t-3} - \varphi^2{}_{1,y}[(P_g + \varphi^2{}_{4,y}P_\ell)/P_m]^2 + 2\varphi_{2,y}[(P_g + \varphi^2{}_{4,y}P_\ell)/P_m][(P_h + \varphi^2{}_{5,y}P_\ell)/P_m] - [(\varphi^2{}_{2,y} + \varphi^2{}_{3,y})/\varphi^2{}_{1,y}][(P_h + \varphi^2{}_{5,y}\, P_\ell)/P_m]^2 + \epsilon_{t,18}.$$

In this specification, optimal output of milk per cow is a function of an intercept, a linear and quadratic term in the DHIA participation variable, and quadratic terms in the real input price variables.

The real input price variables reflect the perfect complementarity between labor and the linear function of grain, hay, and DHIA participation. For example, the input price for grain includes the price per unit of grain and concentrated feed used plus the wage times a factor for the amount of labor necessary to feed the grain. The input price for hay and roughage is defined in a similar manner.

Again, assuming the supply per cow function has been derived through profit maximization, the usual, desirable properties were implied. The function is homogeneous of degree zero in prices, and upward sloping, that is the first derivative of the supply function with respect to product price is greater than zero.

The yield per cow equation was used in the determination of a profitability measure, defined as returns over variable cost. This measure is

$$(19) \quad \pi^* = P_m y^* - P_g g^* - P_h h^* - P_\ell \ell^*,$$

where profit, π^*, in this case, is determined by the interaction of the optimal levels of the output milk and the various inputs.

The avergae price of all milk is defined by

(20) $P_m = [P_I Q_I + P_{II}(Q_{II} + NCR + NGR)]/(Q_I + Q_{II} + NCR + NGR)$,

where P_m is the average price per hundredweight of milk received by farmers; P_I and P_{II} are the average farm prices per hundredweight of Class I (fluid consumption) and Class II (manufacturing consumption) milk, respectively; Q_I and Q_{II} are the private consumption levels for Class I and Class II milk, defined as the total U.S. population multiplied by the per capita demands for Class I and Class II milk, q_I and q_{II}; NCR is net commercial removals; and NGR is the fluid milk equivalent of net government purchases of manufactured milk products.

However the average price received for all milk and the total supply of milk are determined jointly due to the weighted average calculation of the price of milk. Specifically, the denominator of (20), $(Q_I + Q_{II} + NCR + NGR)$ equals the total quantity of milk supplied and $(Q_{II} + NCR + NGR)$ equals the total supply of milk less Class I private consumption. Consequently, endogeneous variables on the right hand sides of the equations are correlated with the error terms. To break this simultaniety and derive consistent parameter estimates, the model equations were estimated with instrumental variables in a two stage least squares procedure.

In the two stage procedure, predicted values for the various endogeneous components entering the equations of the recursive model are estimated and calculated as functions of exogeneous or predetermined variables. Observed values of these elements are then regressed on their predicted counterparts. Predicted values of the variables from this second estimation then form the two stage least squares instruments. These instruments are then used as predetermined variables in subsequent recursive equations. This technique corrects for the endogeneous right hand side variables, resulting in consistent parameter estimates.

The actual prices of Class I and Class II milk are closely related to the support price exogeneously determined in the milk marketing orders due to the purchase, storage, and disposition of manufactured milk products by the CCC. P_{II}, the Class II price is defined as the Class II support price plus some random variation,

$$(21) \qquad P_{II} = \alpha_{0,II} + \beta_{1,II} P_{sup} + \epsilon_{21},$$

where P_{sup} is the Class II support price as announced in the Federal milk marketing orders and ϵ_{II} is unobservable error. A priori, one expects $\alpha_{0,II}$ to equal zero and $\beta_{1,II}$ to equal unity. The actual price received by farmers for manufacturing grade milk, P_{II}, need not equal the support price, P_{sup}, in every period and in fact has not due to market conditions, measurement errors in reporting the actual price received, and aggregation, etc.

The Class I price of milk is defined as the Class II support price plus a differential and an error term

$$(22) \qquad P_{I} = \alpha_{0,I} + \beta_{1,I} P_{sup} + \epsilon_{22}.$$

Here, one expects $\alpha_{0,I}$ to equal the average Class I differential specified in the milk marketing orders and $\beta_{1,I}$ should equal unity.

The Class I differential is a markup above the Class II price in a Federal Milk Marketing Order depending on the location of a milk processing plant and its distance to a major consuming center [USDA,AMS]. In the estimation of (22), P_I was constructed from observed variables because it is not reported by the USDA. By solving (20) for the Class I price, one determines

$$(23) \qquad P_I = [P_m(Q_I + Q_{II} + NCR + NGR) - P_{II}(Q_{II} + NCR + NGR)]/Q_I,$$

where the Class I price is a function of variables with available data.

The per capita demand equations for Class I and Class II consumption are

$$(24) \qquad q_I = \gamma_{0,I} + \gamma_{1,I}(P_I/P_{nf}) + \gamma_{2,I}(P_{II}/P_{nf}) + \gamma_{3,I}(P_b/P_{nf}) + \gamma_{4,I}(AGE) + \gamma_{5,I}(T) + \gamma_{6,I}(INC/P_{nf}) + \gamma_{7,I}(q_{I,t-1}) + \epsilon_{24},$$

$$(25) \qquad q_{II} = \gamma_{0,II} + \gamma_{2,I}(P_I/P_{nf}) + \gamma_{2,II}(P_{II}/P_{nf}) + \gamma_{3,II}(P_{fo}/P_{nf}) + \gamma_{4,II}(AGE) + \gamma_{5,II}(T) + \gamma_{6,II}(INC/P_{nf}) + \gamma_{7,II}(q_{II,t-1}) + \epsilon_{25},$$

where P_I/P_{nf}, P_{II}/P_{nf} are the Class I and Class II milk prices deflated by the Consumer Price Index for nonfood items to reflect own and cross price effects in the demands; P_b/P_{nf}, and P_{fo}/P_{nf} are the Consumer Price Indices of other beverage prices, and prices of fats and oils excluding butter, respectively, again deflated by the nonfood price index to reflect substitution effects; AGE is the average age of the U.S. population to reflect changes in preferences as people age; $q_{I,t-1}$ and $q_{II,t-1}$ are lagged dependent variables to account for persistence effects such as habits; and T is a time trend to reflect the over time growth in the consumption of dairy products. The various prices in the demands for milk are deflated by the non-food price index so the deflator is not affected by the price variable being deflated.

NCR, net commercial removals in (20), represents increases in commercial inventories and net commercial exports, exports less imports. Government purchases, NGR is the control instrument by which the price of Class II milk is supported and represents changes in government owned stocks, foreign and domestic donations, and net government export sales.

Commercial removals were specified

$$(26) \qquad NCR_t = \alpha_{NCR} + \beta_{1,NCR}NGR_t + \beta_{2,NCR}NCR_{t-1} + \epsilon_{t,26},$$

where NGR_t, government purchases, accounts for the replacement of private inventories with government stocks and NCR_{t-1} is a lagged dependent variable to account for the effects of last year's stocks on current period's decisions. Equation (26) was specified without price of milk regressors because the price effects on net commercial removals have been shown to be nonsignificant due to the effects of import and export restrictions on dairy products [LaFrance and de Gorter].

NGR, the net government purchases, are the residual amount after Class I and Class II consumption, and net commercial removals have been deducted from the total milk supplied. The amount of dairy products purchased by the government each year is jointly determined by the interaction of supply and demand forces within the dairy industry and a predicted instrument for it must be constructed. Net government removals were specified

$$(27) \quad NGR_t = \alpha_{NGR} + \beta_{1,NGR}(P_{sup}/P_{nf}) + \beta_{2,NGR}(P_{fo}/P_{nf}) + \beta_{3,NGR}(INC/P_{nf}) + \beta_{4,NGR}T + \beta_{5,NGR}NGR_{t-1} + \epsilon_{t,27},$$

where P_{sup} is the Class II support price; P_{fo} is the Consumer Price Index for fats and oils excluding butter to reflect the costs of close substitutes for manufactured milk products; INC is average per capita disposable income to reflect any income effects in the demands for milk and milk products; P_{nf} is the Consumer Price Index for nonfood items; T is a linear trend; and NGR_{t-1} is the level of net government removals in the previous period.

When (21)-(27) had been estimated, the resulting parameter estimates were used to derive predicted values for P_I, P_{II}, Q_I, Q_{II}, NGR, and NCR. A predicted instrument for the average farm price of milk was constructed as a form of (20) using the predicted values. This instrument is

$$(28) \quad \bar{P}_m = [\hat{P}_I\hat{Q}_I + \hat{P}_{II}(\hat{Q}_{II} + \hat{NCR} + \hat{NGR})]/(\hat{Q}_I + \hat{Q}_{II} + \hat{NCR} + \hat{NGR}).$$

Theoretical Discussion of the Adoption of DHIA Testing

Prior literature suggests that the rate of adoption of some technological improvement, such as herd improvement testing activities will be dependent on expected profitability from the improvement, size of the required investment, and past levels of use of the innovation. In the dairy industry, expected profitability is largely dependent on the supported prices for milk and the input expenses, as evident in the profitability measure (19). Since the investment to participate in DHIA testing is basically a nominal fee per cow, which when discounted for inflation is nearly constant, the hypothesis for this portion of the research is that the rate of adoption of DHIA testing is directly related to the level of profitability created by the dairy support program.

This hypothesis was investigated by estimating a rate of adoption function for DHIA participation. The rate of adoption was initially specified

$$(29) \qquad DHIA_t^* = k \bullet [\exp(\alpha + \beta_1\pi_t^* + \beta_2\pi_t^{*2} + \beta_3 T + \beta_4 T_2 + \beta_5\pi_t^* \bullet T)]/[1 + \exp(\alpha + \beta_1\pi_t^* + \beta_2\pi_t^{*2} + \beta_3 T + \beta_4 T_2 + \beta_5\pi_t^* \bullet T)],$$

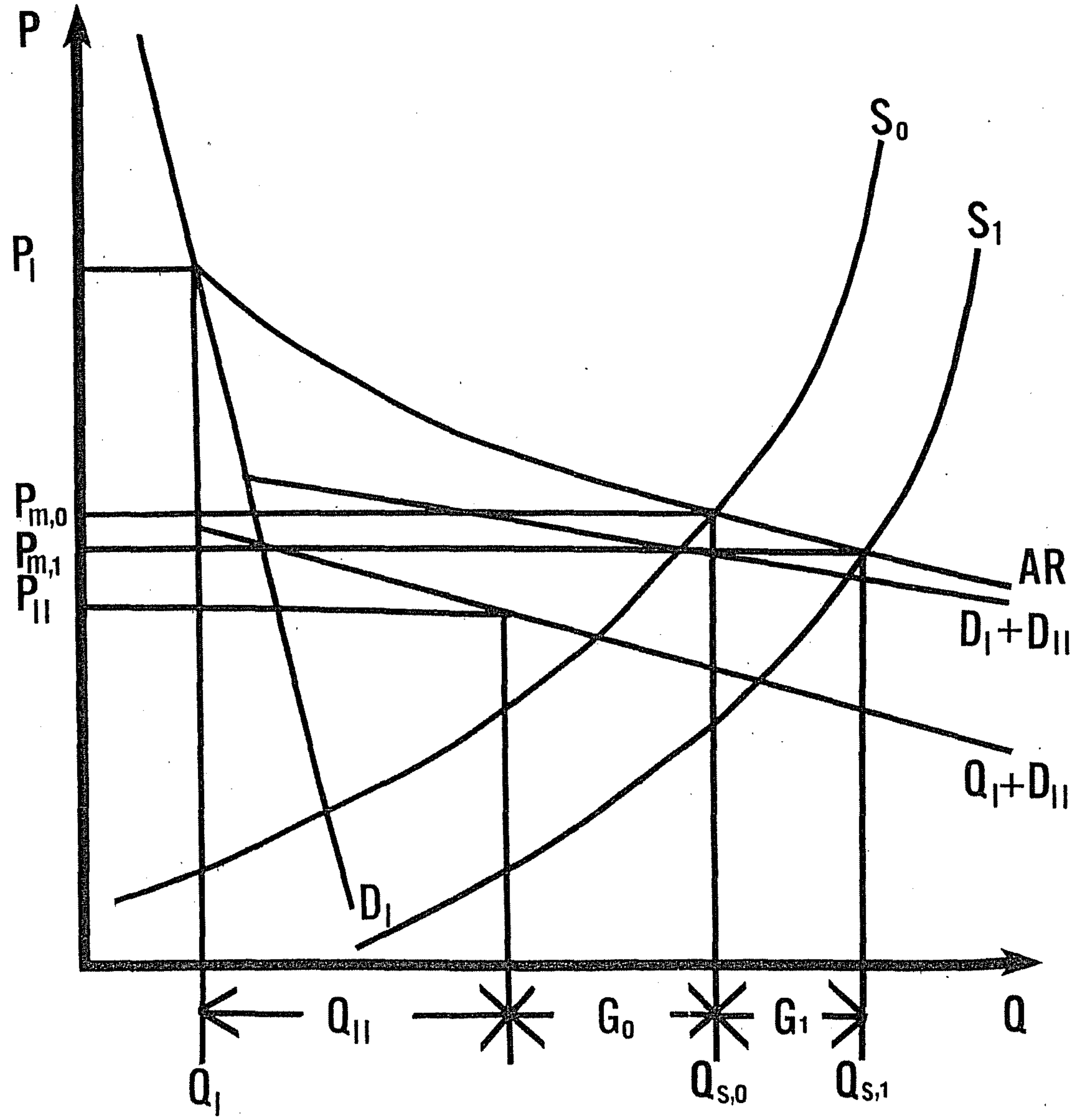
where the level of participation in herd improvement activities is dependent on linear and quadratic terms in the profitability measure calculated in (19); linear and quadratic terms in T, time, entering the estimation as a linear trend; an interaction term between return over variable cost and time; and k, which is the ceiling value. For this study, the ceiling was defined to be 1.0, where the long-run equilibrium level of use equals the available population. Equation (29) and particularly the estimated coefficients on the return over variable cost regressors, were used to test the hypothesis concerning the relationship between the rate of DHIA adoption and expected profitability in the dairy industry. Specifically, the null hypothesis is that profitability in the dairy industry has no effect on the rate of adoption of DHIA testing, while the alternative hypothesis asserts that the level of expected profits do affect the adoption of herd improvement testing. This hypothesis was tested by regressing the participation in DHIA as a function of profits.

Hypothesized Relationship Between Profit and Milk Cow Prices

The final thrust of this project was to investigate the impact of the U.S. dairy regulations on the value of a dairy cow. The dairy program appears to enhance production incentives and profitability in the U.S. dairy industry in the short run. However over time, due to the competitive nature of the production sector in the industry, certain forces in the market will tend to dissipate these short term rents and in the long run, economic profits will be zero. Particularly, there are two forces at work here. First, a rightward shift in the milk supply curve from S_0 to S_1 will reduce the blend price of milk received by farmers from $P_{m,0}$ to $P_{m,1}$, as seen in Figure 3. The reduction in output price will reduce somewhat the short term profits. However, this alone will not drive economic profits to zero.

The second force tending to dissipate profits is the capitalization of those profits into the market price of a dairy cow. As new firms strive to enter the dairy industry, or as existing firms attempt to expand their operations, the market prices of the relatively fixed inventory of producing dairy cattle will be bid up. The consequent increase in prices of replacement animals will tend to increase the average total cost of producing milk. For long run profits to equal zero, the competitive equilibrium condition where the marginal cost of

Figure 3. Price Effects of an Increased Supply of Milk



S_0 = initial supply of milk
S_1 = increased supply of milk
$P_{m,0}$ = initial average price for all milk delivered
$P_{m,1}$ = average price for milk after supply increase
G_0 = initial fluid milk equivalent government purchases of surplus milk products
G_1 = government purchases after supply increase
$Q_{s,0}$ = initial quantity of milk supplied
$Q_{s,1}$ = increased quantity of milk supplied

milk production equals the minimum average total cost equals the average price received from producing milk must exist.

In this study, long run total profit is specified

$$(30) \qquad \Pi = \pi^{*} \bullet C^{*} + P^{*}_{cull\ cows} \bullet CS - P^{*}_{mc} \bullet CP - c(C^{*}),$$

where Π is long-run total profit; $\pi^{*} \bullet C^{*}$ is long-run, per cow, return over variable cost multiplied by the long-run inventory of producing cows; $P^{*}_{cull\ cows} \bullet CS$ is the long-run price of utility cull cows multiplied by the number of culls sold to reflect the salvage value of cattle at the end of their productive life; $P^{*}_{mc} \bullet CP$ is the long run market price of milk cows multiplied by the number of replacement animals pruchased; and $c(C^{*})$ is the opportunity cost of keeping C^{*} animals in a producing herd. Differentiating (30) with the long run inventory of producing cows and setting equal to zero determines the long-run competitive equilibrium condition

$$(31) \qquad \pi^{*} + P^{*}_{cull\ cows} = P^{*}_{mc} + c'(C^{*}).$$

Empirically, the opportunity cost in (31), $c'(C^{*})$, was unobservable and was eliminated from the equation. Consequently, in the long-run equilibrium condition, the long-run price of milk cows was specified as a function of the return over variable cost and the price of cull cows

$$(32) \qquad P^{*}_{mc} = \alpha^{*} + \beta^{*}\hat{\pi}^{*} + \gamma^{*}P^{*}_{cull\ cows},$$

where α^{*}, β^{*}, and γ^{*} are long run parameters. For the long run equilibrium to hold the price of milk cows must be a linearly homogeneous function of the return over variable cost and price of cull cows regressors. The long run intercept α^* was expected to be nonsignificant in a statistical test of the relationship in (32). If the long run constant term was significant the competitive equilibrium condition would not exist and long run profitability would not be dissipated away.

Data Sources

The period of data observation for this project is the years 1950-1985 inclusive. The data to be used in the estimation has been gathered from a number of sources. The amount of grain and concentrated feed per cow, the number of cows on DHIA test, the quantities of Class I and Class II milk consumption, the average farm wage, and the amount of labor used for dairy operations are found in the USDA publication _Agricultural Statistics_. Data for the total milk production, milk per cow, average farm price for all milk, average price for grain and feed concentrates, and replacement cow prices are found in _Agricultural Statistics_, and the Economic Research Service/USDA publication _Dairy Situation and Outlook_. The number of producing milk cows on farms in January and annual average are found in _Agricultural Statistics_, the _Dairy Situation and Outlook_, and the ERS statistical bulletins _Dairy Statistics 1949-1960_, and _Dairy Statistics 1960-1967_. The average support and farm price for Class II milk are found in _Agricultural Statistics_, the _Dairy Situation and Outlook_, and the ASCS' _Commodity Fact Sheet: Dairy Program_, while the Class I farm level price is a constructed data series as previously mentioned. The average price per ton of hay and roughage; the price per bushel of #2 yellow corn at Omaha, Nebraska; the price per short ton of 44% protein soybean meal at Decatur, Illinois; and the Omaha per hundredweight price of utility cull cows are found in the USDA publication Agricultural Prices, and the ASCS' Feed Situation and Outlook. The consumer price indices for all items, non-food items, non-alcoholic beverages, and fats and oils appear in Food Consumption, Prices, and Expenditures, the Bureau of Labor Statistics' CPI Detailed Report, and the Economic Report of the President. The index of all prices paid by farmers is found in Agricultural Statistics, and the Economic Report of the President. Finally, data on the U.S. population, age, and incomes appear in the Economic Report of the President.

CHAPTER 4

EMPIRICAL RESULTS

The previous chapter developed the theoretical basis for this study. This chapter summarizes the empirical results. The estimation of the model is completed using the statistical analysis packages Dynreg [Burt, Townsend, and LaFrance], and Shazam [White].

This chapter is divided into three sections. The first section discusses and summarizes the results derived in constructing the various two-stage least squares instruments used in the final investigations of the study. The second section contains the results from the investigation of the hypothesis concerning the adoption of Dairy Herd Improvement Association quality testing of dairy cattle. The final section summarizes the investigation of the long-run profitability in the dairy industry and its impact on the market price of dairy cattle.

Instrumental Variable Construction

As stated in the previous chapter, many of the prices and quantity figures within the U.S. dairy industry are determined jointly. This results in correlation between the dependent variables and the error terms of the estimated equations. In order to break the simultaniety of the variables, predicted values of these variables are constructed as instruments for a two-stage least squares estimation technique. This section reviews and discusses each estimated instrument, its relationship to the theoretical counterpart specified in Chapter 3, the alterations of the theoretical specifications that were made during the estimation, and reasons why such changes were made.

The Class I and Class II milk price equations estimated to construct predicted instruments are

$$(33)\quad P_I = \alpha_I + \beta_{1,I}D_{73} + \beta_{2,I}D_{74} + \beta_{3,I}D_{75} + \beta_{4,I}D_{76} + \beta_{5,I}P_{sup} + \epsilon_{t,33},$$

$$(34)\quad P_{II} = \alpha_{II} + \beta_{1,II}D_{73} + \beta_{2,II}D_{74} + \beta_{3,II}D_{75} + \beta_{4,II}D_{76} + \beta_{5,II} P_{sup} + \epsilon_{t,34},$$

where P_I and P_{II} are the average prices per hundredweight of Class I and Class II milk, respectively; P_{sup} is the Class II support price, as announced in the Federal milk marketing orders; and D_{73}, D_{74}, D_{75}, and D_{76}, are binary indicator variables equal to one in each of the respective years 1973, 1974, 1975, and 1976, and zero elsewhere in the sample. These indicator variables reflect possible changes in the structure of the dairy industry in these years due to factors such as the Nixon Administration wage and price freeze, the OPEC oil embargo, and the concurrent and subsequent economic disarray.

Net government removals in the current year are estimated as specified in the theoretical model. Net government removals are hypothesized to be

$$(35)\quad NGR_t = \alpha_{NGR} + \beta_{1,NGR}(P_{sup}/P_{nf}) + \beta_{2,NGR}(P_{fo}/P_{nf}) + \beta_{3,NGR}(INC/P_{nf}) + \beta_{4,NGR}T + \beta_{5,NGR}NGR_{t-1} + \epsilon_{t,35},$$

where P_{sup} is the Class II support price of milk; P_{fo} is the Consumer Price Index for fats and oils excluding butter; INC is the average per capita disposable income ; P_{nf} is the Consumer Price Index for nonfood items; T is a linear trend; and NGR_{t-1} is the level of net government removals in the previous period.

Net commercial removals, the increases in commercial stocks and net commercial exports, are estimated as specified in Chapter 3, except that the predicted net government removals instrument is employed as a regressor, rather than its observed counterpart. The estimable form of this equation is

$$(36)\quad NCR_t = \alpha_{NCR} + \beta_{1,NCR}D_{66-85} + \beta_{2,NCR}D_{73-75} + \beta_{3,NCR}\hat{NGR}_t + \beta_{4,NCR}NCR_{t-1} + \epsilon_{t,36},$$

where D_{66-85} is a binary variable equal to one in the years 1966-1985 and zero in the earlier years of the sample; D_{73-75} is an indicator variable equal to one during the years 1973, 1974, and 1975, and zero elsewhere in the sample; $\hat{NGR}_t$ is the predicted level of current net government purchases as derived in (35); and NCR_{t-1} is a lagged dependent variable.

The binary variables in (36) reflect possible structural changes in the dairy market. The first accounts for changes in storage and exports in the later years of the sample period. The second again represents possible changes in market structure caused by the wage and price freeze of the Nixon Administration, the OPEC oil embargo, and consequent economic disarray.

The instruments for the per capita consumption of Class I and Class II milk are estimated as a joint system of equations. As hypothesized in the previous chapter, per capita Class I and Class II milk demands are functions of the Class I milk price, the Class II price, an index of other beverage prices in the Class I equation, the index of prices of fats and oils excluding butter in the Class II equation, a linear trend, the average age of the U.S. population to reflect changes in consumption preferences as people age, and average per capita disposable income. The demand equations are further specified to be homogeneous of degree zero by deflating all price and income regressors by the index of non-food prices. In the initial estimation, the estimated coefficients for the age variable in the Class I equation and the trend in the Class II equation were not statistically different from zero and were omitted from those respective equations.

The system of demand equations was estimated in four fashions to test the significance of two restrictions required to satisfy a set of sufficient conditions for the integrability of a system of more than one linear demand function. These conditions are (1) zero income effects in the demand functions; and (2) symmetry of cross price effects across the equations [LaFrance].

The four versions of the demand system specified are:

(1) non-zero income effects and unrestricted cross price effects;

$$(37a)\quad q_{I,t} = \alpha_I + \beta_{1,I}(\hat{P}_I/P_{nf}) + \beta_{2,I}(\hat{P}_{II}/P_{nf}) + \beta_{3,I}(P_{bev}/P_{nf}) + \beta_{4,I}T + \beta_{5,I}(INC/P_{nf}) + \lambda_I q_{I,t-1} + \epsilon_{t,37a},$$

$$(37b)\quad q_{II,t} = \alpha_{II} + \beta_{1,II}(\hat{P}_I/P_{nf}) + \beta_{2,II}(\hat{P}_{II}/P_{nf}) + \beta_{3,II}(P_{fo}/P_{nf}) + \beta_{4,II}AGE + \beta_{5,II}(INC/P_{nf}) + \lambda_{II} q_{II,t-1} + \epsilon_{t,37b},$$

(2) zero income effects and unrestricted cross price effects;

$$(38a)\quad q_{I,t} = \alpha_I + \beta_{1,I}(\hat{P}_I/P_{nf}) + \beta_{2,I}(\hat{P}_{II}/P_{nf}) + \beta_{3,I}(P_{bev}/P_{nf}) + \beta_{4,I}T + \lambda_I q_{I,t-1} + \epsilon_{t,38a},$$

$$(38b)\quad q_{II,t} = \alpha_{II} + \beta_{1,II}(\hat{P}_I/P_{nf}) + \beta_{2,II}(\hat{P}_{II}/P_{nf}) + \beta_{3,II}(P_{fo}/P_{nf}) + \beta_{4,II}AGE + \lambda_{II} q_{II,t-1} + \epsilon_{t,38b},$$

(3) zero income effects and cross price effects restricted to be equal in the short run;

$$(39a)\quad q_{I,t} = \alpha_I + \beta_{1,I}(\hat{P}_I/P_{nf}) + \beta_{2,I}(\hat{P}_{II}/P_{nf}) + \beta_{3,I}(P_{bev}/P_{nf}) + \beta_{4,I}T + \lambda_I q_{I,t-1} + \epsilon_{t,39a},$$

$$(39b)\quad q_{II,t} = \alpha_{II} + \beta_{2,I}(\hat{P}_I/P_{nf}) + \beta_{2,II}(\hat{P}_{II}/P_{nf}) + \beta_{3,II}(P_{fo}/P_{nf}) + \beta_{4,II}AGE + \lambda_{II} q_{II,t-1} + \epsilon_{t,39b},$$

(4) zero income effects and cross price effects restricted to be equal in the long run;

(40a) $q_{1,t} = \alpha_I + \beta_{1,I}(\hat{P}_I/P_{nf}) + (1.0-\lambda_I)\beta_{2,I}(\hat{P}_{II}/P_{nf}) + \beta_{3,I}$
$(P_{bev}/P_{nf}) + \beta_{4,I}T + \lambda_I q_{I,t-1} + \epsilon_{t,40a}$,

(40b) $q_{II,t} = \alpha_{II} + (1.0-\lambda_{II})\beta_{2,I}(\hat{P}_I/P_{nf}) + \beta_{2,II}(\hat{P}_{II}/P_{nf}) +$
$\beta_{3,II}(P_{fo}/P_{nf}) + \beta_{4,II}AGE + \lambda_{II}q_{II,t-1} + \epsilon_{t,40b}$,

The various restrictions were tested using the estimated results of the four models with a likelihood-ratio test. The null hypothesis for each test is that the restricted model performs as well as the unrestricted specification. The formal statistical hypothesis is

$$H_0: \ell_{restricted} = \ell_{unrestricted}$$

$$H_a: \ell_{restricted} < \ell_{unrestricted}$$

where ℓ is the value of the respective models' likelihood functions. The tests and comparisons are summarized in Table 1.

Neither the zero income effects and long run symmetry of the cross price effects restrictions significantly affect the performance of the system of milk demand equations at the 1 percent level. The predicted values from the fourth model are used as the instruments for the per capita Class I and Class II milk demands in the rest of the study.

A nominal predicted blend price received by farmers for all milk is calculated as specified in (28), using the predicted values of the Class I and Class II prices and demands, net government removals, and net commercial removals

Table 1. Comparison of Class I and Class II Demand Restrictions

Model	Log-Likelihood	Calculated X^2 Test Statistic	Conclusion $\alpha = .01$
1. Unrestricted	-186.62	----	----
2. Zero Income Effects $\beta_{5,I} = \beta_{5,II} = 0.0$	-189.96	6.68	fail to reject
3. Zero Income effects $\beta_{5,I} = \beta_{5,II} = 0.0$ Short Run Cross Price Symmetry $\beta_{2,I} = \beta_{1,II}$ (short run)	-191.33	9.42	fail to reject
4. Zero Income Effects $\beta_{5,I} = \beta_{5,II} = 0.0$ Long Run Cross Price Symmetry $\beta_{2,I} = \beta_{1,II}$ (long Run)	-192.2393	11.24	fail to reject

(41) $\bar{P}_m = (\hat{P}_I\hat{Q}_I + \hat{P}_{II}(\hat{Q}_{II} + N\hat{C}R + N\hat{G}R))/(\hat{Q}_I + \hat{Q}_{II} + N\hat{C}R + N\hat{G}R)$,

where $\hat{Q}_I$ and $\hat{Q}_{II}$ are the per capita Class I and Class II milk demands multiplied by the U.S. population. The observed average price for all milk is then estimated as a function of this calculated prediction to derive a two-stage least squares instrument for the average price of milk received by farmers. The estimable form of the average price of milk is

(42) $P_{m,t} = \alpha_{Pm} + \beta_{1,Pm}\bar{P}_{m,t} + \epsilon_{t,42}$.

The predicted values from (42) are used as the instrument for the price received by farmers for all milk in the remainder of the research.

In Chapter 3, the estimable reduced form of the output per cow equation specified milk per cow as a function of quadratic prices for grain and concentrated feeds, hay and roughage, and labor. The function also specified linear and quadratic terms reflecting the level of Dairy Herd Improvement Association testing three years past.

On dairy farms, the most common feeding practice for producing dairy cows is to monitor and control the animal's intake of grain and concentrated feed and then allow the cow to eat hay or other roughage until it is full. Therefore the amount of hay and roughage consumed is some complementary function of the amount of grain and concentrated feed per cow. The intake capacity of a dairy cow is assumed to be a function of the levels of DHIA testing three years ago. The amount of grain and concentrated feed per cow plus the amount of hay and roughage fed will then equal the intake capacity, assuming the feeding practices above are implemented. Specifically this relationship is assumed to be

$$(43) \quad g_t + h_t = \theta_1 + \theta_2 DHIA_{t-3}.$$

After subtracting the amount of grain fed from both sides of (43), hay and roughage is shown to be a function of the amount of grain fed and the past level of DHIA testing

$$(44) \quad h_t = \theta_1 + \theta_2 DHIA_{t-3} - g_t.$$

This, along with the assumed complementarity of labor with the feed inputs in (11), suggests that the reduced form output of milk per cow should be driven by the levels of DHIA testing three years ago and the price per hundredweight of grain and concentrated feed, deflated by the average blend price of milk.

The estimation of the reduced form supply equation tested this assertion and found it to be valid. A complete output per cow equation was estimated with linear and quadratic terms in DHIA participation three years past, along with quadratic prices of grain, hay, labor and their cross products as regressors. The results of the complete model were then compared with the estimates of a smaller model specification omitting the prices of hay and labor, and the various cross product interaction terms. The estimated form of the complete model, (18) is

$$(45) \quad y_t = \underset{(16.333)}{4.5294} + \underset{(3.2392)}{2.2468}P_g^2 - \underset{(.73481)}{.32658}P_g \bullet P_h - \underset{(1.5296)}{12.665}P_g \bullet P_\ell +$$

$$\underset{(.2215\bullet 10^{-9})}{.39445\bullet 10^{-10}}P_h^2 + \underset{(.69793)}{.86786}P_h \bullet P_\ell - \underset{(.63704)}{1.5984}P_\ell^2 + \underset{(17.965)}{41.366}DHIA_{t-3} -$$

$$\underset{(6.5211)}{43.920}(DHIA_{t-3}^2$$

log-likelihood = 23.344479,

where the numbers in parentheses are asymptotic t-ratios.

The effect of restricting the coefficients of the squared prices of hay and labor and the grain-hay, grain-labor, and hay-labor interaction terms to zero in the smaller equation reduced the value of the log-likelihood of the equation from 23.344479 to 19.70005. Performing a likelihood ratio test on these values results in a test statistic of 7.287958. The conclusion is that at the 1 percent level the hypothesis that the restricted model performs as well as the unrestricted model cannot be rejected. Inclusion of the hay and labor prices and the interaction terms does not significantly contribute to the explanatory power of the model.

Economic theory and the profit maximization hypothesis dictate that input demand and reduced form output supply functions be derived from a production function and imposes certain constraints on the input demand and supply equations. As discussed in the previous chapter, the estimable forms of the input demand for grain and concentrated feed, and the supply of milk in this study are derived from a quadratic milk production function. In the estimation, both equations must be functions of the same explanatory variables, homogeneous of degree zero in all prices, and negatively sloped with respect to the real input, grain and concentrated feed, prices. Also, the coefficient on the grain price variable in the grain input demand is restricted to be twice the corresponding parameter in the milk supply equation. Specifically, the reduced form equations that were estimated are

(46) $y_t = \alpha_y + 1/2\beta_{1,y}(P_g/\hat{P}_m)^2 + \beta_{2,y}DHIA_{t-3} + \beta_{3,y}(DHIA_{t-3})^2 + \epsilon_{t,46}$,

(47) $g_t = \alpha_g + \beta_{1,y}(P_g/\hat{P}_m) + \beta_{2,g}DHIA_{t-3} + \epsilon_{t,47}$.

After estimating this system, although the coefficients were all significantly different from zero and of the theoretically correct sign, examination of the calculated residuals and the Durbin-Watson statistic suggested the existence of serial correlation. The autoregressive errors were particularly evident in the grain input demand. The Durbin-Watson statistics for the supply of milk and grain demand equations are 1.5591 and .3603, respectively. In many cases autocorrelated errors can be corrected by specifying and estimating the equation with an autoregressive error process. However, serial correlation as severe as that in the grain per cow equation is suggestive of misspecification of the model and further investigation of the appropriateness of the explanatory variables is necessary.

Further estimation of the milk and grain per cow system of equations employs the price per bushel of #2 yellow corn at Omaha, Nebraska and the price per short ton of 44% protein soybean meal at Decatur, Illinois as proxy variables for the price of grain and concentrated feeds. The rationale for these choices being that corn and soybean meal are the primary components of the concentrated feed rations fed to producing dairy cattle. The price of corn is specified as a regressor throughout the sample period and both the price of corn and soy meal are included as indicator variables equal to the respective prices for the years 1979-1985 and zero elsewhere in the sample. They are specified in the system to reflect changes in the nature of dairy farmers' responses to price changes during the late 1970's and early 1980's when price movements of agricultural commodities were extremely wide and volatile, after remaining relatively stable during the earlier years of the sample period. This system is specified as

$$(48)\quad y_t = \alpha_y + \beta_{1,y}(P_{corn}/\hat{P}_m)^2 + \beta_{2,y}((P_{sm}D_{79-85})/\hat{P}_m)^2 + \beta_{3,y}((P_{corn}D_{79-85})/\hat{P}_m)^2 + \beta_{4,y}DHIA_{t-3} + \beta_{5,y}(DHIA_{t-3})^2 + \epsilon_{t,48},$$

$$(49)\quad g_t = \alpha_g + \beta_{1,g}(P_{corn}/\hat{P}_m) + \beta_{2,g}((P_{sm}D_{79-85})/\hat{P}_m) + \beta_{3,g}((P_{corn}D_{79-85})/\hat{P}_m) + \beta_{4,g}DHIA_{t-3} + \epsilon_{t,49}.$$

The system using these price variables and the lagged values of DHIA testing is estimated in two forms. The first is an unrestricted system with no constraints being imposed on the parameter estimates. The second model restricts the coefficients of the various price variables in the grain demand equation to be twice those on the corresponding variables in the milk per cow equation. The significance of these restrictions is then examined in a likelihood ratio test. The values of the log-likelihood function for the restricted and unrestricted systems are 28.011 and 57.080, respectively. The likelihood ratio test statistic is calculated to be 58.138 and the hypothesis that the restricted model performs as well as the unrestricted model is rejected by the data at the 1 percent level. Therefore the unrestricted system is used in the remainder of the study.

Some serial correlation still existed in the system using the prices of corn and soybean meal. Again, this is more prevalent in the grain demand equation, as evidenced by a Durbin-Watson statistic of 1.3171. To achieve efficient estimates of the system coefficients, this serial correlation must be accounted for in the estimation of the grain equation.

To account for the serially correlated errors, the data must be transformed by a consistent estimate of the first order autocorrelation coefficient, ρ, from the estimated grain demand. The estimated ρ is .48290. The data observations for the years 1955-1985 are then transformed with the serial correlation coefficient by subtracting from each observation, the previous observation multiplied by 0.48290. The first observation, 1954, was multiplied by $\sqrt{(1.0 - (.48290)^2)}$ for its transformation. Applying the usual least squares techniques to the data transformed in this manner produces generalized least squares estimates of the coefficients which are best linear unbiased [Judge, Hill, Griffiths, Lutkepohl, and Lee, p.440-41].

Reestimation of the milk and grain per cow system using the transformed data revealed that accounting for the serial correlation appears to be sufficient. The new Durbin-Watson statistics for the transformed milk and grain equations are 1.8802 and 2.091, respectively.

As stated previously, economic theory dictates that the marginal effect of an input price be negative in output supply and input demand functions. In the reestimation of the milk and grain system of equations the signs of the coefficients on the price of corn variables were expected to be negative and consistent with economic theory. However, the estimated parameters on the price of soybean meal variables were expected to be positive in (48) and (49) This is explained because the variable measures the price of high (44%) protein soy meal. As the price of soybean meal increases, farmers must substitute other, less nutritious grains and feeds for the relatively more expensive high protein meal. To maintain the same nutrient value of the rations, a greater amount of the other feed must be substituted for the meal, causing the quantity, or weight, of the feed ration to increase. This will lead to a positive sign on the soybean meal coefficients.

Predicted values to be used as a two-stage least squares instrument for the price per hundredweight of grain and concentrated feeds are determined by regressing the observed grain and feed price as a function of the feed ration components specified in the milk and grain system. The estimable form of this equation is

$$(50)\qquad P_g/\hat{P}_m = \alpha_{Pg} + \beta_{1,Pg}(P_{sm}/\hat{P}_m) + \beta_{2,Pg}(P_{corn}/\hat{P}_m) + \epsilon_{t,50},$$

where P_g is the observed price per hundredweight of grain and concentrated feeds, P_{sm} is the price per short ton of 44% soybean meal, and P_{corn} is the price per bushel of #2 yellow corn. All three of the price variables are deflated by the predicted instrument for the average price of milk received by farmers.

After the predicted price per hundredweight of grain and concentrated feeds was determined, a predicted nominal profit per cow, defined as returns over feed cost, was calculated using the constructed instruments for the average blend price of milk, output per cow, grain and concentrated feed per cow, and the price of the grain and feed rations. Predicted nominal profit per cow is specified as

$$(51) \quad \bar{\pi}_t = \hat{P}_m \bullet \hat{y}_t - \hat{P}_g \bullet \hat{g}_t .$$

The calculation of nominal profit per cow is a condensed form of (28) as specified in Chapter 3. The hay and labor components of (28) are eliminated due to the exclusion of the hay and labor prices in the estimation of the output per cow equation (45). The price of grain and concentrated feeds is the primary factor driving the output of milk is thus a reasonable proxy for feed costs in the calculation of nominal profit per cow in (51).

To construct a two-stage least squares instrument for profits as defined in (51), the observed returns over feed cost are regressed as a function of the calculated prediction. Specifically, the relationship is estimated as

$$(52) \quad \pi_t = \alpha_\pi + \beta_\pi \bar{\pi}_t + \epsilon_{t,52},$$

where π_t is defined as $(P_m y_t - P_g g_t)$ in observed units and $\bar{\pi}_t$ is the predicted counterpart from (51). The predicted values from this specification of nominal profit per cow is used in the investigations of the adoption of DHIA quality testing and the relationship between profitability in the dairy industry and fluctuations in the market price of dairy cattle.

A summary of the constructed instruments is listed in Table 2. The estimation procedure for the Class I and Class II milk price equations was ordinary least squares. The procedure for the net government removals is nonlinear least squares. The estimation procedure for the Class I per capita consumption, the price of grain and concentrated feeds, and nominal profit per cow is linear two-stage least squares. The remainder of the equations were estimated using nonlinear two-stage least squares.

In the table, the numbers in parentheses are the respective coefficients' asymptotic t-ratio statistics in absolute value; R^2 is the coefficient of multiple determination; $\bar{R}^2$ is the coefficient of multiple determination adjusted for the degrees of freedom; D.W. is the Durbin-Watson statistic for first order serial correlation; d.f. is the number of degrees of freedom; and s.e.e. is the standard error of the estimate.

Serial correlation among the residuals appeared to be present in many of the estimated equations. If the autoregressive errors are not corrected, the estimated coefficients, while being unbiased and consistent, are neither efficient nor asymptotically efficient [Kmenta,

Table 2. Estimated Instrument Equations for the Dynamic Dairy Model

Class I Milk Price

$$P_I = \underset{(14.321)}{1.8328} + \underset{(4.1246)}{.64215D_{73}} + \underset{(6.8320)}{1.2469D_{74}} + \underset{(2.8463)}{.52015D_{75}} +$$

$$\underset{(4.9557)}{.77197D_{76}} + \underset{(56.958)}{1.0410P_{sup}} \qquad \epsilon_t = \underset{(5.2677)}{.65976\epsilon_{t-1}} + u_t$$

R^2=.99861, $\bar{R}^2$=.99822, D.W.=1.690, d.f.=29, s.e.e.=.156264

Class II Milk Price

$$P_{II} = \underset{(2.5336)}{.21018} + \underset{(4.6664)}{.82622D_{73}} + \underset{(4.2417)}{.79581D_{74}} + \underset{(6.9187)}{1.3010D_{75}} + \underset{(3.2320)}{.57390D_{76}}$$

$$+ \underset{(81.806)}{.96576P_{sup}} \qquad \epsilon_t = \underset{(2.0878)}{.32864\epsilon_{t-1}} + u_t$$

R^2=.99798, $\bar{R}^2$=.99757, D.W.=1.765, d.f.=29, s.e.e.=.174567

Net Government Removals

$$NGR_t = \underset{(4.7194)}{25.385} + \underset{(6.2101)}{3.2082}(P_{sup}/P_{nf}) - \underset{(3.1404)}{9.9519}(P_{fo}/P_{nf}) + \underset{(4.6027)}{.71863T}$$

$$+ \underset{(5.3739)}{.015358}(INC/P_{nf}) + \underset{(2.0878)}{.60904}E(NGR_{t-1})$$

R^2=.81040, $\bar{R}^2$=.77771, D.W.=2.595, d.f.=29, s.e.e.=1.88695

Net Commercial Removals

$$NCR_t = \underset{(6.3785)}{5.0468} - \underset{(5.3501)}{3.3249D_{66-85}} - \underset{(2.6434)}{1.8242D_{73-75}} - \underset{(2.0536)}{.16208\hat{NGR}_t}$$

$$- \underset{(2.5331)}{.42445}E(NCR_{t-1})$$

R^2=.74090, $\bar{R}^2$=.69622, D.W.=1.992, d.f.=29, s.e.e.=.855049

Table 2 (continued)

Class I Per Capita Consumption

$$q_{I,t} = \underset{(3.7873)}{153.81} - \underset{(4.9212)}{13.335}(\hat{P}_I/P_{nf}) + \underset{(1.6472)}{33.264}(1.0-.70264)(\hat{P}_{II}/P_{nf}) +$$

$$\underset{(.99477)}{2.2188}(P_{bev}/P_{nf}) - \underset{(4.3310)}{1.9861}T + \underset{(6.4216)}{.70264}q_{I,t-1}$$

R^2=.996969, D.W.=1.903248, d.f.=28

Class II Per Capita Consumption

$$q_{II,t} = \underset{(3.8333)}{-316.38} + \underset{(1.6472)}{33.264}(1.0-.80828)(\hat{P}_I/P_{nf}) - \underset{(3.1271)}{18.599}(\hat{P}_{II}/P_{nf}) +$$

$$\underset{(4.6467)}{57.639}(P_{fo}/P_{nf}) + \underset{(4.1828)}{10.963}AGE + \underset{(14.639)}{.80828}E(q_{II,t-1})$$

R^2=.938462, D.W.=2.503937, d.f.=28

Average Farm Price for All Milk

$$P_m = \underset{(.2562)}{-.017516} + \underset{(115.94)}{.99391}\hat{P}_m$$

R^2=.99755, $\bar{R}^2$=.99748, D.W.=1.737, d.f.=33, s.e.e.=.179711

Output of Milk per Cow

$$y_t = \underset{(31.729)}{4.4634} - \underset{(7.7493)}{6.0158}(P_{corn}/\hat{P}_m)^2 + \underset{(1.4319)}{.0011427}((P_{sm}D_{79-85})/\hat{P}_m)^2$$

$$- \underset{(1.1575)}{5.9094}((P_{corn}D_{79-85})/\hat{P}_m)^2 + \underset{(25.700)}{42.672}DHIA_{t-3} - \underset{(7.5863)}{44.221}(DHIA_{t-3})^2$$

R^2=.9982, $\bar{R}^2$=.9979, D.W.=1.8802, d.f.=27, s.e.e.=.093524

Table 2 (continued)

Grain and Concentrated Feeds per Cow

$$g_t = \underset{(5.5403)}{1.3627} - \underset{(2.0544)}{1.3680}(P_{corn}/\hat{P}_m) + \underset{(5.9461)}{.15622}((P_{sm}D_{79-85})/\hat{P}_m) -$$

$$\underset{(6.1897)}{12.437}((P_{corn}D_{79-85})/\hat{P}_m) + \underset{(22.209)}{17.782}DHIA_{t-3}$$

R^2=.9665, $\bar{R}^2$=.9623, D.W.=2.091, d.f.=28 s.e.e.=.11490

Price of Grain and Concentrated Feeds

$$P_g/\hat{P}_m = \underset{(9.0580)}{.35115} + \underset{(10.036)}{.97915}(P_{corn}/\hat{P}_m) + \underset{(5.5667)}{.0047675}(P_{sm}/\hat{P}_m)$$

$$\epsilon_t = \underset{(3.1650)}{.51658}\epsilon_{t-1} + \underset{(2.3534)}{.38411}\epsilon_{t-2} + u_t$$

R^2=.92696, $\bar{R}^2$=.91610, D.W.=1.834, d.f.=27, s.e.e.=.020331

Nominal Profit per Cow

$$\pi = \underset{(.1431)}{-.17258} + \underset{(57.737)}{.87847}\hat{\pi} \qquad \epsilon_t = \underset{(2.9081)}{.45720}e_{t-1} + u_t$$

R^2=.99706, $\bar{R}^2$=.99686, D.W.=1.963, d.f.=29, s.e.e.=2.23553 p.278]. This invalidates any hypothesis tests performed with parameter coefficients derived from ordinary least squares techniques when autoregressive disturbances are present.

To correct serially correlated errors, the Class I and Class II milk price equations, and the nominal profit per cow estimation were specified with a first order autoregressive error process. The price per hundredweight of grain and concentrated feeds required the specification of a second order autoregressive error process to remedy the autocorrelated disturbances.

When serially correlated errors appear to exist in the data employed to estimate a difference equation with ordinary least squares techniques, observed values of the dependent variable entered on the right hand side of the equation result in inconsistent estimates of the equation parameters. This is due to the correlation between the lagged dependent variable and the error term. To correct this, a nonstochastic difference equation, with the unconditional expectation of the lagged dependent variable specified as a regressor, is employed. Using the expectation of the dependent variable, which depends only on the systematic portion of the regression, rather than the observed values, eliminates the correlation with the error process providing consistent parameter estimates [Burt, 1980].

The net government removals, net commercial removals, and the per capita Class II consumption equations appeared to exhibit serial correlation of the disturbances and are estimated as nonstochastic difference equations using nonlinear least squares techniques. The

Class I per capita consumption regression appeared to exhibit classical "white noise" residuals and a stochastic difference equation is specified with observed values of the lagged dependent variable entered as a regressor on the right hand side.

Adoption of DHIA Testing

The theoretical model for this research asserted that the level of Dairy Herd Improvement Association testing to improve the quality of dairy herds is a function of the expected level of profitability within the dairy industry and time. To investigate this assertion, the current levels of DHIA testing are estimated as a function of those factors.

The DHIA adoption equation is estimated as a transformation of the logistic function, as specified in Chapter 3. The original logistic function for the adoption of DHIA testing is

$$(53)\quad DHIA_t = [\exp(\alpha + \beta_{1,DHIA}(\hat{\pi}_t/PPF_t) + \beta_{2,DHIA}(\hat{\pi}_t/PPF_t)^2 + \beta_{3,DHIA}T + \beta_{4,DHIA}T^2 + \beta_{5,DHIA}(\hat{\pi}_t/PPF_t)\bullet T + \epsilon_{t,53})] \,/\, [1.0 - \exp(\alpha + \beta_{1,DHIA}(\hat{\pi}_t/PPF_t) + \beta_{2,DHIA}(\hat{\pi}_t/PPF_t)^2 + \beta_{3,DHIA}T + \beta_{4,DHIA}T^2 + \beta_{5,DHIA}(\hat{\pi}_t/PPF_t)\bullet T + \epsilon_{t,53})].$$

The estimable form of the DHIA equation is

$$(54)\quad \ln[DHIA_t/(1.0 - DHIA_t)] = \alpha + \beta_{1,DHIA}(\hat{\pi}_t/PPF_t) + \beta_{2,DHIA}(\hat{\pi}_t/PPF_t)^2 + \beta_{3,DHIA}T + \beta_{4,DHIA}T^2 + \beta_{5,DHIA}(\hat{\pi}_t/PPF_t)\bullet T + \epsilon_{t,54},$$

where $\ln[DHIA_t/(1.0 - DHIA_t)]$ is the natural (base e) logarithm of the ratio of the proportion of dairy cattle on DHIA test to the proportion of animals not on test; $(\hat{\pi}_t/PPF_t)$ is the predicted instrument for profit per cow constructed in (52), defined as returns over feed cost, and deflated by the index of all prices paid by farmers; and T is a linear trend. The ceiling or equilibrium level of use is specified to be 1.0. The error terms in (53) are assumed to be additive in the exponential to allow the linear transformation.

This transformation, while linearizing the response function, does not exhibit a constant variance of the error terms, resulting in a heteroskedastic model [Dixon]. Under heteroskedasticity, the least squares assumption of constant variance of the error terms is violated and the parameter estimates derived from ordinary least squares are not efficient and not best linear unbiased estimates. With heteroskedastic errors, like serially correlated errors, hypothesis tests and test statistics are biased and correction of the error terms is required.

To correct the heteroskedastic errors and derive a constant variance, a weighted least squares procedure is required. Weighting each observation of the dependent and the independent variables, including the constant term, by the square root of the variance of the dependent variable results in best linear unbiased estimates of the parameters. For $DHIA_t > 0.0$, the approximate variance of the logarithm of the ratio of proportions in the logistic transformation has been shown to be

(55) $$\sigma_t^2 = 1.0/n_t(DHIA_t)(1.0 - DHIA_t),$$

with the appropriate weights specified as

$$w_t = \sqrt{[n_t(DHIA_t)(1.0 - DHIA_t)]}, \quad (56)$$

where n_t is the total inventory of producing cows on farms in time t; and $DHIA_t$ is the proportion of all producing cows on DHIA test in the current period [Neter, Wasserman, and Kutner, pp.362-63; Berkson].

The weighted least squares adoption path exhibited serially correlated errors when estimated with a "white noise" error process. Reestimation of (54) with a second order autoregressive error process appeared to correct the correlated disturbances. The results of this estimation are

$$\ln[DHIA_t/(1.0 - DHIA_t)] = \underset{(7.1885)}{-2.4268} - \underset{(1.0012)}{.10090}(\hat{\pi}_t/PPF_t) \quad (57)$$

$$+ \underset{(.71787)}{.005393}(\hat{\pi}_t/PPF_t)^2 + \underset{(4.6962)}{.1061}T - \underset{(2.3989)}{.0008959}T^2 -$$

$$\underset{(.32221)}{.0010633}(\hat{\pi}_t/PPF_t) \cdot T$$

$$\epsilon_t = \underset{(11.313)}{1.3207}e_{t-1} - \underset{(6.4324)}{.75093}e_{t-2} + u_t$$

R^2=.99761, $\bar{R}^2$=.99691, D.W.=2.156, d.f.=24, s.e.e.=.0342861.

The hypothesis of interest for this portion of the research is

$$H_0: \beta_1 = \beta_2 = \beta_6 = 0$$

$$H_a: \beta_1 \neq 0 \text{ or } \beta_2 \neq 0 \text{ or } \beta_5 \neq 0.$$

The null hypothesis asserts that the estimated coefficients on the real profit per cow regressors are not significantly different from zero and expected profits have no impact on farmers' decisions to begin to test the quality of their dairy herds using DHIA procedures. The alternative hypothesis states that the parameters are statistically significant and DHIA participation is affected by the level of expected profitability within the U.S. dairy industry.

Equation (57) was reestimated with the coefficients of the return over feed cost variables restricted to equal zero in order to calculate an F-statistic based on the difference between the error sum of squares without the profitability regressors and that with return over feed cost variables included. This difference is divided by the number of restrictions to calculate a mean square error for the restrictions. This is then divided by the mean square error for the complete specification including the profitability variable to form the F-statistic. The calculated test statistic is then compared with the table value of the F-distribution at the appropriate level of statistical significance and degrees of freedom. The results from the reestimation of (57) are

$$(58)\quad \ln[DHIA_t/(1.0 - DHIA_t)] = \underset{(103.65)}{-2.8208} + \underset{(21.453)}{.089706T} - \underset{(6.3242)}{.00082173T^2}$$

$$\epsilon_t = \underset{(10.219)}{1.3128e_{t-1}} - \underset{(5.3475)}{.68696e_{t-2}} + u_t$$

R^2=.99741, $\bar{R}^2$=.99703, D.W.=2.2221, d.f.=27, s.e.e.=.03373481.

The null hypothesis that the reduced specification with the coefficient of the return over feed cost regressor restricted to equal zero is identical to the complete model is tested at the 5 percent level of confidence. The calculated F-statistic to test the significance of the estimated parameter of the predicted profitability regressor is

$$F(3,24) = .71288$$

and at the 5 percent level the null hypothesis that the return over variable cost coefficients are not significantly different from zero cannot be rejected. Although the marginal effects of return over variable cost are, as expected, positive for the last twenty years of the sample, the nonsignificance of the profit coefficients contradict the assertion from the theoretical model that the rate of adoption of DHIA testing activities is directly related to the level of profitability available in the U.S. dairy industry. The marginal effects of (58) with respect to the profit variable and time are presented in Table 3.

The results here suggest that the level of participation in the Dairy herd Improvement Association is determined exogeneously over time, independent of the dairy program and the supported prices farmers receive for milk. Dairy producers appear to be attempting to improve the productive capacity of their herds without regard to the available level of profitability as defined here. In this case, the primary factor affecting the rate of adoption of DHIA testing activities is time, reflecting the period for a farmer to gather and analyze

Table 3. Marginal effects of Profit and Time in the Adoption of DHIA

Year	$\frac{\partial[\ln(DHIA_t/1.0 - DHIA_t)]}{\partial(\pi_t)}$	$\frac{\partial[\ln(DHIA_t/1.0 - DHIA_t)]}{\partial(T)}$
1954	-.03143	.10510
1955	-.02421	.10409
1956	-.01854	.10301
1957	-.01525	.10189
1958	-.01661	.10073
1959	-.01487	.09957
1960	-.00726	.09820
1961	.00394	.09681
1962	-.00669	.09544
1963	-.00654	.09415
1964	-.00321	.09298
1965	-.00199	.09160
1966	.01043	.09056
1967	.02001	.08931
1968	.02866	.08807
1969	.02503	.08693
1970	.03560	.08587
1971	.03688	.08434
1972	.03062	.08306
1973	.03377	.08143
1974	.03137	.08006
1975	.03379	.07878
1976	.03481	.07757
1977	.04302	.07576
1978	.04180	.07403
1979	.04573	.07245
1980	.06065	.07050
1981	.04834	.06828
1982	.04992	.06618
1983	.03789	.06459
1984	.02901	.06310
1985	.02549	.06266

information about the DHIA testing procedures and to begin to participate in the programs. Estimation of (58), with return over variable cost omitted still explains 99.5% of the variation in the dependent variable. This situation would result in a monotonically increasing adoption path in the early stages of development, as over time, more producers become familiar with and adopt DHIA testing techniques.

As evident in Figure 4, the observed proportion of total dairy cattle on DHIA test has increased steadily throughout the sample period until 1982 when the structural effects of the Federal government dairy herd buyout begin to impact the dairy industry. Over the years of the sample the level of DHIA participation increased nearly five-fold. In contrast, the increase in the real return over feed cost, as seen in Figure 5, has been much smaller and subject to much greater fluctuation throughout the sample period.

However, making decisions such as whether to begin to test and improve the quality of a dairy herd without regard to available revenue or profits appears to be inconsistent with the assumption of profit maximization made in the theoretical model and a number of factors may account for the unexpected result. Dairy producers may be responding to a level of profitability, but not that as defined and calculated here.

The constructed instruments and the final DHIA adoption equation were estimated using aggregated data for the respective prices and quantities. Consequently, the return over variable cost measure of profitability employed in the investigation is also an aggregate figure. The rate of adoption of DHIA testing is however, based on

Figure 4. Observed DHIA Participation

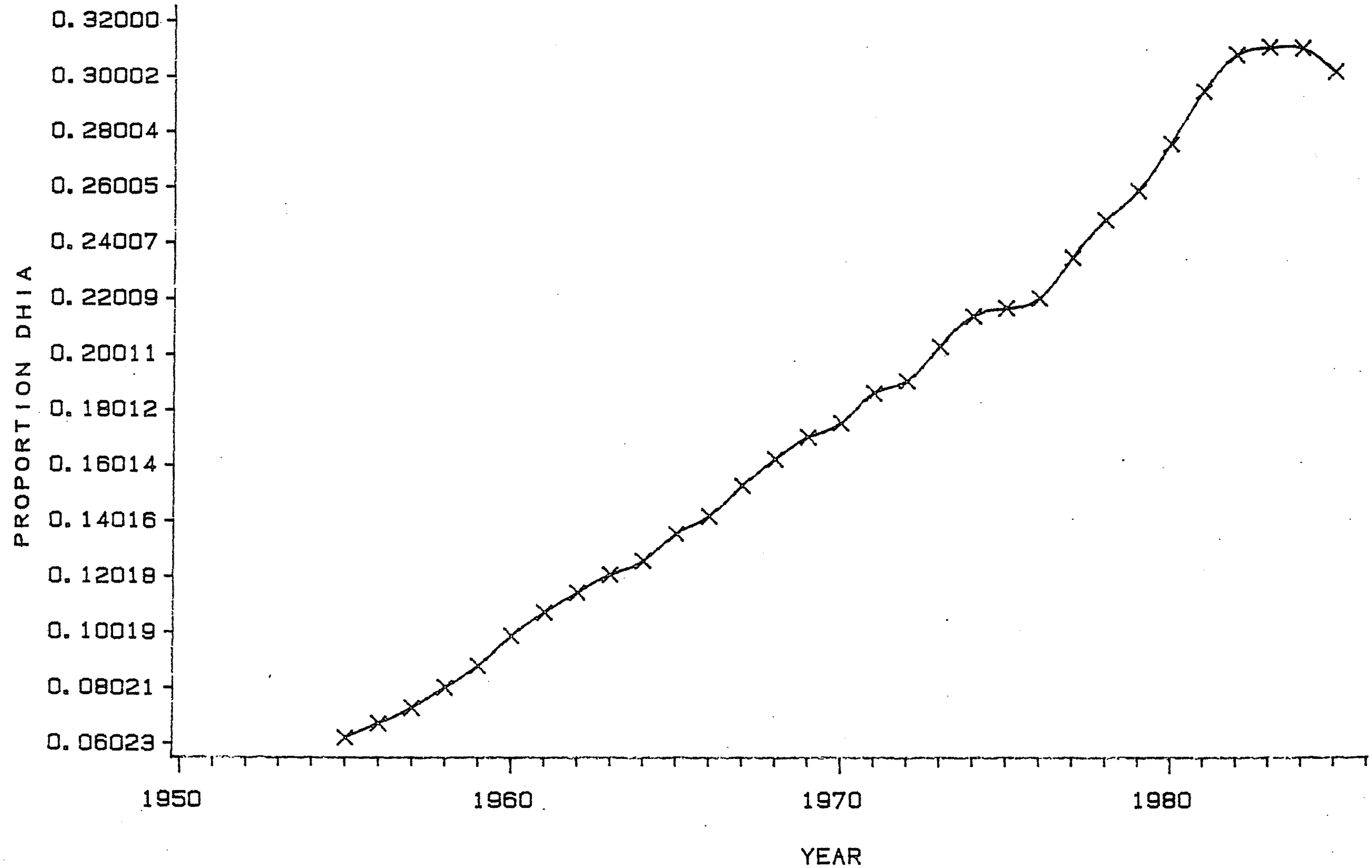
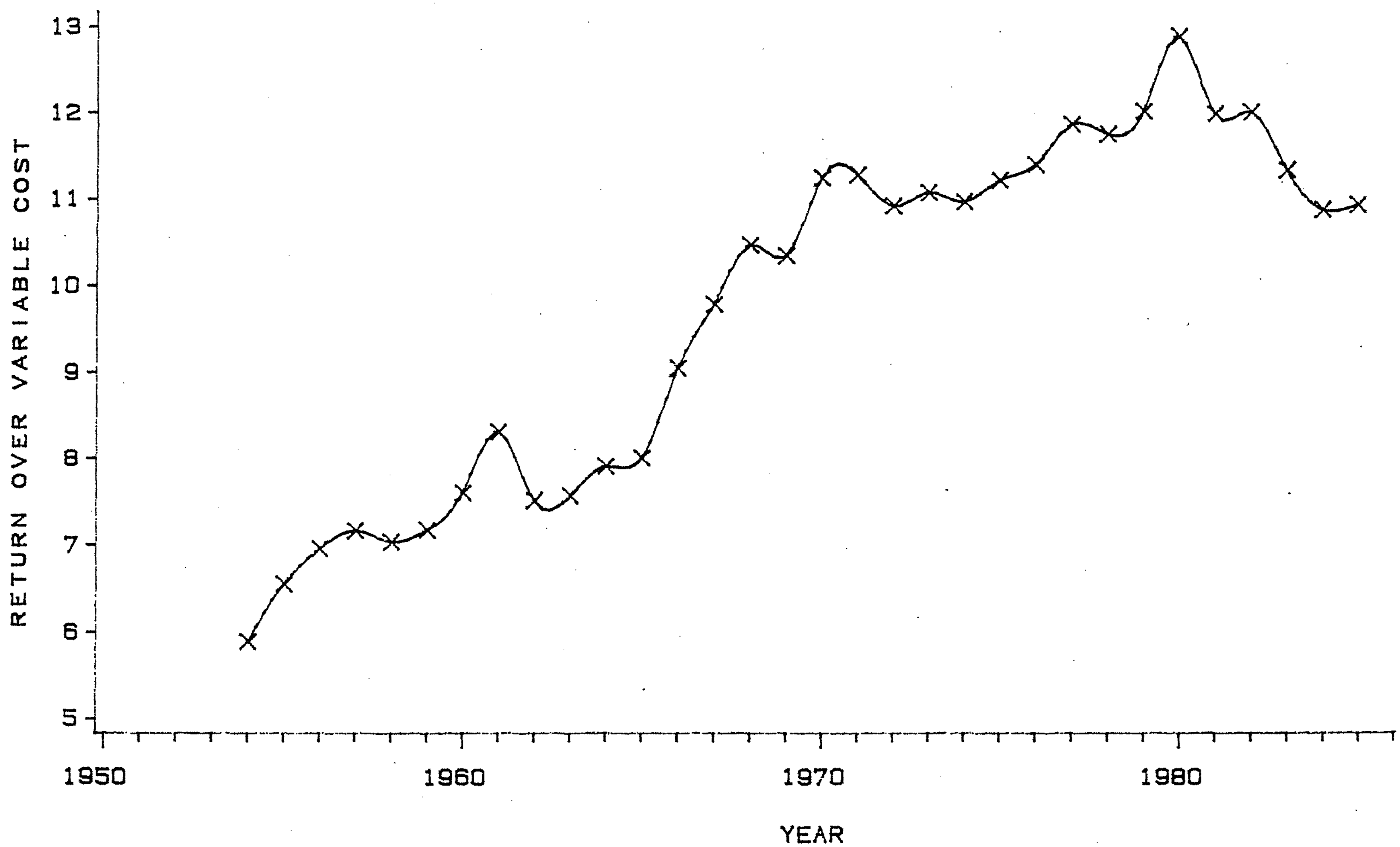


Figure 5. Observed Return over Variable Cost



individual dairy producer decisions. This inconsistency may, to an extent, explain the insignificant relationship.

Further, the research completed here assumed the rate of DHIA adoption to be a function of a general level of profitability for all producers of dairy products. Mansfield showed that the rate of adoption of a technological improvement is impacted by the expected profitability from the adoption of the improvement [Mansfield]. If the profitability figures were gathered from individual dairy operations, particularly from those operations already using the DHIA testing procedures, a significant, direct relationship may arise.

Finally, profitability defined as return over feed cost may simply not be the appropriate revenue measure to which dairy producers respond in deciding to test and improve the quality of their herds. Factors other than feed costs such as fixed costs or costs of capital may enter the decision making process. Possibly farmers may be responding only to the level of gross revenue and the average price received by farmers for all milk may be the appropriate regressor. Further research of this question is necessary to substantiate the results derived in this study or determine the correct measure of profitability to which dairy producers respond.

Relationship between Profitability and Milk Cow Prices

The final thrust of this thesis investigates the relationship between profitability and fluctuations in the market prices of dairy cattle. As discussed in the theoretical chapter, as the level of profitability increases, the market prices of replacement milk cows are expected to be bid up by farmers attempting to enter the dairy industry or to expand existing herds. The bidding up of the cost of replacement cattle shifts up the average total cost schedules of dairy production, dissipating the additional returns.

Economic theory dictates that firms in a competitive industry must earn zero economic profits in the long run. This follows from the existence of a long run equilibrium condition where marginal cost equals minimum average total cost equals price.

The dairy industry, though regulated and supported by the Federal government mandates, can be examined in a competitive framework because a basically homogeneous product is supplied and there are few barriers to entry other than the relatively fixed short run stock of producing dairy cattle. Therefore a long-run competitive equilibrium condition where the long-run price of replacement dairy cattle is a linearly homogeneous function of the long-run return over fixed cost and the price of utility cull cows was expected to exist, implying that long run economic profits are dissipated and driven to zero.

To investigate this assertion, a long run price of milk cows equation is derived. The long run equation follows that specified by Burt for the capitalization of rents into long run land prices [Burt, 1984]. The estimable form of the long run price of cows equation is

$$(59) \quad P_{mc,t} = \alpha + \beta_1 \hat{\pi}_t + \beta_2 \hat{\pi}_{t-1} + \gamma_1 P_{cull\ cows,t} + \lambda_1 P_{mc,t-1} + \lambda_2 P_{mc,t-2} + \epsilon_{t,59},$$

where $P_{mc,t}$, $P_{mc,t-1}$, and $P_{mc,t-2}$, are current and lagged nominal prices of milk cows; $\hat{\pi}_t$, and $\hat{\pi}_{t-1}$ are the current and lagged levels of predicted per cow return over feed cost constructed in (52) as a profitability proxy; and $P_{cull\ cows}$ is the current, nominal price per hundredweight of utility cull cows at Omaha. The price for cull cows is specified in (59) as a salvage value for culled heifers and older cattle to reflect the impact on milk cow prices of fluctuations in the beef market.

In the long run, there is assumed to be no change in the variables across time periods and equilibrium values of P_{mc}, $\hat{\pi}$, and $P_{cull\ cows}$, can be defined. Specifically, $P_{mc,t} = P_{mc,t-1} = P^*_{mc}$, $\hat{\pi}_t = \hat{\pi}_{t-1} = \hat{\pi}^*$, and $P_{cull\ cows,t} = P_{cull\ cows,t-1} = P^*_{cull\ cows}$. Substituting the equilibrium values into (59) and rewriting determines the long run price of milk cows equation

(60) $$P^*_{mc} = \alpha^* + \beta^*\hat{\pi}^* + \gamma^*P^*_{cull\ cows},$$

where

(60a) $$\alpha^* = \alpha/(1.0 - \lambda_1 - \lambda_2),$$

(60b) $$\beta^* = (\beta_1 + \beta_2)/(1.0 - \lambda_1 - \lambda_2),$$

(60c) $$\gamma^* = \gamma/(1.0 - \lambda_1 - \lambda_2).$$

For the assertion that profits from the dairy industry are capitalized into the prices of replacement dairy cattle and dissipated, the long run price of milk cows equation (60) must be homogeneous of degree one in $\hat{\pi}^*$ and $P^*_{cull\ cows}$. In this case, from the properties of linearly homogeneous functions, increasing the level of profitability and the price of cull cows by the same positive factor will increase the market price of milk cows by that same factor and the competitive equilibrium condition will continue to hold [Chiang, p.410-14].

The hypothesis tested here is

$$H_0: \alpha^* = 0$$

$$H_a: \alpha^* \neq 0.$$

The null hypothesis states that the estimated intercept in the long run price of milk cows equation are not significantly different from zero. The alternate hypothesis asserts that the constant term is statistically significant.

The estimated form of (59) is

$$(61) \quad \underset{}{P_{mc,t}} = \underset{(1.4953)}{-45.483} - \underset{(1.4532)}{57.461D_{81-85}} - \underset{(.72552)}{38.160D_{73}} + \underset{(3.8689)}{250.66D_{79}} -$$

$$\underset{(.80954)}{1.9954\hat{\pi}_t} + \underset{(.93549)}{3.2333\hat{\pi}_{t-1}} + \underset{(2.1034)}{5.9233P_{cull\ cows}} + \underset{(8.6606)}{1.0838E(P_{mc,t-1})}$$

$$- \underset{(2.0494)}{.41007E(P_{mc,t-2})}$$

R^2=.99526, $\bar{R}^2$=.99345, D.W.=1.805, d.f.=21, s.e.e.=27.6138,

where D_{81-85}, D_{73}, and D_{79}, are binary indicator variables to reflect structural changes in the dairy industry due to the effects of the Federal government dairy herd buyout in 1981-1985, and the sharp and unexpected movements of agricultural commodity prices in 1973 and 1979, respectively; and $E(P_{mc,t-1})$, and $E(P_{mc,t-2})$ are unconditional expectations of the first and second order lag on the dependent variable, respectively. Again a nonstochastic difference equation is specified because (61) appeared to exhibit serial correlation among the disturbances when observed values for $P_{mc,t-1}$ and $P_{mc,t-2}$ were used.

To test the significance of the long run intercept, (61) was reestimated with the intercept omitted. Further, the 1981-1985, and 1973 indicator variables and the current return over variable cost did not appear to be statistically different from zero in (61) and are consequently omitted from the reestimations. Omission of the intercept, two binary variables, and current profitability coefficients resulted in

$$(62) \quad P_{mc,t} = \underset{(11.139)}{312.12D_{79}} + \underset{(5.9125)}{1.9481\hat{\pi}_{t-1}} + \underset{(6.9749)}{2.2085P_{cull\ cows}} + \underset{(30.789)}{1.2216}$$

$$E(P_{mc,t-1}) - \underset{(11.694)}{.57678}E(P_{mc,t-2})$$

R^2=.99402, $\bar{R}^2$=.99306, D.W.=1.812, d.f.=25, s.e.e.=28.48618.

The hypothesis that the specification with the four coefficients restricted to equal zero performs as well as the full model (60) was tested at the 5 percent level of significance. The calculated test statistic here is

$$F(4,21) = 1.401301.$$

The conclusion is that the null hypothesis is not rejected at the 5 percent level of significance.

The calculated long run price of milk cows equation is,

(63) $P^*_{mc} = 5.5129\pi^* + .47830P^*_{cull\ cows}$

$\text{Elasticity}_{\pi} = .6298^{a} \quad \text{Elasticity}_{P\text{cull cows}} = .3198,$

where the coefficient on the price of cull cows is divided by 13.0 to transform the per hundredweight cull cows price into per cow units consistent with the other variables in the equation. The U.S. Department of Agriculture assumes that the live weight of culled utility dairy cows is 1300 lbs. each [USDA, NEWS].

The empirical results here suggest that, in the long run, the market price or value of dairy cattle is a linearly homogeneous function of the return over variable cost and the price of utility cull cows. Consequently, the long run competitive equilibrium where marginal cost equals marginal revenue appears to exist and long run economic profits are driven to zero.

These conclusions hold rather important implications concerning the effectiveness of the U.S. dairy support program. While the dairy program and the mandates of the Federal Milk Marketing Orders are supporting the prices of milk received by farmers above that which would exist under a competitive framework, the results of this portion of the research suggest that the increased returns farmers receive are capitalized into the market price of replacement dairy cattle. Over the long run, economic profits to the dairy industry, even with the milk price supports provided by the government, are driven to zero by virtue of the competitive nature of the industry. In effect, the

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[a] Elasticities are calculated at the sample means.

support efforts of the U.S. government, and the associated costs incurred from the dairy programs, appear to be supporting the incomes and net worth of those producers who raise and market replacement dairy cattle.

The final chapter of this thesis summarizes the main results obtained during the course of this research. The thesis is completed by discussing possible implications and extensions of these research results.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

In this study an attempt was made to estimate a dynamic model of the U.S. dairy industry and use those empirical results to investigate the factors impacting the adoption of Dairy Herd Improvement Association quality testing of dairy cattle. The model was also employed to examine the relationship between the level of profitability and the market price of milk cows.

The empirical research recursively constructed predicted values as instruments for various price and quantity figures of the supply and demand sectors of the U.S. dairy industry. The constructed instrumental variables attempted to break the simultaneity between the various price and quantity components in a two-stage least squares procedure. The constructed instruments were used to derive a predicted profit per cow, defined as return over feed cost, to be used in the investigations concerning the rate of adoption of DHIA testing and the market prices of dairy cattle.

In the theoretical model, the rate of adoption of DHIA activities was hypothesized to be directly related to the level of profitability available in the dairy industry. As the return over feed cost increased, an increase in participation in the Dairy Herd Improvement Association was expected. To investigate this assertion the level of DHIA participation was estimated as a transformed logistic function of return over variable cost and time, which entered as a linear trend.

The results of the empirical research appeared to contradict these initial expectations. The estimated parameter of the return over feed cost regressor was not statistically different from zero and only the linear trend appeared to affect the level of participation in the Dairy Herd Improvement Association.

The results suggested that the rate of adoption of DHIA testing is determined exogeneously, unaffected by the support efforts of the U.S. dairy program. However, making decisions concerning inputs to a production process without considering the expected level of profitability appears to be inconsistent with the optimization assumption of profit maximization and a number of factors such as aggregation bias and misspecification of the profitability measure may be contributing to its lack of effect on the participation in DHIA activities.

The research here also investigated the relationship between the nominal price of replacement dairy cattle and nominal profits, again defined as predicted returns over feed cost. In the theoretical model economic profits in the dairy industry were hypothesized to be capitalized into the market prices of dairy cattle. In the long run, the price of replacement dairy cattle, defined to be marginal cost of dairy production, was expected to equal the marginal revenue from producing milk, defined as the sum of per cow return over variable cost and the price of utility cull cows, implying the long run economic profits are driven to zero. The empirical results of the research substantiate the hypothesized relationship. The long run price of milk cows equation was estimated, as expected, to be a linearly homogeneous function of nominal return over feed cost and the price of utility cull cows and the equilibrium condition appears to hold.

The results of this portion of the research hold significant implications concerning the effectiveness of the U.S. dairy support programs. One of the underlying goals of the Federal dairy regulations is to increase dairy farmers' incomes. To achieve this goal the average price farmers receive for all milk is supported above that which would exist in a competitive environment. The empirical results obtained here, suggest that the increased revenue does not significantly raise producers incomes in the long run. Rather, the profits from dairy production are capitalized into market prices of replacement dairy cattle and dissipated away. Thus, the efforts of the government to support producers incomes are, in the long run, frustrated by the competitive nature of the U.S. dairy industry.

A number of implications for further research have arisen in the investigations accomplished here. Further analysis of the rate of adoption of Dairy Herd Improvement Association testing activities is required to either substantiate the unexpected results derived in this thesis, or to determine the appropriate measure of profitability to which dairy producers ultimately respond in adopting DHIA procedures.

Viewed as a technological improvement to a production process, DHIA testing may hold potential long run economic benefits for consumers due to the increased supply of milk resulting from the more productive dairy herds. Additional research may determine the nature, size, and distributions of such economic benefits.

Finally, the investigation here suggests that additional revenue from dairy production is dissipated into the market prices of replacement dairy cattle and consequently does not increase producer incomes in the long run. Possible extensions of this portion of the thesis could attempt to more exactly determine the nature and the rate of the capitalization of the dairy program rents over time.

REFERENCES

REFERENCES

American Agricultural Economics Association Task Force on Dairy Marketing Orders. Federal Milk Marketing Orders: a Review of Research on their Economic Consequences. Occasional Paper #3. Ames, Iowa, (1986).

Beattie, B.R., and C.R. Taylor. The Economics of Production. New York:John Wiley and Sons Inc., 1985.

Berkson, J. "A Statistically Precise and Relatively Simple Method of Estimating the Bio-Assay with Quantal Response, Based on the Logistic Function." Journal of the American Statistical Association. 48(1953):565-99.

Bureau of Labor Statistics. CPI Detailed Report. Washington D.C. (various issues).

Burt, O.R. "Estimation of Distributed Lags as Nonstochastic Difference Equations." Department of Agricultural Economics and Economics Staff Paper 80-1. Montana State University, Bozeman, Montana, (1980).

Burt, O.R. "Econometric Modelling of the Capitalization Formula for Farmland Prices." Department of Agricultural Economics and Economics Staff Paper 84-7. Montana State University, Bozeman, Montana, (1984).

Burt, O.R. S. Townsend, and J.T. LaFrance. "Instruction Manual for DYNREG:a Nonlinear Least Squares Algorithm for Distributed Lag Models and/or Regression Models with Time Series Error Terms." Department of Agricultural Economics and Economics Staff Paper 86-4. Montana State University, Bozeman, Montana, (1986).

Buxton, B.M. "Welfare Implications of Alternative Classified Pricing Policies for Milk." American Journal of Agricultural Economics. 59(1977):525-29.

______, and J.W. Hammond. "Social Cost of Alternative Dairy Price Support Levels." American Journal of Agricultural Economics. 56(1974):279-87.

Chiang, A.C. Fundamental Methods of Mathematical Economics. New York:McGraw-Hill Book Co., 1984.

Dahlgran, R.A. "Welfare Costs and Interregional Income Transfers due to Regulation of Dairy Markets." American Journal of Agricultural Economics. 62(1980):288-96.

_______, "Dairy Marketing and Policy Analysis: a Critical Review of Recent Empirical Studies." Department of Economics and Business Report #62. North Carolina State University, Raleigh, North Carolina, (1981).

Dixon, R. "Hybrid Corn Revisited." Econometrica. 48(1980):1451-65.

Economic Report of the President. U.S. Government Printing Office. Washington D.C. (various issues).

Gaumnitz, E.W. and O.M. Reed. Some Problems Involved in Establishing Milk Prices. USDA, AAA. (1937).

Griliches, Z. "Hybrid Corn: an Exploration in the Economics of Technological Change." Econometrica. 25(1957):502-22.

Harris, E.S. Classified Pricing of Milk: some Theoretical Aspects. Technical Bulletin 1184. USDA/AMS. (1950).

Heady, E.O., N.L. Jacobson, J.A. Schnittker, and S. Bloom. "Milk Production Functions and Marginal Rates of Substitution Between Forage and Grain." in Agricultural Production Functions, ed. E.O. Heady, and J.L. Dillon. Iowa State University Press, Ames, Iowa, 1960.

Heady, E.O., J.P. Madden, N.L. Jacobson, and A.E. Freeman. "Milk Production Functions Incorporating Variables for Cow Characteristics and Environment." Journal of Farm Economics. 46(1964):1-19.

Hein, D. "The Cost of the U.S. Dairy Price Support Programs: 1949-1974." Review of Economics and Statistics. 59(1977):1-8.

Hoover, L.M., P.L. Kelly, G.M. Ward, A.M. Feyerman, and R. Chaddha. "Economic Relationships of Hay and Concentrate Consumption to Milk Production." American Journal of Agricultural Economics. 49 (1967) :64-78.

Ippolito, R.A. and R.T. Masson. "The Social Cost of Government Regulation of Milk." Journal of Law and Economics. 21(1978):33-65.

Judge, G.J., R.C. Hill, W.E. Griffiths, H. Lutkepohl, and T.C. Lee. Introduction to the Theory and Practice of Econometrics. New York:John Wiley and Sons Inc. 1982.

Kmenta, J. Elements of Econometrics. New York: Macmillan Publishing Co., Inc. 1986.

LaFrance, J.T. "Linear Demand Functions in Theory and Practice." Journal of Economic Theory. 37(1):147-66.

LaFrance, J., and H. de Gorter. "Regulation in a Dynamic Market: the U.S. Dairy Industry." American Journal of Agricultural Economics. 67(1985): 821-32.

Mansfield, E. "Technical Change and the Rate of Imitation." Econometrica. 29(1961):741-66.

Masson, R.T., and P.M. Eisenstat. "Goals and Results of Federal Milk Regulation: a Revaluation", Journal of the Northeastern Agricultural Economics Council. 6(1977):193-214.

Neter, J., W. Wasserman, and M.H. Kutner. Applied Linear Statistical Models, 2nd ed. Homewood, Ill.:Richard D. Irwin Inc. 1985.

Paris, Q., F. Malossni, A.M. Pilla, and A. Romita. "A Note on Milk Production Functions." American Journal of Agricultural Economics. 52(1970):594-602.

Salathe, L., J.M. Price, and K.E. Gadson. "The Food and Agricultural Policy Simulator: the Dairy Sector Submodel." Agricultural Economics Research. 34(1982):1-14.

Song, D.H. and M.C. Hallberg. "Measuring Producers' Advantage from the Classified Pricing Policies of Milk." American Journal of Agricultural Economics. 64(1982):1-7.

Taylor, C.R. "A Simple Method for Estimating Empirical Probability Density Functions." Western Journal of Agricultural Economics. 9(1984):66-76.

USDA. Agricultural Statistics. Washington D.C. (various issues).

_____,AMS. Federal Milk Order Market Statistics, Annual Summary. Washington D.C. (various issues).

_____,ASCS. Dairy Program, Commodity Fact Sheet. Washington D.C. (various issues).

_____,ERS. Dairy Situation and Outlook. Washington D.C. (various issues)

_____,ERS. Dairy Statistics through 1960. Statistical Bulletin 303. Washington D.C. (1962).

_____,ERS. Dairy Statistics, 1960-1967. Statistical Bulletin 430. Washington D.C. (1968).

_______,ERS. Feed Situation and Outlook. Washington D.C. (various issues).

_______,ERS. Food Consumption, Prices, and Expenditures. Washington D.C. (various issues).

______,NEWS. USDA News Division, Office of Information. Washington D.C. August, 1986.

______,Statistical Reporting Service. Agricultural Prices. Washington D.C. (various issues).

White, K.J. "A General Computer Program for Econometric Methods - SHAZAM." Econometrica. 46(1978):239-40.

APPENDIX

ORIGINAL DATA

Table 4. Original Data

Year	Avg. Milk Price	Avg. Sup. Price	Mfg. Milk Price	Avg. Cl. 1 Price	Avg. Grain Price	#2 Corn Price	Util. Cows Price	Non-Food CPI	Beverage CPI
1950	3.89	3.07	3.16	4.77	3.08	1.21	19.50	0.711	0.867
1951	4.58	3.47	3.85	5.40	3.52	1.59	24.03	0.757	0.955
1952	4.85	3.79	4.06	5.71	3.75	1.77	18.54	0.775	0.961
1953	4.32	3.77	3.48	5.31	3.43	1.53	12.04	0.790	0.988
1954	3.97	3.30	3.14	4.94	3.30	1.46	11.11	0.795	1.173
1955	4.00	3.15	3.15	4.97	3.10	1.46	10.99	0.797	1.051
1956	4.14	3.23	3.25	5.15	3.00	1.38	10.91	0.811	1.099
1957	4.21	3.25	3.27	5.26	3.00	1.30	13.40	0.838	1.091
1958	4.13	3.11	3.15	5.21	2.89	1.12	17.87	0.857	1.014
1959	4.16	3.06	3.17	5.25	2.89	1.09	17.47	0.873	0.921
1960	4.21	3.11	3.25	5.28	2.90	1.07	15.31	0.888	0.915
1961	4.22	3.37	3.36	5.24	2.91	1.01	15.65	0.897	0.915
1962	4.09	3.18	3.20	5.14	2.93	1.03	15.37	0.908	0.901
1963	4.10	3.13	3.21	5.12	3.03	1.13	14.73	0.920	0.912
1964	4.15	3.15	3.26	5.18	3.02	1.17	13.24	0.932	1.023
1965	4.23	3.22	3.34	5.22	3.03	1.26	14.44	0.945	1.015
1966	4.78	3.69	3.94	5.66	3.15	1.29	17.83	0.967	1.009
1967	5.02	4.00	4.06	6.07	3.23	1.30	17.22	1.000	1.000
1968	5.24	4.21	4.22	6.34	3.10	1.14	17.94	1.044	1.019
1969	5.49	4.28	4.45	6.63	3.15	1.20	20.29	1.101	1.046
1970	5.71	4.57	4.70	6.88	3.28	1.28	21.32	1.167	1.174
1971	5.87	4.86	4.86	7.08	3.44	1.44	21.62	1.221	1.216
1972	6.07	4.93	5.08	7.23	3.52	1.23	25.21	1.258	1.213
1973	7.14	5.31	6.20	8.18	4.88	1.80	32.82	1.307	1.302
1974	8.33	6.33	7.13	9.79	6.23	2.79	25.56	1.437	1.556
1975	8.75	7.36	8.62	10.10	6.25	3.05	21.09	1.571	1.790
1976	9.66	8.06	8.56	11.06	6.30	2.66	25.31	1.675	2.140
1977	9.72	8.82	8.70	11.07	6.20	2.15	25.32	1.784	3.224
1978	10.60	9.42	9.65	11.85	6.08	2.09	36.78	1.912	3.398
1979	12.00	10.70	11.10	13.22	6.68	2.28	50.10	2.130	3.561
1980	13.05	12.33	12.05	14.55	7.42	2.49	45.72	2.440	3.958
1981	13.76	13.12	12.73	15.41	8.02	3.13	41.93	2.706	4.126
1982	13.59	13.10	12.66	15.17	7.45	2.46	39.96	2.884	4.242
1983	13.58	13.06	12.61	15.23	7.88	2.82	39.35	2.983	4.322
1984	13.46	12.60	12.49	15.00	8.16	3.20	39.81	3.113	4.430
1985	12.75	11.98	11.72	14.50	7.35	2.60	38.31	3.233	4.532

Table 4. (continued)

Fats & Oils CPI	Milk Cows Price	Per Cap. Disp. Income	Total U.S. Pop.	Average U.S. Age	Yield per Cow	Grain per Cow
0.885	198.	1267.	152.271	32.06660	5.314	1.629
1.035	247.	1349.	154.878	32.01794	5.333	1.605
0.878	243.	1396.	157.553	31.99775	5.374	1.628
0.882	177.	1458.	160.184	31.95212	5.542	1.670
0.929	149.	1477.	163.026	31.90199	5.657	1.659
0.901	146.	1560.	165.931	31.84348	5.842	1.758
0.920	153.	1608.	168.903	31.76767	6.090	1.825
0.961	166.	1666.	171.984	31.68051	6.303	1.945
0.950	210.	1692.	174.882	31.59908	6.585	2.003
0.906	233.	1786.	177.830	31.54801	6.815	2.050
0.865	223.	1829.	180.671	31.50865	7.029	2.259
0.926	224.	1857.	183.691	31.44578	7.290	2.404
0.925	221.	1940.	186.538	31.40061	7.496	2.723
0.899	215.	2017.	189.242	31.40973	7.700	2.646
0.896	209.	2133.	191.889	31.42435	8.099	3.040
0.961	212.	2268.	194.303	31.46332	8.304	2.953
0.998	246.	2428.	196.560	31.53852	8.507	3.200
1.000	260.	2534.	198.712	31.67012	8.797	3.374
0.978	274.	2752.	200.706	31.82273	8.992	3.519
0.979	300.	2949.	202.677	31.95431	9.434	3.726
1.053	332.	3121.	205.052	32.07092	9.751	3.979
1.152	358.	3330.	207.661	32.15747	10.015	4.070
1.166	393.	3609.	209.896	32.34636	10.259	4.298
1.290	496.	3950.	211.909	32.54675	10.119	4.389
1.794	500.	4285.	213.854	32.75930	10.293	4.384
1.986	412.	4689.	215.973	32.97404	10.360	4.357
1.737	478.	5178.	218.035	33.19138	10.894	4.545
1.914	504.	5707.	220.239	33.38777	11.206	4.709
2.100	675.	6304.	222.585	33.56360	11.243	4.803
2.266	1040.	6960.	225.055	33.72565	11.488	5.070
2.412	1190.	7608.	227.738	33.85603	11.889	5.260
2.671	1200.	8324.	230.043	33.98249	12.177	5.300
2.596	1110.	8825.	232.345	34.11340	12.306	5.380
2.631	1030.	9503.	234.538	34.24668	12.585	5.438
2.875	895.	10235.	236.681	34.37798	12.506	5.253
2.939	860.	10810.	238.816	34.50845	13.031	5.430

Table 4. (continued)

Producing Milk Cows on Farms	Per Cap. Class I Demand	Per Cap. Class II Demand	Net Com. Rem.	Net Govt. Rem.
21.944	347.40918	385.50601	3.999	1.000
21.505	349.32523	365.68735	3.821	.125
21.338	348.46079	349.31131	2.036	2.700
21.691	343.98801	336.82105	1.793	9.375
21.581	344.74295	339.65768	4.544	5.975
21.044	345.32632	342.14426	3.993	4.875
20.501	345.76672	337.71463	4.320	5.100
19.774	341.90021	331.14316	2.495	6.375
18.711	334.51508	322.84421	3.936	4.325
17.901	327.27884	323.15131	2.889	3.425
17.515	322.68774	324.40915	3.074	3.115
17.243	312.48297	320.73056	1.363	8.022
16.842	309.33362	302.64835	1.349	10.748
16.260	308.60281	302.33035	1.815	7.772
15.677	305.39920	307.54114	1.672	7.677
14.954	302.62479	294.61142	2.462	5.665
14.093	297.61902	313.21732	-.821	.645
13.501	286.14563	272.18054	.388	7.427
13.038	280.66763	277.08020	.140	5.150
12.307	273.20273	273.25699	.870	4.479
12.000	264.86221	275.52304	.420	5.774
11.839	259.55887	274.89645	.297	7.268
11.700	262.80432	276.66873	1.445	5.345
11.413	258.23499	276.18216	.062	2.185
11.230	243.81575	287.63150	.584	1.346
11.139	243.59865	285.22479	-.856	2.036
11.032	242.62716	294.84473	1.759	1.236
10.945	239.29528	288.25317	.388	6.080
10.803	235.28619	298.98013	-.200	2.743
10.743	232.97045	305.03442	.213	2.119
10.810	227.68191	301.20755	-.844	8.800
10.923	223.87411	293.03598	.999	12.861
11.033	216.06267	302.72443	.683	14.282
11.098	215.32427	307.87106	.151	16.814
10.833	211.67822	324.20990	-.029	8.645
11.025	212.72141	335.92813	-.537	13.174