Summer 8-18-2016

An Analysis of Farm Profitability, Exit Decision, and Price Supports in the Maine Dairy Industry

Dylan D. Bouchard
dylan.bouchard@maine.edu

Recommended Citation

Bouchard, Dylan D., "An Analysis of Farm Profitability, Exit Decision, and Price Supports in the Maine Dairy Industry" (2016). *Electronic Theses and Dissertations*. 2469.
http://digitalcommons.library.umaine.edu/etd/2469

AN ANALYSIS OF FARM PROFITABILITY, EXIT DECISION, AND PRICE SUPPORTS IN THE MAINE DAIRY INDUSTRY

By

Dylan David Bouchard

B.S. Economics, University of Maine

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Arts

(in Economics)

The Graduate School

The University of Maine

August 2016

Advisory Committee:

Xuan Chen, Assistant Professor of Economics, Advisor

Caroline Noblet, Assistant Professor of Economics

Gary Anderson, Associate Extension Professor, Cooperative Extension

THESIS ACCEPTANCE STATEMENT

On behalf of the Graduate Committee for Dylan Bouchard, I affirm that this manuscript is the final and accepted thesis. Signatures of all committee members are on file with the Graduate School at the University of Maine, 42 Stodder Hall, Orono, Maine.

Xuan Chen, Assistant Professor of Economics August 2, 2016

LIBRARY RIGHTS STATEMENT

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at the University of Maine, I agree that the Library shall make it freely available for inspection. I further agree that permission for “fair use” copying of this thesis for scholarly purposes may be granted by the Librarian. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature:

Date:

AN ANALYSIS OF FARM PROFITABILITY,

EXIT DECISION, AND PRICE SUPPORTS

IN THE MAINE DAIRY INDUSTRY

By

Dylan David Bouchard

Thesis Advisor: Dr. Xuan Chen

An Abstract of the Thesis Presented
in Partial Fulfillment of the Requirements for the
Degree of Master of Arts
(in Economics)
August 2016

This paper is separated into three distinct chapters investigating different aspects of the Maine dairy industry. First, the paper provides a broad overview of the United States dairy industry with an emphasis on New England dairy farms. Structural industry changes, dairy legislation, and milk prices are topics of focus. The second chapter considers farm profitability and economies of scale among Maine dairy farms and compares the findings with similar studies from other states and previous studies of Maine dairy farms. The third chapter seeks to estimate the benefits of Maine's Dairy Relief Program in terms of industry sustainability.

The first chapter provides elaborate background about the United States dairy industry. First, technological advancements in dairy farming in the past 100 years are discussed. The changing distribution is explained, as the number of farms in the past several decades has declined substantially. The apparent trend is that farms remaining in business are getting larger, while small farms are exiting the industry more frequently. Further, milk prices are explored in terms of consumer demand, and price asymmetry

between producers, processors, and retailers. Lastly, a brief overview is provided of risk management programs for dairy farms over the past few decades.

In the second chapter, 79 total farms from the 2010 and 2013 dairy cost-of-production studies were used to assess farm profitability and economies of scale. Estimation of a per-unit cost function indicates that costs fall at a decreasing rate with output and eventually increase. Further, estimation of a Cobb-Douglas production function suggests increasing returns to scale exist in the Maine dairy industry. These two findings reinforce the hypothesis that small farms have higher per-unit costs, as was indicated in the raw data and in similar cost-of-production studies.

The third chapter uses simulations to assess the benefits of Maine's Dairy Relief program. A sample of 204 total farms from four cost-of-production studies was used to estimate Average Variable Cost (AVC). The AVC function was then used in combination with milk price and output data for all Maine dairy farms to estimate variable profit per cwt for all farms in the state from June 2004 to May 2015, which was necessary to run the simulation program. In each iteration, these estimated variable profits were used to establish a rule-of-thumb filter for removing observations for a probit regression. After removal of filtered observations, a binary probit was estimated with exit decision modeled as a function of seasonality, price lags in the previous six months, and AVC lags in the previous six months. Based on the corresponding probit probabilities of exit, a stochastic exit decision was forecasted without price supports for each farm-month combination. The results suggest that approximately 30% more farms would have exited and exits would have occurred sooner if the price floors had not been enacted in 2004.

Though tier 1 farms observe the greatest difference in number of exits, the three tiers representing larger farms are substantially impacted as well.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

THE UNITED STATES DAIRY INDUSTRY: AN OVERVIEW

1.1. History of US Dairy Farms, Processors, and Retailers

Dairy technology today is considerably more sophisticated than early in our nation's history. Weimar and Blayney (1994) provide a comprehensive review of the history of developments in the United States dairy industry. Notable developments took place as early as 1857, such as the discovery that heating milk postpones souring. It wasn't until 1922, however, that insulated milk tanks became commonplace (Weimar & Blayney, 1994). Several gains were noteworthy in the 1890's including the Babock test to measure milk components, gasoline tractors, an early version modern milking machine, and advances in the understanding of feed rations for dairy cattle (Weimar & Blayney, 1994). 1905 marked the invention of the milk drying plant (Weimar & Blayney, 1994). Adoption of milking machines was slow at first, with 55,000 milking machines on US dairy farms by 1920. By 1944, however, this figure had increased more than tenfold to 685,000 milking machines across the US. Several important developments took place in the 1920's and 1930's as well (Weimar & Blayney, 1994). Over the 1930's and 1940's, high temperature, continuous flow pasteurization was developed (Weimar & Blayney, 1994). In particular, a universal hauling method, artificial insemination, and bulk tank handling were all notable advances during this period (Weimar & Blayney, 1994). Lastly, the introduction of the personal computer in the 1980's allowed farmers to calculate feed rations in order to minimize expenditures without the help of dairy specialists (Weimar & Blayney, 1994).

Dramatic changes took place during the twentieth century in the structure of processing and retail milk sales. By 1925, farmers were paid for their milk according to its use, known as classified pricing (Shields, 2010). In 1950, over half of milk produced was delivered to households in quart bottles, but by 1997, only 2% of milk was delivered to households, with most milk being sold by supermarkets in gallon jugs (Manchester & Blayney, 1997). Additionally, the number fluid milk plants declined substantially from approximately 10,000 plants in 1940 to 478 plants in 1995 (Manchester & Blayney, 1997). Throughout the second half of the twentieth century, the cost of moving milk from producer to consumer declined significantly due to improved roadways and faster and larger trucks for transporting milk (Shields, 2010). Today, bulk milk is often shipped large distances from areas where demand exceeds local production, and milk processors often ship cheese, yogurt, and flavored milk to distribution centers across the country (Shields, 2010).

The early 1900's marked the introduction of milk cooperatives, where farmers worked together to bargain with milk handlers and offset their market power (Shields, 2010). The number of dairy cooperatives has been declining since 1940, as many have merged to benefit from centralized management (Shields, 2010). In particular, the number of dairy cooperatives has decreased from approximately 2,300 in 1940 to 155 in 2007 (Shields, 2010). In turn, dairy cooperatives have gained market power, as the share of milk marketed by cooperatives has increased from approximately 50% in 1940 to 83% in 2007 (Shields, 2010).

1.2. United States Dairy Industry

The historical trend regarding the distribution of dairy farms has been rather consistent. Average farm size is growing, small farms are exiting the industry, and existing farms are getting larger. In response to the trend, several federal dairy support programs have been developed.

1.2.1. Changing Industry Structure

Over the course of the twentieth century, the presence of dairy cattle on US farms became more specialized and consolidated. Specifically, 70% of US farms owned dairy cattle in 1930, and this figure had fallen to 13% of farms by 1978 (Weimar & Blayney, 1994). Annual losses in number of dairy farms averaged 96,000 in the 1960's and 37,000 in the 1970's (Shields, 2010). In the past several decades, the number of dairy farms has continued to decline, while average production per farm has risen. The number of US dairy farms fell from 648,000 operations in 1970 to 75,000 operations in 2006, an approximate decrease of 88% (MacDonald, 2007). Despite this decrease, milk production per cow doubled between 1970 and 2006 (from 9,751 to 19,951 pounds per year), total milk production rose, and average milk production per farm increased twelvefold (MacDonald, 2007). In recent years, annual losses in number of dairy farms have slowed to approximately 2,000 to 5,000 farms per year (Shields, 2010). Additionally, milk produced per cow rose nearly 50% and average number of cows per farm has more than tripled from 1980 to 2003 (Blayney & Normile, 2004).

It is useful to consider the distribution of dairy farms according to size and how athis figure has evolved over time. The smallest category of dairy farms (those with fewer than 30 cows) made up 30% of all dairy operations in 2006 (MacDonald, 2007).

However, this size group only represented 2% of the nation's cows and produced approximately 1% of the nation's milk (MacDonald, 2007). Farms with 30-200 cows also declined substantially in recent years, falling by nearly 30% from 2000 to 2006 (MacDonald, 2007). The number of large farms, however, has risen in recent years. The number of farms with 500-999 cows remained relatively constant from 2000 to 2006, with slight increases in proportion of US cattle inventory and US milk production (MacDonald, 2007). Number of farms with 1000-2000 cows increased approximately 25% from 2000 to 2006, with marginal increases in proportion of US cattle inventory and US milk production (MacDonald, 2007). Most notable was the growth in number of farms with at least 2000 cows, which more than doubled over this period (MacDonald, 2007). Further, this largest category doubled in both proportion of US cattle inventory and US milk production (MacDonald, 2007).

1.2.2. Federal Dairy Legislation

Federal regulations on milk production date as far back as the 1800's, notably the Sherman Antitrust Act in 1890 prohibited milk cooperatives from engaging in price bargaining (Weimar & Blayney, 1994). However, non-stock cooperatives were permitted to collectively bargain for prices under the Clayton Act enacted in 1914 (Weimar & Blayney, 1994). Purity standards were enacted in 1906 under the Pure Food and Drug Act, and by 1919, first standards for butter and cheddar were developed by the USDA (Weimar & Blayney, 1994). 1935 marked the implementation of the Agricultural Development Act, which allowed for marketing agreements, milk orders, classified pricing, and milk pooling (Weimar & Blayney, 1994). Federal standards for grading and inspecting dairy products were constructed under the Agricultural Resource and Marketing Act in 1946 (Weimar & Blayney, 1994).

In the 1960’s, changes in the Federal Milk Marketing Orders linked several separate orders with the goal of establishing a common base for classified milk pricing (Weimar & Blayney, 1994). The Agriculture and Food Act of 1981 established minimum prices in terms of dollars per hundredweight rather than as a percentage of parity (Weimar & Blayney, 1994). In the 1980’s, rBST was deemed safe for human consumption, the food security act set class I differentials in the Federal Milk Marketing Order, and the Dairy Export Incentive Program was established to assist US dairy producers in tapping into foreign markets (Weimar & Blayney, 1994). By the 1990’s, several states had enacted their own legislation to raise in-state milk prices above the federal level (Weimar & Blayney, 1994).

Early dairy policies sought to address three problems, namely producers lacked bargaining power, producers suffered volatile prices, and severe shortages were frequent due to fluid milk being highly perishable (Shields, 2009). Two early dairy support programs resulted that are still functioning today: the federal milk marketing orders (FMMO’s) established in the 1930’s and the Dairy Product Price Support Program (DPPSP) established in 1949 (Shields, 2009). The FMMO’s mandated minimum milk prices for processors to pay producers, establishing a classified pricing system requiring processors to pay higher prices for fluid milk (Class I), than for manufactured milk products (Class II), cheese (Class III), and butter and dry milk (Class IV), where the differences in class prices represent different market values for the products (Shields, 2009). Lower classes of milk have shorter shelf-life than higher classes, and hence have lower prices (Beshore, 2003). In addition, the program established pooling of receipts to pay all farmers a blend price, which sought to provide equitable revenue sharing of homogeneous milk sold to both the high-valued fluid market and the lower-valued manufacturing market (Shields, 2009).

The Dairy Product Price Support Program (DPPSP), authorized by the 2008 farm bill, established price supports for producers by purchasing surplus product from processors whenever the market price fell to support levels (Shields, 2009). Specifically, the program supports prices of cheddar cheese, butter, and nonfat dry milk (United States Department of Agriculture, Farm Service Agency, 2011). Additionally, the Secretary is required to implement price adjustments when purchases exceed a specified level to avoid excess accumulation of dairy products (United States Department of Agriculture, Farm Service Agency, 2011). Dairy product price supports have become less effective as processors have become less willing to engage in government transactions and even impeded US dairy exports, altered domestic market outcomes, and constrained dairy product innovation (Schnepf, 2012). The Agricultural Act of 2014 repealed the DPPSP (H.R. 2642, 2014).

The Dairy Export incentive program (DEIP), funded by the Commodity Credit Corporation (CCC), was developed in 1985 to help counter foreign dairy subsidies by providing bonus payments to US dairy exporters (Shields, 2009). Specifically, the payments allowed exporters to sell certain milk powder, butterfat, cheddar, mozzarella, Gouda, feta, cream, and processed American cheeses in the world market for less than the products were purchased (Dictionary of trade policy terms, 2007). As the use of dairy export subsidies has declined worldwide in recent years, the DEIP has rarely been used in recent years (Schnepf, 2012). The Agricultural Act of 2014 repealed the DEIP (H.R. 2642, 2014).

The Milk Income Loss Contract (MILC) paid participating farmers in months where the Boston Class I price fell below a specified federal target price (Shields, 2009). The payment was calculated as 45% of the difference between the target price and the monthly minimum Class I milk price, with a specified payment limit according to size (Shields, 2009). A provision of the 2008 farm bill adjusts the MILC target price of $16.94 upwards any month in which the average feed cost is above $7.35 per hundredweight (Chite & Shields, 2009). The production limits only allowed for protection of approximately 30% of US milk production, making the program relatively unpopular among large dairy farmers (Schnepf, 2012). The Agricultural Act of 2014 repealed the MILC program (H.R. 2642, 2014).

Since the 1980's, milk orders have raised the blend price approximately 1-2% (Helmberger & Chen, 1994). Price supports have raised the blend price well above the market-clearing price, as high as 21% in 1983, and in turn, large government stocks of surplus dairy have accumulated (Helmberger & Chen, 1994). It is suggested that the price supports have led to an approximate 1% increase in the number of US dairy cattle from 1980-83, and without the price supports, the number of cows would have fallen (Helmberger & Chen, 1994). The elimination of the milk orders and price supports was estimated to lower the blend 18.7% in the short run and 5.4% in the long run during this period (Helmberger & Chen, 1994).

Sumner (1999) considers the impacts of domestic price regulations and trade policy, particularly those due to the Federal Milk Marketing Order (FMMO). After examining the trade barriers and export subsidies created by FMMO regulations, the results indicate that if these explicit import barriers were removed, supply would increase due to pooling and milk prices would fall due to classified pricing. Together, this supply increase and price reduction would encourage dairy exports and lead to a reduction in dairy imports. Further, it is suggested that the FMMO disincentivizes moving milk across regions, which in turn may cause milk to be produced where there is little comparative advantage as well as a reduction in United States milk production. If these disincentives were reduced, supply price would rise and more milk would be produced in low cost regions.

1.3. Dairy Production and Legislation in New England States

Our study focuses on the production costs incurred by the conventional dairy farms of Maine. The state of Maine has a unique tier-pricing program established in 2004, which has been funded by milk-handling fees paid by processors (Drake 2011). The dairy farms in the state are categorized into four tiers based upon their annual production levels. Farms move through each of the four tiers as their total production increases. All farms begin the year in tier 1 and move into tier 2 after they produce 16,790 cwt. Likewise, farms move to tier 3 after producing 49,079 cwt. Farms producing more than 76,800 cwt move into tier 4. The tier a farm is classified in therefore represents the tier in which they end the production year. Every year the state government issues a unique kick-in milk price for each tier. That kick-in price is the average estimated cost of farmers within that tier. When the Boston Blend milk price dips below one tier’s kick-in price, the tier program issues payments to farmers of that tier. The cost-of-production study aims to provide a precise baseline estimate of cost of production for each tier so that state legislators can better manage the tier-pricing program, as directed by *An Act to Encourage the Future of Maine's Dairy Industry* (Chapter 648 H.P. 1445-L.D. 1945), established by L.D. 1758 and defined in Maine Revised Statutes, Title 7, § 3153-b. Given the nature of volatile production costs in dairy farming, it is important to update the baseline cost estimates for each tier every three years. The historical tier definitions and target prices are displayed in the Tables 1 and 2 (L.D. 1945; L.D. 852; L.D. 1758; L.D. 1905).

In particular, Maine lost 106 dairy farms from 2000 to 2004 (Drake 2011). The Maine Dairy Relief Program paid producers approximately $13.9 million from 2004 to 2007, and $30 million from July 2007 to 2011 (Drake 2011). Nevertheless, the number of dairy farms in Maine decreased from 393 farms in 2004 to 342 farms in 2007 (Drake 2011). From 2011 to 2015, the tier program has paid dairy farmers approximately $17 million. Since the program began, tier payments were triggered in 72% of months for tier 1, 48% of months for tier 2, 27% of months for tier 3. Tier 4, which was created in 2010, had tier payments triggered 12% of months (Maine Milk Commission pers. comm.).

A price support program called the Northeast Dairy Compact (NEDC) was developed in 1997 by New England state legislatures with the approval of Congress and the USDA (Balagtas & Sumner, 2003). The NEDC was a precursor to the Dairy Market Stabilization Program. The compact announces a fixed minimum price for Class I milk, rather than a fluid differential, and the producer price for milk is the larger of the NEDC minimum price and the FMMO minimum Class I (Balagtas & Sumner, 2003). When the FMMO minimum class I price drops below the determined NEDC minimum price, processors are to pay the difference back to the NEDC Commission, which in turn distributes revenues back to producers (Balagtas & Sumner, 2003). As a result, producers in the Northeast receive higher milk price on average and produce more output, which leads to lower milk prices in the rest of the country (Balagtas & Sumner, 2003).

Foltz (2004) explores the effects of the NEDC on the United States dairy industry, finding that the Compact's price strategy led to a reduction in dairy farm exits and a slight increase in herd sizes (Foltz, 2004). Despite these benefits from the Compact, development pressures and low unemployment rates increased farm exits (Foltz, 2004). Chidmi et al. (2005) assess the impacts of the NEDC and retail oligopoly power on fluid milk prices, finding milk price increases from oligopoly power are of greater magnitude than increases from NEDC by sevenfold, with retailer markup of approximately 25%. Additionally, it is suggested that the Milk Income Loss Contract (MILC), which provides partial subsidies to farmers, provides large gains to retailers and processors and modest gains for farmers and consumers (Chidmi et al., 2005). Sumner (2005) explores the impacts of NEDC on milk prices, finding the program benefitted farmers in the northeast, hurt farmers in the rest of the United States, and cost fluid milk buyers in the northeast. Similarly, Collerill (2005) suggests that the compact increased raw milk prices 2-3 cents per gallon, but if the compact had not been in place, milk prices would have been approximately 10 cents per gallon lower. It is suggested that retail prices increased much more than 2-3 cents per gallon due to increases in other costs and increased tacit collusion and net profits among channel firms (Cotterill, 2005). Estimates of differences in milk prices in the absence of the Compact range from 5.7 to 20.7 cents per gallon and are very sensitive to the modelling approach (Cotterill, 2005).

1.4. Consumer Demand for Milk

Global demand for milk has been on the rise since 2008 due to increasingly westernized diets that include more dairy consumption and a broader range of dairy products available (2013 Dairy Industry: A Market Assessment, 2013). Furthermore, United States dairy exports have been increasing in recent years. The proportion of US milk production exported increased from approximately 10% in 2010 up to 16.7% in 2012 (2013 Dairy Industry: A Market Assessment, 2013). Economic forecasts suggest global sales of dairy products will be valued at $494 billion by 2015, with the US accounting for a quarter of this production (2013 Dairy Industry: A Market Assessment, 2013). Schmit & Kaiser (2006) forecast the demand for fluid milk and cheese from 2007 to 2017 using expected changes in population structure and spending patterns. Model simulation results suggest that milk demand per capita will continue to fall at a slower rate and cheese demand per capita will continue to rise (Schmit & Kaiser, 2006).

An important economic consideration regarding milk consumption is the price elasticity of demand. An examination of the impact of food prices on consumption by Andreyeva et al. (2010) suggests that the demand for dairy products and fluid milk are inelastic with elasticity absolute values of approximately .65 and .59, respectively. Equivalently, quantity demanded of dairy products and fluid milk will change by .65% and .59% given a 1% in the consumer price of milk, respectively. The authors point out that economic shocks that change purchasing behavior are generally unable to be predicted by elasticities calculated from data collected under normal market circumstances (Andreyeva et al., 2010). Glaser & Thompson (2000) suggest that organic milk sales have risen over the past 8 years, which is likely due to more organic milk processors and more organic milk sold by supermarkets. Further, the authors indicate that organic milk is considerably elastic to price decreases, but less so as expenditure shares increase (Glaser & Thompson, 2000). Further, cross-price elasticities suggest branded milk prices affect organic purchases much more than the converse, and quantities purchased of organic milk will increase as milk expenditure declines (Glaser & Thompson, 2000). Hovhannisyan & Bozic (2014) suggest that elasticity of demand increases for both brands, and the national-brand has a higher elasticity (Hovhannisyan & Bozic, 2014). Additionally, demand elasticity for national-brand milk declines faster with falling prices than store-brand milk (Hovhannisyan & Bozic, 2014).

Additionally, it is useful to consider consumer welfare and how it is affected by altered milk prices. Huang & Blayney (2003) consider the effects on consumer welfare from changes in milk prices using a Hicksian Compensating Variation approach. After analyzing several combinations of the Federal Milk Marketing Order, Dairy Support Payment Program, Milk Income Loss Contract, and Dairy Export Initiative Program, the authors find absence of one or more of these support programs will lead to a larger market quantity and lower market price, causing consumer welfare to rise and consumer expenditures to fall by approximately $1-2 Billion (Huang & Blayney, 2003).

1.5. Milk Prices in the United States

Milk pricing in the United States dairy industry is rather complex. Milk prices, which are very volatile, are determined by a variety of factors and have followed a relatively consistent trend composed of an approximate three-year cycle. Asymmetric price transmission exists and has been widely studied. Additionally, consumer demand for milk is thought to be inelastic.

1.5.1. Price Transmission: Producer to Processor to Consumer

The existence of spatial asymmetry in milk price transmission from farmer to retailer is suggested in the literature. Capps, Jr. & Sherwell (2005) test for asymmetric price transmission using the Houck approach and the von Cramon-Taubadel & Loy ECM approach. The results suggest that farm-retail price transmission is indeed asymmetric, and price-transmission elasticities are higher for rising farm prices than corresponding elasticities for falling farm prices (Capps, Jr. & Sherwell, 2005). Similarly, Lass (2005) finds asymmetries in milk pricing from farmer to retailer in both short-run and long-run. It is suggested that transmission rates are greater for the Compact period (100-120%) than the pre-Compact period (66-88%), and that retail prices respond rapidly to farm price increases, but slowly to farm price decreases (Lass, 2005).

Bolotova & Novakovic (2012) examined the impacts of the New York State Milk Price Gouging Law 200% Rule, which established that retail prices of fluid milk products higher than 200% of the Class I price were unconsciously excessive (June 1991-October 2008). The authors find that in the pre-law period, supermarket pricing was characterized by incomplete and asymmetric price transmission, while supermarkets used market margin stabilization practice with complete and symmetric price transmission in the law-period (Bolotova & Novakovic, 2012).

Xia & Sexton (2009) consider retail pricing for skim, 1%, 2%, and whole milk in the context of horizontally differentiated products with different prices. The results indicate that an increase in butterfat cost leads to a larger cost difference among fluid milk prices by lowering the skim milk price in a monopoly setting and increasing the skim milk price in an oligopoly setting (Xia & Sexton, 2009). Further, the 2% milk price is also reduced by an increase in butterfat cost in a monopoly setting (Xia & Sexton, 2009). Similarly, Carman (2005) considers the milk pricing behaviors of supermarkets in 9 metropolitan markets. A correlation analysis indicates price independence across tested cities (Carman, 2005). Further, rankings of dairy product prices suggest that prices are not primarily based on costs, which is indicative of a non-competitive market (Carman, 2005). The estimated retail price response to changes in farm prices is found to be consistent with monopoly behavior for several milk products on the market (Carman, 2005).

Lui, Sun, & Kaiser consider the market power of milk processors under the government regime, where the market price equals the support price, and under the equilibrium regime, where market price is above the support price. The authors suggest dairy markets have become more concentrated as indicated by increases in 20-firm concentration ratios from 1963-87 for butter, cheese, and fluid milk from 31% to 94%, 59% to 68%, and 48% to 67%, respectively (Lui, Sun, & Kaiser, 2003). The results suggest that the equilibrium regime yields a more competitive outcome, implying that deregulation would promote a competitive market (Lui, Sun, & Kaiser, 2003).

Chouinard et al. (2010) explore the impacts on consumers from federal milk marketing orders. Using non-linear three-stage least squares regression, the results suggest that families with young children were worse off, while wealthier, childless families were better off. Further, households with lower incomes bear a greater burden from the federal milk marketing orders than higher income households (Chouinard et al., 2010).

1.5.2. Milk Price Volatility

Milk pricing is generally thought to follow a three-year cycle, categorized by a year of depressed prices, a recovery year, a high year, and then another down year (Laughton, 2013). Average annual milk prices in New England have been consistent with this trend in recent years, beginning with 2009's low price of $13.80, then $18.07 in 2010, a record-high of $21.53 in 2011, and another down year in 2012 with an average of $19.74 (Laughton, 2013). Further, the trend continued as the average milk price rose 8% to $21.30 in 2013 and rose nearly 20% in 2014 to $25.52 (Laughton, 2013). Likewise, national milk prices follow a very similar trend, as is observed in the data published by the United States Department of Agriculture, National Agricultural Statistics Service, or NASS, (2015). In early 2006, the milk price dropped to $14 per cwt, but by late 2007, this figure had risen to $22 per cwt. By early 2009, the price dropped further to $12 per cwt, and it was not until mid-2011 the price had again risen to $22 per cwt. By, mid-2012, the milk price dropped down to $16 per cwt, and by late 2014, the price reached a record-high of nearly $26 per cwt .

Nicholson & Stephenson (2015) constructed a time-series model to assess the nature of cyclical behavior of quarterly all-milk price in the United States from 1996 to 2014. The results indicate a deterministic trend and seasonal price movement exist, but the predominant source of variation is a stochastic large-amplitude cycle with a period of 3.3 years (Nicholson & Stephenson, 2015). Similarly, Dong et al. (2011) investigated milk price volatility and its determinants, recognizing that volatility gradually decreases as the USDA monthly price announcement date approaches. The authors found that volatilities in both corn futures market and financial market cause milk price volatility, with the financial market being the primary source (Dong et al., 2011). Further, demand and supply conditions in the dairy market, along with US exchange rates are found to have positive and statistically significant effects on milk price volatilities (Dong et al., 2011).

The all-milk price per cwt, which also fluctuates consistently, rose over this period from $16.13 in 2004 to $20.12 in 2013 (National Agricultural Statistics Service, 2014). Despite this increase in milk prices, the milk-feed price ratio has declined substantially. In 2004, the milk-feed price ratio was $3.10 per cwt. By 2013, this figure had fallen to $1.75 per cwt (National Agricultural Statistics Service, 2014).

1.6. Risk Management Programs for Dairy Farms

In recent years, insurance programs have been developed to help dairy farmers minimize risk against low milk prices or high feed prices. Livestock Gross Margin for Dairy Cattle (LGM-Dairy) was created in 2008 under the Federal Crop Insurance Act to protect against a drop in the gross margin (i.e. milk price minus feed costs) (Shields, 2011). The prices used to calculate the gross margin are based on Chicago Mercantile Exchange Group futures contract daily settlement prices rather than market prices (United States Department of Agriculture, Risk Management Agency, 2015). In order to incentivize the use of LGM-Dairy, USDA began subsidizing the policy premiums and moved the premium due date to the end of the insurance period (Shields, 2011). Premiums are determined by a dollar deductible that is chosen by the farm operator ranging from $0 to $2 in $0.10 increments (United States Department of Agriculture, Risk Management Agency, 2015). The Federal Crop Insurance Act, however, limits expenditures on livestock policies to $20 million per year, which limits farms from using the program as a form of year-round insurance (Shields, 2011; Burdine et al., 2014). Additionally, farmers prefer to purchase LGM-Dairy contracts through insurance agents rather than futures brokers, and options for coverage levels are available to suit a vast array of dairy farm sizes (Burdine et al., 2014).

From 2009 to 2012, there was substantial growth in the number of participating farms, proportion of US milk covered, and liability of LGM-Dairy (Burdine et al.,2014). Specifically, the amount of milk covered by LGM-Dairy increased from 401,680 to 40,504,408 cwt, and proportion of US milk covered by LGM-Dairy increased from 0.02% to 2.03% over this period (Burdine et al., 2014). Further, liability increased from $4.7 million to $704 million and proportion of federal livestock insurance accounted for by LGM-Dairy rose from 10% to 96.5% over this period (Burdine et al., 2014).

Burdine et al. (2014) evaluate the risk-reducing effectiveness of LGM-Dairy using historical futures price data, finding that significant reductions in downside margin risk ranging from 24% to 41%, and the supply response to risk reduction is small, assuming minimal subsidization. It is suggested that for equal levels of coverage, premium levels can differ largely according to coverage distribution, and farmers therefore can potentially utilize LGM-Dairy by designing a least-cost strategy and saving on premium costs (Valveker et al., 2010). By examining the interaction between risk preferences, contract design, and premium subsidization, it is demonstrated that the difference in mean expected utility between no deductible and $0.10 per cwt deductible was $30, while between $1.90 per cwt and $2.00 per cwt was only $8 (Valvekar et al., 2010). The results also indicated that premium subsidization largely increased total optimal coverage, as was seen after LGM-Dairy began such subsidies and insured milk increased nearly threefold (Valvekar et al., 2010).

A more recent insurance option for dairy was developed under the Agricultural Act of 2014 called the Margin Protection Program (MPP) (House report 113-333, 2014). Proposed by the National Milk Producers Federation (NMPF), the program sought to protect margins without production limits similar to those imposed by LGM-Dairy (Shields, 2015). Participants in the MPP receive payments when the calculated national margin (average milk price minus average feed cost) drops below a margin selected by the producer (Shields, 2015). Available margins range from $4.00 to $8.00 per hundredweight with higher premiums for higher margins (Shields, 2015). To help small farms in the program, lower premiums are charged for the first 4 million pounds, while higher premiums are charged for larger output levels (Shields, 2015).

CHAPTER 2

ANALYZING PROFITABILITY OF MAINE DAIRY FARMS USING AN ON-SITE INTERVIEW APPROACH

2.1. Introduction

In recent years, New England dairy farms have observed rising production costs Drought conditions in 2012 contributed to increased feed costs in the New England dairy industry in 2013 (Laughton, 2013). Specifically, feed costs per cwt rose by $0.25, an increase of approximately 3% from 2012 to 2013 (Laughton, 2013). Likewise, crop input costs increased approximately 6% per cwt, while fuel costs fell by 2% per cwt from 2012 to 2013. Further, labor costs and hauling costs both increased approximately 1% per cwt (Laughton, 2013). Despite these cost increases, profitability climbed during this period due to increases in milk prices of greater magnitude (Laughton, 2013).

Further, cash operating costs increased slightly from 2012 to 2013, and total costs including depreciation and family living increased approximately $0.35 per cwt. Net cost of production, which deducts non-milk income from total cost, increased about $1 per cwt from 2012 to 2013 in the northeast (Laughton, 2013). New York dairy farms are observed to have the lowest net cost per cwt in the northeast, followed by southern and northern New England, respectively (Laughton, 2013). Though southern New England has the highest total cost per cwt of the three mentioned regions ($25.14), this region received the highest government payments as well, allowing for a more competitive net cost of production. Total cost per cwt falls substantially as herd size is increased, suggesting economies of scale for dairy farms in the northeast (Laughton, 2013).

Despite the difficulties present in 2013, profitability was able to rise in 2014 in the Northeast. Specifically, profitability per cow more than doubled over this time period. Net earnings per cow rose to $1176 per cow, an increase of approximately $490 per cow from 2013 to 2014. This is largely due to the increase in milk price to $25.52 per cwt, an increase of approximately $4.22 per cwt (Laughton, 2014). Further, cash flow was sufficient to cover operating expenses, debt replacement, and family living (Laughton, 2014). While oil and grain prices declined over this period, feed costs rose slightly. Additionally, labor and repair costs rose 11% and 27% respectively (Laughton, 2014).

Our study focuses on the production costs incurred by the conventional dairy farms of Maine. The state of Maine has a unique tier-pricing program established in 2004, which has been funded by milk-handling fees paid by processors (Drake 2011). The dairy farms in the state are categorized into four tiers based upon their annual production levels. Farms move through each of the four tiers as their total production increases. All farms begin the year in tier 1 and move into tier 2 after they produce 16,790 cwt. Likewise, farms move to tier 3 after producing 49,079 cwt. Farms producing more than 76,800 cwt move into tier 4. The tier a farm is classified in therefore represents the tier in which they end the production year. Every year the state government issues a unique kick-in milk price for each tier. That kick-in price is the average estimated cost of farmers within that tier. When the Boston Blend milk price dips below one tier's kick-in price, the tier program issues payments to farmers of that tier. The cost-of-production study aims to provide a precise baseline estimate of cost of production for each tier so that state legislators can better manage the tier-pricing program, as directed by *An Act to Encourage the Future of Maine's Dairy Industry* (Chapter 648 H.P. 1445-L.D. 1945), established by L.D. 1758 and defined in Maine Revised Statutes, Title 7, § 3153-b. Given the nature of volatile production costs in dairy farming, it is important to update the baseline cost estimates for each tier every three years. The proposed updated tier definitions and target prices must be voted on by the Maine legislature (L.D. 1945; L.D. 852; L.D. 1758; L.D. 1905).

This chapter is separated into two primary sections of a profitability analysis. First, a cost analysis is conducted using output and expenditure data from Maine dairy farms in the 2010 and 2013 production years. Second, an empirical production function is estimated using input, cost, and output data for the same group of farms. The dataset used in the final analyses contains the 39 and 37 farms from the 2010 and 2013 cost-of-production surveys, respectively, used to determine the kick-in prices for each tier.

We expected that costs per cwt fall at a decreasing rate as production level goes up, as demonstrated in the findings of previous studies. A substantial level of heterogeneity in production costs is observed. We suggest a kick-in price for each tier and fit a non-linear cost curve with our collected samples. We expected the cost and production functions to demonstrate economies of scale in the Maine dairy industry, as was found in previous studies of Maine dairy farms.

In general, this empirical study evaluates the cost of producing milk in Maine. Effectiveness of the tier-pricing program is quantified and associated policy implications are suggested.

2.2. Data Collection

We have adopted an on-site interview approach to accurately measure dairy farms' costs of production, as was done in the 2010 cost-of-production study. Our economists and extension specialists traveled to each of the participating farms. We carefully reviewed their tax forms and expense receipts, and recorded all the information while interviewing the farmers in detail. There were no organic farms included in the cost-of-production study. Additionally, three Amish farms were included in our sample to reflect a broader range of production systems.

During the visits, all relevant cost components were collected. These components include hired labor, feed, equipment and repairs, livestock, milk marketing, crops, real estate, and depreciation. Further, from Schedule F and Form 4562 on 2013 tax forms, we recorded the breakdown of depreciation costs. We asked farmers the value of expenses pre-paid in 2012 for 2013 and in 2013 for 2014. Lastly, we asked farmers the number of unpaid labor hours they employed in 2013. Given our limited sample size of 40 farms, extra caution was taken to ensure accurate data collection. The number of farms sampled in each tier was representative of the statewide tier distribution of dairy farms. Though farmers were not directly compensated for participation in the study, farms with high costs may be incentivized to participate in the study in hopes the target prices would be influenced by the reported high costs.

As a precursor to our farm visits, we issued a mail-in survey to all conventional dairy farmers in the state. The survey inquired about production level for 2013 and 2014 based on both number of cows and quantity of cwt’s shipped. The farmers were asked if they utilized a computerized record system, and what program they used to store such information. Regarding labor, farmers were asked how many total employees they hired, and how many of these were unpaid family laborers. Finally, farmers were asked how many acres of pasture, grass, and corn silage they owned, and whether a milking parlor or stanchion was employed on their farm.

The per unit costs are averaged for each tier with costs broken down into three categories: operating cost per cwt, purchased input cost per cwt, and total cost per cwt. Operating cost incorporates all major components of variable costs. In our study it includes expenses from hired labor, feed, machinery and equipment, livestock, milk marketing, crops, real estate, and miscellaneous variable expenses. Purchased input cost includes all components used to calculate operating cost with the addition of depreciation and extraordinary livestock expenses. Total cost was calculated by adding total value of unpaid labor to purchased input cost. We valued non-management labor at $10 per hour and multiplied the number of unpaid labor hours by this wage to arrive at a total value of unpaid family labor for a particular farm.

2.3. Cost of Milk Production

This section considers how costs of producing milk have changed in recent years, compares those costs to those incurred in nearby regions, and discusses the data we employ in this chapter's cost analysis. Specifically, we compare our findings to similar studies conducted by Farm Credit East and Cornell.

2.3.1. Previous Studies Assessing the Cost of Producing Milk in Maine

Before addressing current dairy production costs, it is useful to examine how these costs have changed in recent years. A survey approach was adopted to evaluate Maine dairy farmers' cost for the 2001, 2004, and 2007 production years (Dalton and Bragg, 2003; Bragg and Dalton, 2006; Bragg et al., 2009). These surveys inquired about farm size, input use, production costs, and output. Comparing the results from these three surveys can help gain valuable insight about the Maine dairy industry in these years.

In the 2001 and 2004 surveys, farms are separated into three categories: small, medium, and large. In each of these categories, average number of dairy cows increased. Specifically, average dairy herd sizes increased from 44 to 55, 95 to 162, and 200 to 304, in the small, medium, and large farm groups, respectively (Dalton and Bragg, 2006). Further, the statewide average dairy herd size more than doubled during this period. Average value per animal increased substantially as well for each category of dairy farms. Likewise, average total value of dairy livestock increased for each sized farm and overall (Bragg and Dalton, 2006). Further, the average family and non-family labor hours employed by small, medium, and large dairy farms increased significantly during this period. Number of full time equivalents (FTE) increased for each size farm as well. Interestingly, the sample of small farms employed zero hours of paid labor in both 2001 and 2004 (Bragg and Dalton, 2006).

The 2001 survey calculated costs for a single representative Maine dairy farm, arriving at an operating cost of \$13.75 per cwt. Relative to a typical dairy producer in the northern crescent, which includes New England, New York, Eastern Pennsylvania, Michigan, Wisconsin, and Minnesota, Maine farms have higher costs of approximately \$1.59 per cwt, which are likely due to energy costs, property taxes, and repair expenses (Dalton and Bragg, 2002). In the 2004 survey, representative costs are calculated for a small, medium, and large Maine dairy farm. Operating costs per cwt are found to be \$14.97, \$13.97, and \$12.79 for small, medium, and large farms, respectively. The USDA estimate for a northern crescent farm implies Maine dairy farms had higher operating costs of approximately $1.64 per cwt in 2004 (Bragg and Dalton, 2006).

The 2007 cost of production survey for Maine dairy farms divided farms into four categories: small, medium, large, and very large. Average herd size ranged from 53 cows for small farms to 751 for very large farms. Hired labor per cwt rose slightly with farm size, while family labor per cwt decreased with farm size. Annual milk production ranged from 7,283 cwt for small farms to 23,251 for very large farms. Further, milk shipped per cow rose with farm size. Average operating expenses per cwt were $21.57, $19.63, $16.62, and $15.08 per cwt for small, medium, large, and very large farms respectively. A statewide representative Maine dairy farm for 2007 was estimated to have operating costs of $28.56, approximately $7.50 higher than a representative dairy farm in the northern crescent as given by the USDA (Bragg et al., 2009).

Kersbergen et al. (2013) conducted on-site interviews to replace the mail survey approach. Farmers were interviewed regarding expenditures to produce milk in 2010. In their study, operating costs consist of expenses from hired labor, feed, machinery and equipment, livestock, milk marketing, crops, real estate, and miscellaneous variable expenses. In their study, Short Run Breakeven (SRBE) price is defined as operating expenses plus value of unpaid family labor, which is assumed to be valued at $10 per hour. Their results indicate average SRBE ranged from $25.27 in tier 1 to $18.18 in tier 4. Not only did large farms have lower per-unit costs, they also produced more milk per cow. Average number of cwt's produced per cow ranged from approximately 164 to 247 in tiers 1 and tier 4, respectively. Further, large farms incurred higher feed expenditures per cwt. Tier 1 farms averaged $6.65, while tier 4 farms averaged $8.20 per cwt.

2.3.2. Empirical Cost Analysis and Results

Complete data were obtained from 40 farms. Cash operating costs were adjusted for prepaid expenses in both years 2012 and 2014. Categories of operating costs included hired labor, dairy feed, machinery rent/lease, machinery repairs, fuel, breeding, veterinary, medicine, milk marketing, dues, bedding, licenses/registration, utilities, milkroom supplies, production testing, fertilizer/lime/sprays, repairs, property taxes, interest, insurance, and miscellaneous livestock expenses. Shortrun Breakeven (SRBE) is calculated as the adjusted cash operating cost.

Figure 2.1 Q-Q plot of dairy farm costs per cwt

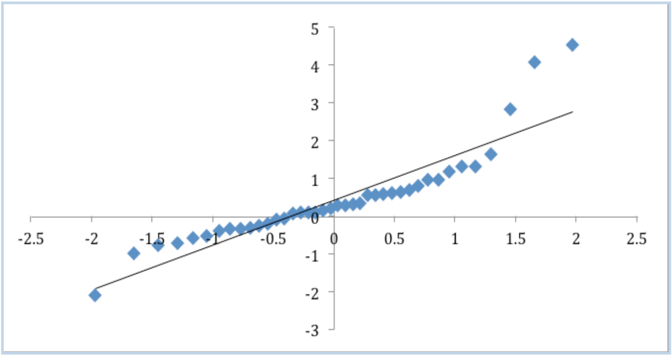
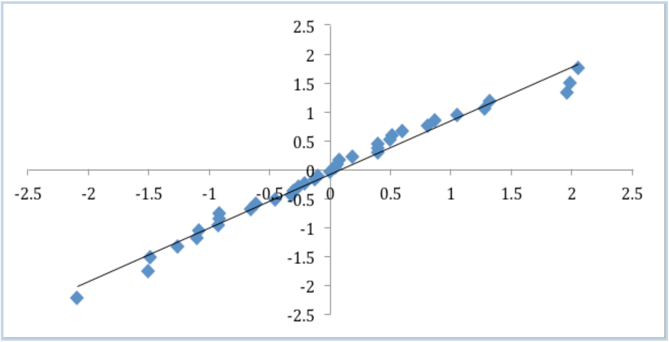


Figure 2.2 Q-Q plot of costs per cwt (no outliers)



Before calculating average costs for each tier and suggesting kick-in prices, using a method called a q-q plot (Hogg, Tanis, and Zimmerman, 2015, pp. 238-256), we graphed the data to test for normality and the presence of outliers (Figure 2.1). Using Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling tests, we were able to determine that the data were not normally distributed and that there were significant outliers. These outliers skewed the distribution above and below the solid line in the q-q plot (Figure 2.1). Based on these plots and tests, we removed three outliers and reconstructed a q-q plot of the data after outlier removal to demonstrate its normality (Figure 2.2). The data follow a normal distribution much more closely after outlier removal. Final analysis was performed on these 37 farms from 2013 along with the 39 farms used in the 2010 cost-of-production study.

The table below displays the characteristics and tier distribution from sampled farms in the 2010 (Kersbergen et al. 2013) and 2013 production years. Average annual production increased in all four tiers from 2010 to 2013, most notably in tier 4. Average herd size fell slightly in tiers 1 and 3, and rose in tiers 2 and 4 (herd size was collected informally as an average number of milking cows per year and not collected from DHI data).

Table 2.1 Tier Summary for 2010 Farms

	Tier 1	Tier 2	Tier 3	Tier 4
Number of Farms	17	11	4	7
Average Herd Size*	54	129	271	454
Average Annual Production	8,850	25,848	64,788	112,493

Table 2.2 Tier Summary for 2013 Farms (outliers removed)

	Tier 1	Tier 2	Tier 3	Tier 4
Number of Farms	16	10	3	8
Average Herd Size*	50	157	260	686
Average Annual Production	9,783	33,928	60,398	172,422

*Herd sizes were estimated by farm owners when asked during interviews.

The tables above show the average yield per cow and per unit costs by tier. Tier 1 has significantly smaller yield per cow than the three larger tiers, and each tier has a higher yield per cow than the previous. Each of the three average per unit cost categories decrease as tier increases. The observed inverse relationship between farm size and per unit costs is consistent with the calculated yield per cow of each tier. Average herd size and annual production both increased for tiers 1, 2, and 4 between 2010 and 2013.

Table 2.3 Average per cwt costs and production per cow in 2010 (CPI adjusted)

	Tier 1	Tier 2	Tier 3	Tier 4
Production per cow (cwt)	164	201	240	248
Operating Cost	\$20.89	\$21.66	\$19.16	\$18.97
+ Depreciation*	\$23.34	\$23.54	\$20.88	\$20.52
+ Unpaid Family Labor**	\$29.57	\$25.17	\$21.47	\$20.88

Table 2.4 Average per cwt costs and production per cow in 2013 (outliers removed)

	Tier 1	Tier 2	Tier 3	Tier 4
Production per cow (cwt)	189	200	207	210
Operating Cost	\$24.25	\$23.64	\$21.83	\$21.47
+ Depreciation*	\$26.50	\$25.19	\$23.21	\$23.11
+ Unpaid Family Labor**	\$27.28	\$25.74	\$23.33	\$23.11

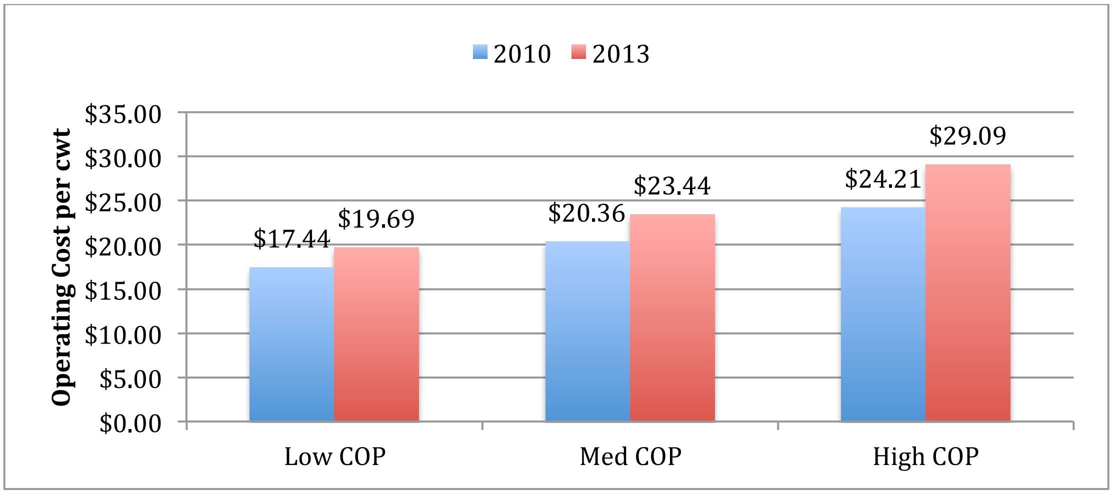
*A measure of total depreciation, which includes section 179.

**Unpaid family labor is valued at \$10 per hour and does not include value of operator/management labor.

For comparison purposes, we use the consumer price index (CPI) to convert the expenditure values in the 2010 study into 2013 dollars. By comparing these per unit costs, one can see a substantial increase in costs from 2010 to 2013. Production per cow fell slightly for tiers 3 and 4 but increased for tiers 1 and 2. While purchased input cost and total cost per cwt both increased for each tier, operating costs saw the largest increase of the three categories, with an increase of approximately \$5 per cwt for tier 1.

To further explore the factors driving profitability, farms were divided into three cost-of-production (COP) groups, regardless of size. These three groups were compared in terms of operating cost per cwt and feed cost per cwt. Each group contains a third of our sampled farms (ie. low COP are the bottom third of sample farms ranked on operating costs). As before, we use the CPI to convert the expenditure values calculated in the 2010 study into 2013 dollars.

Figure 2.3 Average Operating Costs per cwt for Maine Dairy Farms 2010 and 2013



In figure 2.3 above, average operating costs per cwt are given for the low, medium, and high cost of production farms sampled in the 2010 and 2013 COP studies. For the high COP group, operating costs per cwt increased more than $4 from 2010 to 2013.

Figure 2.4 Feed Costs per cwt for Maine Dairy Farms in 2010 and 2013

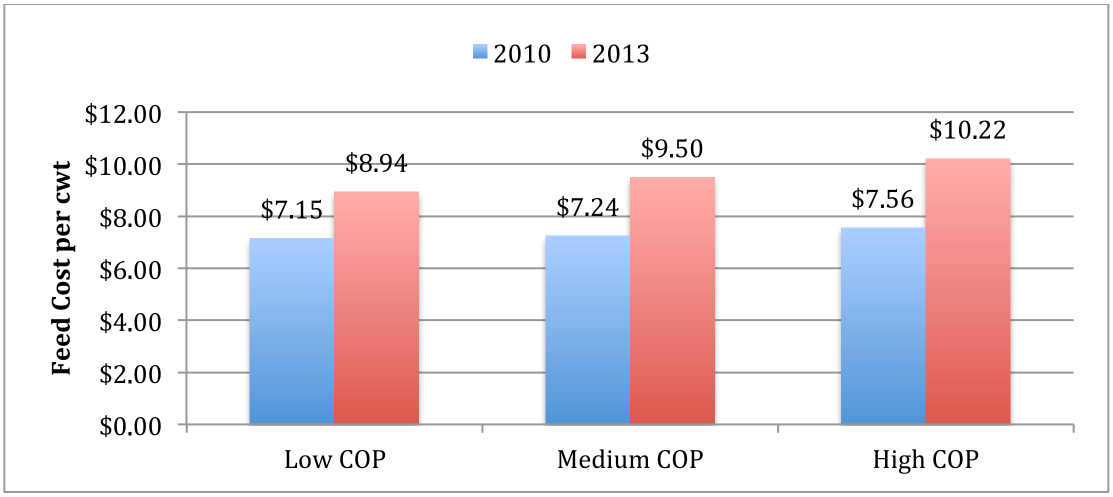


Figure 2.4 above illustrates the average feed costs per cwt for the low, medium, and high cost of production farms. For medium and high COP groups, feed costs per cwt rose by over \$2, a notable increase in proportional terms. The increased feed costs and operating costs per cwt are further evidence of rising dairy production costs from 2010 to 2013.

In order to quantify per unit costs in relation to farm size, it is useful to estimate a cost-production function in the context of the Maine dairy industry. Using 37 farms from 2013 and 39 from 2010, we estimated per unit variable and total cost as functions of output and squared output. We defined variable cost as operating costs plus depreciation, and total cost as operating cost plus depreciation and unpaid family labor, which is valued at a CPI adjusted \$10 per hour. Variable costs represent short run costs of producing milk, while total costs represent long run costs. The specifications and estimation results are displayed below.

$$Average\ Variable\ Cost = \beta_0 + \beta_1 * cwt + \beta_2 * cwt^2 + \varepsilon \qquad \textbf{(2.1)}$$

$$Average\ Total\ Cost = \alpha_0 + \alpha_1 * cwt + \alpha_2 * cwt^2 + u \qquad \textbf{(2.2)}$$

Table 2.5 Estimation Results for Average Variable Cost

Variable	Estimate	Standard Error
Intercept	25.02272	0.59849
cwt	-0.00003***	0.00001
cwt^2	7.14E-11**	2.90E-11

$R^2 = .104; F = 4.259; n = 76$

Note: *, ** represent 5% and 10% significance level respectively

Table 2.6 Estimation Results for Average Total Cost

Variable	Estimate	Standard Error
Intercept	27.93863	0.70017
cwt	-0.00006***	0.00001
cwt^2	1.20E-10***	3.35E-11

$R^2 = .239; F = 11.285; n = 75$

Note: *, ** represent 5% and 10% significance level respectively

As expected, the estimation results suggest per unit costs fall at a decreasing rate as production scale is increased. The quadratic term in the specification allows us to calculate the production level corresponding to the minimum operating cost per cwt. Our estimation results suggest that variable cost per cwt and total cost per cwt are minimized at an output level of approximately 210,084 and 273,438 cwt per year, respectively. Given the negative sign estimated for the linear term above, our results suggest that economies of scale exist in the Maine dairy industry. Expanding output should therefore imply a decrease in per unit costs, all else equal. This suggests that, in general, smaller farms tend to have higher per unit costs than large farms, which is consistent with the average costs for each tier in the raw data.

Given the recent trend of the shrinking number of dairy farms and increasing size of existing farms, it seems the tier-pricing program holds many potential benefits. Acting as a type of safety net, the tier pricing program could help keep small dairy farms operating longer than in the absence of the program. Though the tier-pricing program protects against low milk prices, it does not address rising feed costs, which substantially influence profitability. That said, the existing price floor might not be enough to keep a small dairy farm in business in the presence of high feed costs.

2.3.3. Cost Comparison Across Regions

In comparison to other dairy farms in the northeast, those located in Maine tend to have higher per unit costs. The 2013 Northeast Dairy Farm Summary released by Farm Credit provides average per unit costs for 517 participating dairy farms. From looking at the table below, one can see average operating costs, purchased input costs, and total costs are higher for our sample than Farm Credit's larger sample of dairy farms in the northeast. These data indicate operating cost and purchased input cost per cwt are $1 to $2.50 higher for Maine dairy farms relative to dairy farms in the northeast. Further, feed cost per cwt is nearly $2 higher for Maine dairy farms as well.

Table 2.7 Costs per cwt by Region

Region	Feed Cost	Depreciation	Operating Cost
Maine*	$9.32	$1.81	$23.32
New York**	$7.44	$1.48	$20.37
Northern New England**	$8.49	$1.28	$20.97
Southern New England**	$8.50	$1.42	$22.84

*These averages are calculated for our entire sample of 37 farms after removing three statistical outliers.
**These averages are calculated by Farm Credit East. Northern New England is Maine, New Hampshire, and Vermont. Southern New England is Massachusetts, Connecticut, and Rhode Island.

One can see in the table above that Maine dairy farms have substantially high depreciation, feed costs, and operating costs per cwt relative to other regions in the northeast. Note that Farm Credit averages are calculated using accrual-based accounting, while our study uses cash-based accounting. Operating costs per cwt increased from $17.09 in 2010, to $20.63 in 2013 – an approximate increase of 21% (Laughton, 2013). Maine dairy farms also witnessed a rise in operating costs, ranging from 22% in tier 4 to 38% in tier 1. From a descriptive analysis, our data suggests that production costs for conventional Maine dairy farms have significantly increased since 2010.

The average costs of production from our study are significantly higher than those calculated by Farm Credit East and dairy business summaries. Average feed, interest, depreciation, and operating costs per cwt are all higher for our farms relative to these similar studies. It should be noted that Farm Credit East and Cornell use accrual based accounting in their studies, while we use cash based accounting. Further, one should note that farms included in the Farm Credit East and Cornell samples tend to have better records and be better managed than an average dairy farm in the region, while our sample of Maine dairy farms is representative of an average Maine dairy farm. Thus, differences between our sample and the two comparison studies should be interpreted conservatively.

Table 2.8 Costs per cwt Comparison Across Studies

Expenses per cwt	Maine	Farm Credit*	Cornell**
Hired Labor	$2.91	$3.09	$2.86
Feed	$9.32	$7.75	$7.59
Interest	$0.93	$0.49	$0.47
Operating Expenses	$23.32	$20.63	$19.55
+Depreciation	$25.13	$22.06	$21.14

*These are averages of 368 farms calculated by Farm Credit East using accrual based accounting.
**These averages are of 109 farms calculated by Cornell using accrual based accounting.

As can be seen in the table above, the average costs of production from our study are significantly higher than those calculated by Farm Credit East and Cornell dairy business summaries. Average operating costs and purchased input costs are approximately $3 higher for our sample of Maine dairy farms relative to the Farm Credit and Cornell samples. Further, feed cost per cwt is nearly $2 higher for Maine dairy farms. Feed prices in New England reflect transportation costs incurred traveling from the Midwest, as can be seen in Table 2.9. The higher prices paid for feed in Maine relative to other states in the Northeast are explained by these higher transportation costs and are evident from the higher feed costs per cwt. This distinction in feed costs per cwt can be seen in Tables 2.7 and 2.8.

Table 2.9 Grain Prices per ton in the Northeast

Location	Soybean Meal	Cornmeal
Central Maine	$344	$196
Central Connecticut	$415	$200
Western Vermont	$302	$162
Central New York	$309	$168

2.4. Dairy Production Analysis

This section addresses related literature to our production analysis, introduces our production function estimation, and discusses implications of our findings. In particular, we estimate a Cobb-Douglas production function using two distinct methods and examine returns to scale among Maine dairy farms.

2.4.1. Relevant Literature

As less efficient farms exit the industry and low-producing cattle are removed from herds, both small and large farms have experienced an increase in production per cow (National Agricultural Statistics Service, Agricultural Statistics Board, United States Department of Agriculture, 2010). From 2008 to 2013, the number of dairy operations decreased by 16%, while output per farm increased by approximately 18%, and total production remained relatively constant over this period (Horwitz, 2013). The structural change that is taking place is apparent: average farm size is growing, while the number of farms is declining (MacDonald, 2007). Though larger operations tend to have more severe excess nutrient application, which causes water and air pollution, the productivity gains from increasing scale outweigh the added manure treatment and removal costs (MacDonald, 2007). Thus, this existing structural change is unlikely to be reversed in the near future (MacDonald, 2007).

There are a variety of techniques employed in empirical production function estimation. A recently developed method of coping with unobserved input quantities allows one to derive a new specification that reveals input quantity data (Grieco et al., 2014). Another model employs an empirical framework allowing for flexible parameterizations of exogenous influences, demonstrating that variables can have non-monotonic effects on efficiency (Wang, 2002). Another specification focuses on the skew of the error distribution, suggesting that allowing the skew to be either positive or negative strengthens the model's ability to predict (Carree, 2002). Further, addressing heteroskedasticity in production function estimation demonstrates that translog estimation causes all explanatory variables to inversely affect the error term. Thus, disregarding heteroskedasticity causes average inefficiency to be overestimated when the inefficiency error dominates stochastic error (Kim et al., 2008).

Existing research suggests cost efficiency and capital intensity, livestock quality, and herd size (Jiang & Sharp, 2015). It is also suggested that farm efficiency increases with family labor and milking frequency (Cabrera et al., 2010). Further, efficiency significantly falls as parcel distance increases and rise and parcel size increases, suggesting that efforts to improve parcel structure are justified (Niskanen & Heikkila, 2015). Several factors are thought to influence marginal costs of milk production, including output, milk yield, labor input, and fodder production (Wieck & Heckelei, 2007). Organic dairy farms are less efficient, and the driving factors behind adopting organic technology are efficiency and subsidy (Kumbhakar et al., 2009). Similarly, Kompas & Che (2006) find constant returns to scale among Australian dairy farms, with key determinants of efficiency being proportion of irrigated farm area and type of dairy shed used. Additionally, the results suggest farms in the "high-efficiency" category employ either rotary or swing-over dairy shed technology and have nearly 3 times the proportional amount of irrigated farm land (Kompas & Che, 2006). Tauer (2001) considers the competitiveness of small New York dairy farms and finds most of the high costs on these farms are due to inefficiency, which indicates efficient small farms can compete with efficient large farms.

2.4.2. Estimation of Cobb-Douglas Production Function

To further consider economies of scale in the Maine dairy industry, we estimate a production function with five inputs: cows, feed, labor, capital, and miscellaneous inputs. Feed includes both purchased feed and feed grown on the farm. Capital includes depreciation, machinery repairs, utilities, and fuel. Miscellaneous inputs include minor inputs such as bedding, breeding, and veterinarian visits. Due to our limited data, input expenditures are used as a proxy to represent input quantities for feed, labor, capital, and miscellaneous inputs. Therefore, our production function models assume firms face equal prices across these inputs.

A large variation is observed in our dependent variable, quantity of milk shipped (measured in cwt), which ranges from 819 to over 475,000 cwt. Similarly, number of cows ranges from 9 to 1730. Some farms had zero expenses for hired labor, crops, and real estate expansion. Three Amish farms, which hand-milked cows, were also included in the dataset. It is evident from the raw data that feed is the most substantial cost component, followed by hired labor. The descriptive statistics for the variables in the model are displayed in the table below.

Table 2.10 Descriptive Statistics of Inputs and Output

Label	Mean	Median	Std Dev
cwt	44,849	17,636	66,307
Cows	193	90	248
Feed	$403,000.36	$73,890.90	$653,332.09
Labor	$159,515.25	$174,506.07	$270,042.03
Capital	$245,170.10	$119,622.09	$347,086.07
Other	$181,132.89	$80,704.40	$267,507.35

First, we estimate a Cobb-Douglass production function using Ordinary Least Squares (OLS) regression. As can be seen in equation (2.3) below, quantity is equal to a constant, $\boldsymbol{\beta}$, multiplied by the product of input quantities $i = 1,2,\dots,k$ raised to their respective powers, $\boldsymbol{\alpha_i > 0}$.

$$Q_t = \beta \Pi_{\mathrm{i}=1}^{k} X_{it}^{\alpha_i} \tag{2.3}$$

For estimation purposes, it is convenient to perform a linear transformation of the Cobb-Douglass function by taking the natural logarithm of both sides to achieve our OLS specification, which is displayed in the two equations below.

$$ln(Q_t) = \beta_0 + \Sigma_{\mathrm{i}=1}^{k} \mathrm{\alpha_i} \ln(X_{it}) + \varepsilon_t \tag{2.4}$$

$$\varepsilon \sim N(0, \sigma_\varepsilon^2) \tag{2.5}$$

This transformation is possible with the assumption of strict monotonicity of all inputs on the dependent variable, i.e. $\boldsymbol{\alpha_i > 0 \ \forall \ i = 1, 2 \dots \ k}$. Our first specification follows the functional form displayed above using the logged number of shipped hundredweights (cwt) as the dependent variable. The model assumes a homogenous input price across firms for all inputs. We expect positive coefficients for all explanatory variables, as more of an input should positively contribute to quantity of output. The coefficients can be interpreted as the proportional change in output associated with a 1% in a particular input.

To further explore the effects of inefficiency on the production process, one can estimate the function using stochastic frontier analysis (SFA). This specification is an expansion of equations (2.4) and (2.5) that decomposes the error term into a stochastic disturbance term (v_t) and an inefficiency term (u_t) as seen in equation (2.7) below. This specification (equations 2.6-2.10), is designed to disentangle the firm's production efficiency from other deviations about the deterministic frontier that are outside the firm's control (Aigner et al., 1977).

$$ln(Q_t) = \beta_0 + \Sigma_{\mathrm{i}=1}^{k} \mathrm{\alpha_i} \ln(X_{it}) + \varepsilon_t \tag{2.6}$$

$$\varepsilon_t = v_t - u_t \tag{2.7}$$

$$v \sim N(0, \sigma_v^2) \tag{2.8}$$

$$u = |U| \tag{2.9}$$

$$U \sim N(0, \sigma_u^2) \tag{2.10}$$

As before, we expect positive coefficients for all explanatory variables, as more of an input should positively contribute to quantity of output. The coefficients can be interpreted as the proportional change in output associated with a 1% change in a particular input.

The production efficiency is estimated for each firm, so one can determine how efficient an industry is on average by taking the average technical efficiency (TE). In particular, TE describes a firm's distance from the production frontier. For instance, a TE value of 0.82 indicates a firm is producing 82% of its maximum possible output from its input set. The calculation of TE is displayed in equation (2.11) below.

$$TE_i = \frac{\exp(x_i{}'\beta + v - u)}{\exp(x_i{}'\beta + v)} = \exp(-u) \tag{2.11}$$

To determine if there is significant inefficiency in an industry, one must consider the gamma parameter given in the SFA estimation results. The gamma term, displayed in equation (2.12) below, describes the proportion of the residuals explained by inefficiency.

$$\gamma = \frac{\sigma_u^2}{\sigma_\varepsilon^2}, where\ \varepsilon = v - u\ and\ \sigma_\varepsilon^2\ = \sigma_v^2 + \sigma_u^2 \qquad \textbf{(2.12)}$$

The estimation results are displayed in the table below. As expected, the coefficient values in the OLS and SFA models are very similar. All slope coefficients are positive, as was expected. Each slope coefficient was significant at the 10% level in the SFA model, while only cows, feed, and labor were significant in the OLS model.

Table 2.11 Regression Results for Cobb-Douglas Production Functions

Variable	OLS	Stochastic Frontier Analysis
Intercept	1.438313	2.1148478
	(0.423228)	(0.3996751)
ln(cows)	0.52636***	0.59017***
	(0.073652)	(0.0722236)
ln(feed)	0.377271***	0.3188103***
	(0.060626)	(0.0589134)
ln(labor)	0.037068***	0.0350866***
	(0.008478)	(0.0070988)
ln(capital)	0.042974	0.039953*
	(0.031723)	(0.0210829)
ln(other)	0.050166	0.047466*
	(0.030325)	(0.0243207)
gamma	-	0.8628768***
		(0.0857728)
n	76	76

Note: ***, **, * indicates significance at the 1%, 5%, 10% levels, respectively.

In both models, cows and feed are the inputs with the most substantial contributions to output. In the OLS and SFA models, the estimated output elasticities, i.e.

proportional contributions to output due to a 1% increase, were approximately .53 and .59 for cows, respectively and approximately .38 and .32 for feed, respectively. In both models, the output elasticities with respect to labor, capital, and miscellaneous inputs were all very close, ranging from .037 to .05. Summing the five slope coefficient estimates gives an estimated degree of homogeneity greater than 1 in both models, suggesting increasing returns to scale. Equivalently, doubling the quantities of cows, feed, labor, and capital is expected to increase milk production by a factor greater than two.

2.5. Conclusions

The finding in the production analysis that increasing returns to scale exist is consistent with our cost function estimation results, equations (2.1) and (2.2), which are indicative of economies of scale and suggest that variable cost per cwt and total cost per cwt are minimized at output levels of approximately 210,084 and 273,438 cwt per year, respectively. These values are greater than our average tier 4 farm output of 172,422 cwt per year but also smaller than the largest farm in our sample. These models reinforce the hypothesis that small farms are less efficient in production and thus have higher per unit costs than large farms, which is consistent with the descriptive statistics. Additionally, large farms produce more milk per cow (Tables 2.3 and 2.4) and receive hauling discounts in feed deliveries and bulk-tank pickups.

The mean technical efficiency for the sample of Maine dairy farms was approximately 0.859, suggesting on average, these farms produced 85.9% of their maximum possible output from the employed input set. Cabrera et al. (2010) estimated technical efficiency of Wisconsin dairy farms and found the mean technical efficiency of sampled farms to be 0.88. This indicates the sample of Wisconsin dairy farms are 2.1% more efficient on average than our sample of Maine farms, but these estimates are very close and should therefore be interpreted conservatively.

Lastly, the gamma term in the SFA model was significant at the 1% level. This indicates firm-level inefficiency has significant explanatory power in this Cobb-Douglas specification. Our data employs input expenditures as a proxy for input quantities, so this result should be interpreted with caution. Differences in input prices would lead to biased estimates of technical efficiency, since the SFA model tends to overestimate technical efficiency for firms relatively low input prices and underestimate technical efficiency for firms with relatively high input prices.

CHAPTER 3

ASSESSING MAINE'S DAIRY RELIEF PROGRAM AS A SAFETY NET WITH A HYBRID APPROACH

3.1. Introduction

The structural change that is taking place in the US dairy industry is apparent: average farm size is growing, while the number of farms is declining (MacDonald, 2007). From 2001 to 2009, the number of dairy operations declined 33%, despite a 15% increase in total milk production (United States Department of Agriculture, National Agricultural Statistics Service, 2010). Further, the number of farms with more than 500 cows increased approximately 20% in this period (United States Department of Agriculture, National Agricultural Statistics Service, 2010). The number of farms with fewer than 500 cows fell by 35% (United States Department of Agriculture, National Agricultural Statistics Service, 2010). As a result, the share of milk produced by farms with more than 500 increased by 21%, while share of milk produced by farms with fewer than 500 cows fell by approximately 20% (United States Department of Agriculture, National Agricultural Statistics Service, 2010).

The trend of increasing farm size and decreasing number of farms has been consistent in the New England states as well. Sobson (2004) found that from 1993 to 2003, the average number of cows rose from 122 to 212, an increase of nearly 74%. Additionally, farms became more productive over this period. Pounds of milk sold per cow increased from 18,254 to 21,261 and milk sold per worker increased from 653,683 to 901,480 (Sobsen, 2004). Further, average herd size for this sample has grown steadily from 288 in 2003 to 368 in 2012, an average of 2.8% per year or 28% overall (Laughton, 2013). In particular, the number of conventional dairy farms in Maine has fallen by nearly 100 farms from 2004 to 2014 (Maine Milk Commission pers. comm.).

The state of Maine has a unique tier-pricing program (hereafter ‘tier program’) established in 2004. The dairy farms in the state are categorized into four tiers based upon their production levels. Every year the state government issues a unique kick-in milk price for each tier. That kick-in price is the average estimated cost of farmers within that tier. When the price Maine farmers are receiving from the marketplace dips below one tier's kick-in price, the tier program issues payments to farmers of that tier.

We perform a Monte Carlo simulation to assess the decision to exit and effectiveness of Maine’s tier pricing program. The first dataset used is a panel of conventional Maine dairy farms including 72 farms from 2001, 60 farms from 2004, 36 farms from 2010, and 36 farms from 2013. These data contain annual expenses for the respective production years and annual output, from which we calculate per unit costs. The second dataset contains annual output for all conventional dairy farms in Maine from 2004 to 2014, and total monthly output for the state during that period. The third dataset is the historical tier prices and state premiums received by dairy farms in Maine since the program began in 2004.

3.2. Data

The four-year panel of 204 farms was collected through two distinct methods. Specifically, data for the 2001 and 2004 production years were collected through a mail survey, while data for the 2010 and 2013 production years were collected through an on-site interview approach. Mean annual production and production variance increased with time, with the exception of 2004 have a greater deviation than the 2010 sample. Average variable cost (AVC) and average total cost (ATC) are in 2013 dollars after adjustments using the Consumer Price Index (CPI). Mean AVC and ATC are within $1 in the 2001 and 2004 samples. Likewise, the mean ATC and AVC are within $1 in the 2010 and 2013 samples and are approximately $3 higher than in the 2001 and 2004 samples. Deviation in per-unit costs appears to decline with sample size, as 2001 has the largest deviation in AVC and ATC, while 2013 has the smallest. These descriptive statistics are displayed in Table 3.1 below.

Table 3.1 Average Costs and Output of Maine Dairy Farms in Previous Studies

Year	Variable	Mean	Median	Std. Dev.	N
2001	Average Variable Cost	20.19	20.23	4.72	72
2004	Average Variable Cost	19.29	18.63	4.33	60
2010	Average Variable Cost	23.12	22.84	3.87	36
2013	Average Variable Cost	23.56	23.45	2.93	36
2001	Average Total Cost	22.21	13.91	5.02	72
2004	Average Total Cost	21.89	13.37	4.64	60
2010	Average Total Cost	24.83	18.67	4	36
2013	Average Total Cost	25.37	18.53	3.4	36
2001	Output (cwt)	22,482.87	11,778.10	38,603.02	72
2004	Output (cwt)	29,594.80	10,853.21	53,470.36	60
2010	Output (cwt)	40,846.19	19,596.25	42,156.15	36
2013	Output (cwt)	57,076.08	21,944.34	85,059.00	36

The Maine Milk Commission recorded the annual output data of conventional Maine dairy farms from 2004-14. Note the production year begins in June and ends in May. One can see in the table below that mean annual production has fluctuated from 2004-14, with the highest value in 2006 and lowest in 2004. Most notable, however, is the dramatic reduction in the number of conventional dairy farms in Maine. With the exception of 2012, each year the number of conventional dairy farms either dropped or remained relatively constant. Over this eleven-year period, the number of conventional dairy farms in Maine decreased by 98. Also notice the Herfindahl Index (HHI), which measures market power in an industry has increased from 126.05 in 2004 to 224.06 in 2014, indicating an increase in firm concentration in the Maine dairy industry. There were no organic dairy farms in either of the dairy farm datasets (tables 3.1 and 3.2). The output data for all conventional dairy farms did not include data on number of cows. That said, when a dairy farm exits the industry, the farm's cows are generally sold to other dairy farms in the same state.

Table 3.2 Annual Milk Production of Conventional Maine Dairy Farms (cwt)

Year	Total Production	Mean	Median	Range	Std. Dev.	N	HHI
2004	5,535,939	16,776	8,103	350,031	29,819	330	126.05
2005	5,349,637	16,823	8,288	338,199	29,984	318	131.35
2006	10,118,566	31,621	14,759	693,757	58,818	320	139.38
2007	10,668,298	33,760	15,433	805,968	65,740	316	151.64
2008	5,516,261	18,266	8,218	433,092	35,477	302	158.03
2009	5,408,524	19,884	8,579	493,700	40,186	272	186.92
2010	5,427,391	20,481	8,608	470,850	40,233	265	183.36
2011	5,644,124	20,982	8,622	469,840	41,451	269	182.26
2012	5,983,364	18,757	6,757	448,272	39,112	319	167.66
2013	5,652,376	20,115	6,574	494,870	43,527	281	202.22
2014	5,537,230	23,867	7,742	511,083	48,903	232	224.06

Prior to conducting stochastic simulations, we considered the proportion of farm exits by tier. Farms that exit and re-enter are included in the calculation as farms that exit. Total farms for each tier represents all farms that ended a production year in that tier at least once from 2001-2015. The table below displays the proportion of farms that exit at least once in each tier from 2001-2015. As can be seen below, 84% of farms who exit in this time period were tier 1 farms. We observed 64%, 37%, and 30% of tier 1, tier 2, and tier 3 farms eventually exit, respectively. None of the tier 4 farms in our dataset exit the industry in this time period.

Table 3.3 Farm Exits within each Tier from 2004-2015

	Tier 1	Tier 2	Tier 3	Tier 4
Farms that Exit	221	30	12	0
Total Farms in Tier	344	82	40	18
Proportion of Farms that Exit	64%	37%	30%	0%
Tier's Proportion of Total Exits	84%	11%	5%	0%

The tier definitions established by the Maine legislature have changed three times since the tier program began in 2004. Table 3.4 below displays the historical tier definitions. Note the program began with three tiers of production size but increased the number of tiers to four beginning in 2010. Likewise, the minimum prices for each tier have adapted to reflect increasing costs-of-production. The nominal target prices for each tier are displayed in table 3.5 below.

Table 3.4 Historical Tier Definitions

Tier	2004-2006	2006-2010	2010-2016
1	0 to 1,678,999	0 to 2,135,599	0 to 1,679,099
2	1,679,000 to 2,604,999	2,135,600 to 4,907,999	1,679,100 to 4,907,999
3	2,605,000 and up	4,908,000 and up	4,908,000 to 7,680,399
4	N/A	N/A	7,680,400 and up

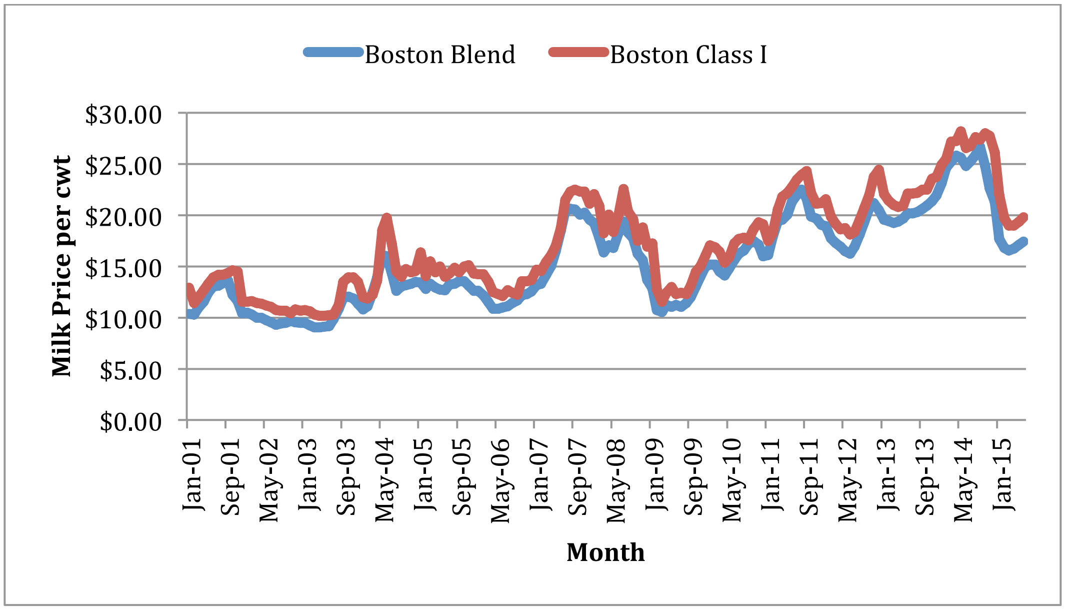
Table 3.5 Historical Target Prices for each Tier

Time Period	TIER ONE	TIER TWO	TIER THREE	TIER FOUR	Legislation
2004 to 2006	$16.18	$15.59	$13.12	N/A	L.D. 1945
2006 to 2010	$18.68	$16.23	$15.43	N/A	L.D. 852
2010 to 2012	$20.70	$18.07	$17.29	$16.51	L.D. 1758
2012 to Present	$21.00	$20.36	$18.01	$17.83	L.D. 1905

Our dataset also contained Boston Blend and Class I milk prices by month from 2001 to 2015. These milk prices vary considerably throughout time, as can be seen in the graph below. Notice that between January 2006 and September 2007, milk prices increased approximately $10 per cwt (nearly a 100% increase in the Boston Blend price).

These prices tend to be very cyclical in nature, and this price volatility is a major factor in exit decisions of dairy farms.

Figure 3.1 Monthly Boston Blend and Class I Prices per cwt from 2001-2015



3.3. Relevant Literature

Although economic theory suggests that a firm will shut down when its revenues are below variable costs, a variety of factors have been suggested to influence exit decisions. Dalton & Bragg (2004) conducted an analysis of a panel of Maine dairy farms suggesting that higher age, off-farm income, fewer returns on variable costs, and greater diversification all increase the likelihood of the choice to exit. Further, it is suggested that federal and state programs would be effective in keeping dairy farmers in business (Dalton & Bragg, 2004). Similarly, Dong et al. (2013) explore non-price determinants of exit and expansion decisions among US dairy farms. The authors find unpaid, non-operator labor signals the presence of a successor, and greater long-term debt is indicative of commitment to future operation (Dong et al.,2013). Further, efficient farms tend to be larger and are more likely to remain operating than exit (Dong et al., 2013).

Foltz (2004) considers the decision to exit among Connecticut dairy farms with emphasis on the Northeast Dairy Compact (NEDC). Using a random effects probit model to consider exit decision as a function of price and non-price variables, the results suggest that higher cow productivity, local unemployment rate, and population density all decrease the probability of dairy farm exits (Foltz, 2004). Contrary to popular belief in Connecticut that small dairy farms had low probability of survival, number of cows is found to be an insignificant determinant of farm exit (Foltz, 2004). NEDC was found to maintain an extra 4% of Connecticut dairy farms in business, but this was at the cost of political confrontation and a \$0.05 to \$0.10 per gallon increase in consumer costs of milk (Foltz, 2004). Tauer (2006) employs a Dixit entry/exit model to investigate price ranges expected to incentivize exit or entry into the dairy industry and finds the per cwt entry and exit prices to be \$17.52 and \$10.84, respectively for large farms. Small farms, however, were found to have respective entry and exit prices of \$23.71 and \$13.48 per cwt (Tauer, 2006).

Stokes (2006) uses Markov Chain Analysis to consider the determinants of dairy farm exit and expansion. The results suggest higher milk prices lower the probability of exit, while higher milk price volatility, higher land values, and presence of the dairy termination program all increase the probability of exit (Stokes, 2006). For small startup dairy farms, milk price volatility is found to decrease the probability of entry, while milk prices and land values increase the probability of entry (Stokes, 2006). Lastly, milk produced per cow is found to increase the likelihood of dairy farm expansion, while land values decrease the probability of expansion (Stokes, 2006).

Tauer and Mishra (2006) estimate a stochastic cost equation using national dairy production data from 2000. They separated cost of production into frontier and inefficiency components and found farms can decrease cost with increased daily use of the milking facility, but only if done so efficiently (Tauer & Mishra, 2006). Furthermore, parlors over stanchions and use of a nutritionist reduced costs, but older farmers were observed to be less efficient (Tauer & Mishra, 2006). Similarly, Byma & Tauer (2010) use an unbalanced panel from 1993 to 2004 to estimate a stochastic cost function. The results suggest dairy farm efficiency increases with operator education, farm size, and participation in a farm management program, but goes down as the farmer ages (Byma & Tauer, 2010).

Higher costs tend to be observed for small dairy farms relative to large ones. Understanding the reasons behind the economies of scale is important to policymakers. Alvarez et al. (2008) stratify farmers according to intensification and estimate separate stochastic cost frontiers. The results indicate that intensive farms were closer to cost frontier than were extensive ones, implying a positive relationship between intensification and efficiency (Alvarez et al., 2008). Likewise, Tauer (2001) finds smaller farms tend to be less efficient in general, but can indeed compete with large farms if the efficiency components are effectively managed.

Two measures of dairy farm profitability have been suggested in the literature. Wolf (2010) discusses the use of milk-to-feed price ratio (MF) as a measure of dairy farm profitability. While MF was a generally accepted proxy for farm profitability from 1985 to 2006, income over feed cost (IOFC) was the preferred proxy from 2007 to 2009 (Wolf, 2010). During periods of volatility, MF is a poor measure of profitability and thus IOFC is preferred (Wolf, 2010).

Simulation analysis has been used to develop risk models as farm management tools. Although these models provide a good visual interpretation of risk, they serve to simplify and stimulate discussion of potential risks rather than as an exact measurement tool (Malan et al., 2010). Similarly, Attonaty et al. (1999) explore using simulation tools to expand farmer interactivity by developing a set of if-then rules regarding optimal practices to carry out under given circumstances. While the success of this model is determined by the management research conducted by the farmer, the desired level of interactivity is unlikely to be achieved without early intervention of consultants (Attonaty et al., 1999). Neyhard et al. (2013) analyze price risk management strategies with simulations. They use simulated combinations of futures and options contracts for feed and milk to determine farmers' abilities to meet cash flow needs and reduce variance in net income, finding that hedging 50% of milk produced resulted in higher returns to investment (Neyhard et al., 2013). Further, variance in net income can be reduced with risk management, but at the cost of a lower expected net income (Neyhard et al., 2013). Jin & Frechette (2015) test for the presence of fractional integration in the volatilities of agricultural futures prices and find a strong long-term dependence, suggesting fractional integration does exist.

Bozic et al. (2012) examine structural differences between dairy farms growing their own feed and those purchasing it. They found contracts insuring average IOFC margins over several months are relatively cheaper than those insuring similar coverage levels one month at a time, and thus both analyzed farm profiles can protect against catastrophic margin risk (Bozic et al., 2012). Valveker et al. (2011) examine the interaction between risk preferences, contract design, and premium subsidization. Using an expected utility framework, a nonlinear optimization model was constructed. The results indicate that premium subsidization largely increased total optimal coverage, as was seen after LGM-Dairy began such subsidies and insured milk increased nearly threefold (Valveker et al., 2011).

Valveker et al. (2010) explore optimal cost-minimization strategy for dairy farmers with respect to LGM-Dairy, modeling an optimization problem where the insurance premium is minimized by controlling distribution of coverage. The results indicate the optimal strategy consisted of first selecting nearby contract months with higher proportions than for later months (Valveker et al., 2010). Wolf & Tonsor (2013) analyze dairy farmer preferences for policy alternatives, including eliminating existing policies, implementing new dairy policies related to both income support and growth management, and ending ethanol subsidies. The results suggest for small-scale dairy farmers, the most preferred policy was IOFC margin protection, followed by growth management and competitive price pay, while large-scale dairy farmers preferred eliminating ethanol subsidies to any other policy changes (Wolf & Tonsor, 2013).

3.4. Approach

We use the panel of 204 Maine dairy farms to estimate per unit variable costs and per unit total costs as a quadratic function of output with a time trend. Average variable cost (AVC) includes hired labor, feed, equipment and repairs, livestock, milk marketing, crops, and real estate, and unpaid labor valued at a CPI adjusted $10 per hour. Average total cost (ATC) includes all components of AVC plus depreciation. We save the residual data from our ordinary least squares (OLS) regression for later use in simulation analysis.

Using the data from 2004-14, we calculate the monthly proportion of annual output each year using the state aggregate monthly output. By multiplying the respective proportion for each month by annual output, we estimate monthly output for each farm to increase our sample size. Using these monthly output estimates with the estimated AVC and ATC functions, we estimate monthly AVC and ATC for each farm from 2004 to 2014 in a deterministic fashion. We use our monthly output estimates for all conventional dairy farms in Maine from 2004-14 to determine monthly tiers and s according to each year's respective tier definitions and prices. We use our monthly output, AVC, and tier prices, to estimate monthly variable profits for each farm.

In each simulation, values are drawn from a normal distribution based on the residuals from the AVC regression to calculate stochastic AVC. Variable profits are calculated using hypothetical milk prices in the absence of the tier program. After establishing exit and stay 'rule-of-thumb filters', we run a binary probit with exit decision as the dependent variable on observations satisfying the rule-of-thumb filter. While, the probit coefficient estimates are used to generate exit probabilities for farm-months inside the rule-of-thumb filter, farm-months removed from the probit dataset are assigned exit probabilities equivalent to proportion of farm-months filtered out. An exit decision is forecasted for each farm-month and total number of months produced is calculated for each farm.

The forecasted exit decisions in each simulation are based on prices in the hypothetical absence of the tier program. To determine the effectiveness of the tier program, the forecasted number of months produced is compared to the observed number of months produced with tier prices for each farm. Additionally, the average across simulations of probit coefficients and rule-of-thumb filters is compared to deterministic outcome.

3.5. Cost Estimation

Per-unit costs were estimated as a polynomial function of output including a time trend using ordinary least squares regression. The respective specifications for AVC and ATC are displayed below.

$$AVC = \beta_0 + \beta_1 * CWT + \beta_2 * CWT^2 + \theta * Trend + \varepsilon \quad \textbf{(3.1)}$$

$$ATC = \alpha_0 + \alpha_1 * CWT + \alpha_2 * CWT^2 + \delta * Trend + u \quad \textbf{(3.2)}$$

The panel data contains farms from four years, and the CPI adjusted cost values are all in 2013 dollars. We expect per unit costs to fall at a decreasing rate as output increases.

Table 3.6 AVC Estimation Results

Variable	Estimate	S.E.	p-value
Intercept	-818.387	127.8017	<.0001
CWT	-5.6E-05	1.15E-05	<.0001
CWT^2	1.18E-10	3.24E-11	0.0004
Trend	0.41924	0.06376	<.0001

$R^2 = .218; F = 18.61; N = 204$

Table 3.7 ATC Estimation Results

Variable	Estimate	S.E.	p-value
Intercept	-746.386	135.7705	<.0001
CWT	-5.6E-05	1.22E-05	<.0001
CWT^2	1.14E-10	3.44E-11	0.0011
Trend	0.3844	0.06773	<.0001

$R^2 = .183; F = 14.97; N = 204$

For both per-unit cost measures, a negative coefficient for output and positive coefficient for squared output are observed (see Tables 3.6 and 3.7). These results are significant at the 1% level and consistent with the hypothesis that AVC and ATC fall at a diminishing rate with increased output. These results indicate that economies of scale exist in the Maine dairy industry, which can be explained by volume discounts received on large purchases from larger farms. According to our per-unit cost estimates, AVC is minimized at approximately 477,563 cwt per year, while ATC is minimized at approximately 493,980 cwt per year.

Additionally, the time trend variable was significant for both the AVC and ATC estimations. The time trend values indicate that real AVC increases approximately $0.42 per year, while real ATC increases approximately $0.38 per year. In reality, real per-unit costs are unlikely to monotonically increase with time as is suggested by these regression results but instead behave in a more cyclical manner. The time trend term is rather a linear approximation of increased costs of producing milk as a function of time.

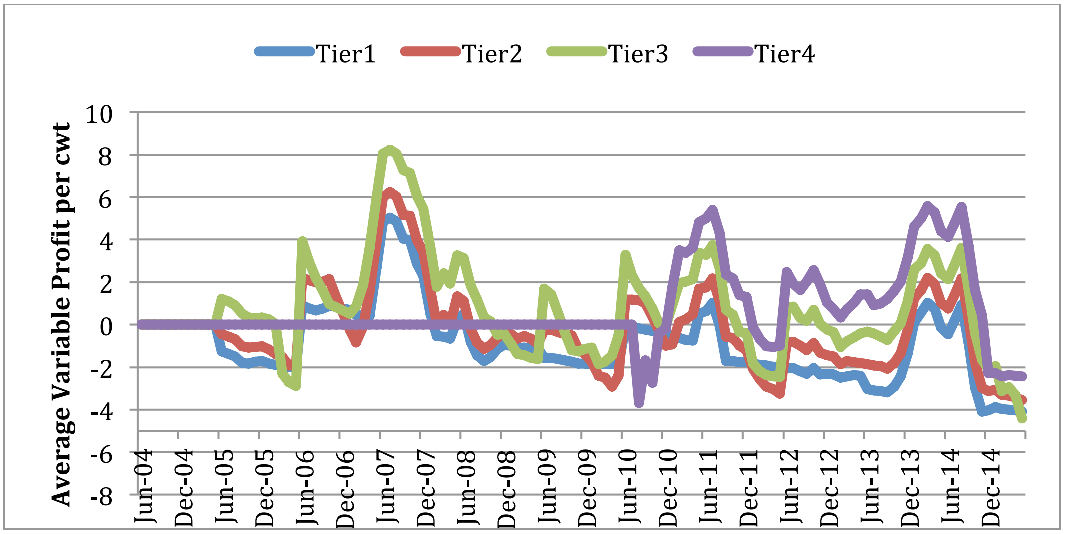
In order to use these estimation results for simulations, it is necessary to test the error distribution for normality. The Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling tests were employed to test the two error distributions for normality. For both distributions, all four tests failed to reject the null hypothesis of normality distributed residuals at the 10% level. The error distribution of ATC errors has greater dispersion than the AVC error distribution. Specifically, the AVC and ATC error distributions are centered at zero with standard deviations of $4.02 and $4.27, respectively. The respective ranges of the AVC and ATC error distributions are $20.45 and $24.53. These descriptive statistics are displayed in table 3.8 below.

Table 3.8 Residual Distributions for Per-unit Costs

Error Term	Mean	Std. Dev.	Max	Min
ε_{AVC}	0	4.02	10.45	-10.00
ε_{ATC}	0	4.27	15.00	-9.53

After estimating monthly profits for each farm from 2001-2015, we examined the profit distributions of each tier over time. In the figure below, we plotted average variable profit per cwt for each tier by month.

Figure 3.2 Average Variable Profit per cwt by Tier



As can be seen in the figure above, tiers categorized by larger farms tend to have greater profits and variable profits per cwt. One exception to this trend is between April and September of 2010 when tier 4 farms earned an average loss per cwt below the other tier averages. While tiers representing smaller farms are guaranteed higher prices by price floors implemented in the tier program, larger-farm tiers tend to have lower costs per cwt, as demonstrated by the per-unit cost regressions.

3.6. Simulation Results

We adopted a simulation approach to explore the sampling distribution of the parameters of interest. Namely, the rule-of-thumb filters, probit output coefficients, and exit time were recorded after 100 iterations to calculate the respective means, medians, and standard errors across simulations. The results from the simulations were then compared to the same parameters observed in the deterministic setting with price supports from Maine's Dairy Relief Program present. In order to estimate the program's value as a safety net for Maine dairy farms, we assumed a lack of price supports from the tier program in the calculation of probit coefficients and thus forecasting of exit times.

Likewise, a similar process was conducted in a deterministic setting to assess observed farm exits with price supports from the tier program. We used results from the AVC regression in Table 3.6 to estimate deterministic profits for all farm-months in our dataset in which farms produced milk. As in the stochastic setting, rule-of-thumb exit and stay filters were calculated based on estimated variable profit per cwt in the previous six months. Farm-months not satisfying the rule of thumb filter were assigned exit probability equal to probability of being filtered. A probit was conducted using farm-month observations satisfying the rule-of-thumb filter.

We compare observed farm exit decisions under the tier program to simulated farm exit decisions without price supports. Specifically, we consider the difference in number of farms that exit in each tier as well as the difference in timing of exits. Further, we compare the rule-of-thumb filters and marginal effects on probability of exit from price and AVC in previous months.

3.6.1. Calculation of the Rule-of-Thumb Filters

Of all farm-months in which a farm either produces or exits, exits represented less than 1% of these observations. Exit accuracy is defined as the proportion of farm-month combinations (hereafter 'farm-months') representing exit in which the criteria are satisfied. Analogously, accuracy of remaining in business (hereafter 'stay accuracy') is defined as the proportion of farm-months where farms produce (hereafter 'stays') in which the criteria are satisfied. This decomposition of accuracies allowed us to use exit and stay accuracy to determine the exit filter and stay filters, respectively.

The rule-of-thumb filters were determined using the following method. Criteria for exit and stay filters are based on stochastic variable profit per cwt in the previous six months, i.e. criteria is considered satisfied for farm-months in which the average variable profit per cwt in the past six months is below a value when the farm exited or greater than a given value when the farm remained in business. Values of the rule-of-thumb were tested in each iteration until the exit and stay filters were determined. The exit and stay filters were the tested values corresponding with closest exit accuracy rate and stay accuracy to 95%, respectively.

The average rule-of-thumb exit and stay filters and associated proportions from 100 iterations are displayed in the tables below. For comparison purposes, the deterministic and stochastic rule-of-thumb filters are displayed in the tables as well. As can be seen, the simulations generated rule-of-thumb filters further from zero than the deterministic setting. In comparison to the deterministic outcome, the simulation average stay filter was approximately $1.62 more extreme, while the simulated exit filter was about $0.55 more extreme. Despite these differences, the number of observations filtered out in the stochastic and deterministic settings nearly equal, given the outlier probabilities are approximately equal between these.

Table 3.9 Rule-of-thumb: Exit Filter

	Stay Filter	Proportion of Exits
Observed	3.80	0.9511
Simulation Average	4.35	0.9525

Table 3.10 Rule-of-thumb: Stay Filter

	Exit Filter	Proportion of Stays
Observed	-2.64	0.9508
Simulation Average	-4.28	0.9528

3.6.2. Probit Estimation

After establishing rule-of-thumb filters in each iteration, a binary probit was conducted on the observations inside this interval. In the model, exit decision is a function of seasonality, price lags in the previous six months, and variable costs per cwt (AVC) lags in the past six months. The probit specification and estimation results are listed below.

$$Exit_{i,t} = f\left(Season_t, Price_{i,t-1}, \dots, Price_{i,t-6}, AVC_{i,t-1}, \dots, AVC_{i,t-6}\right) + \varepsilon_{i,t} \quad \textbf{(3.3)}$$

Table 3.11 Probit Coefficient Estimates

Variable	With Price Support (observed)	Without Price Support (Simulation)	Simulation 95% CI	
Intercept	-5.2011	-3.8758	-4.1889	-3.5662
Fall	-0.6089***	-0.5331***	-0.5548	-0.5098
Winter	-0.6853***	-0.5190***	-0.5422	-0.4986
Spring	-0.7138***	-0.5693***	-0.5875	-0.5577
Price Lag 1 Month	-0.0388	-0.0208	-0.0330	-0.0120
Price Lag 2 Month	-0.0103	-0.0472	-0.0603	-0.0353
Price Lag 3 Month	0.1119**	0.1172**	0.0991	0.1369
Price Lag 4 Month	-0.0443	-0.0519	-0.0733	-0.0275
Price Lag 5 Month	-0.0244	0.0276	-0.0095	0.0575
Price Lag 6 Month	-0.0102	-0.0308	-0.0553	-0.0103
AVC Lag 1 Month	-0.6931***	0.0122**	0.0022	0.0242
AVC Lag 2 Month	-0.0649	0.0131**	0.0021	0.0218
AVC Lag 3 Month	0.7297***	0.0145**	0.0052	0.0231
AVC Lag 4 Month	-0.1609	0.0150***	0.0055	0.0245
AVC Lag 5 Month	0.2736	0.0144**	0.0048	0.0241
AVC Lag 6 Month	0.0744	0.0172**	0.0088	0.0276

A decrease in profitability should increase the probability of exit. We expect the price coefficients to be negative and the variable cost coefficients to be positive, since price increases raise profitability, while cost increases reduce profitability. The table below displays the probit estimates from the deterministic setting as well as average parameter estimates and parameter confidence interval in the simulations. The intercept is larger in the simulation setting without price floors for milk, suggesting that without the tier program, Maine dairy farms have a higher probability of exit. In both the deterministic and simulation settings, the seasonality dummies were all associated with negative coefficients, indicating that the base season, summer, has the highest probability of exit. All variables are significant in the simulation probit estimation, while only the seasonality, one price lag, and two AVC lags are significant in the deterministic model.

The coefficient estimates of AVC and Price lags in the deterministic setting were mixed in sign, while the results in the simulation setting for these coefficients was more intuitive. Specifically, the AVC coefficients in the simulation setting were all positive, as was hypothesized. Only one of the six price lag coefficients were correctly hypothesized as negative, however. The lower bound of the 95% confidence interval (CI) for each AVC lag coefficient was positive, further reinforcing our hypothesis. The confidence intervals for the price lags, however, were positive for four of the six coefficients. Notice that in the deterministic setting, five of six price lags produce negative coefficients.

3.6.3. Forecasted Impact of the Maine Dairy Relief Program

The final part of the simulation was to forecast a decision to remain in business or exit for all farm-months in which we observed production. The probability of exiting for a given farm-month was assigned a value based whether or not the observation satisfied the rule-of-thumb filter in that particular iteration. If the value of variable profit per cwt in the previous six months did not satisfy the rule-of-thumb filter, then an exit probability equal to proportion the data that were filtered out was assigned. If the farm-month was not filtered out, the associated probit probability was assigned.

To forecast these exit decisions, the probability of exiting in each farm-month was compared to a draw from a uniform distribution about [0,1]. If the draw from the uniform distribution was less than the probability of exit, then the farm is forecasted to exit. Otherwise, the farm is forecasted to remain in business. Once a farm is forecasted to exit, forecasts are not generated for subsequent months unless re-entry was observed for the farm. This framework allows for an intuitive comparison of number of months produced between the observed reality and the forecasted outcome in the absence of price supports.

Table 3.12 below displays number of farms that exit in each tier that we observed for Maine dairy farms from 2004 to 2015. The simulation results indicate the tier program has had a substantial impact on reducing farm exits within each tier. As expected, the tier program appears to have the greatest impact on tier 1, reducing the number of farms that exit approximately 24% from 301 without price supports to 221 with price supports. Tiers 2, 3, and 4 reaped benefits from the program as well, with exits without price supports forecasted 37, 18, and 8 exits greater than the observed values with price supports. In total, the results suggest program reduced the number of farm exits from 406 without tier payments to 263 with tier payments, a reduction of approximately 30% in terms of total farms in the state.

Table 3.12 Number of Farms that Exit With and Without Price Supports

	Exits With Price Support (observed)	Exits Without Price Support (simulation)	Total Farms
Tier 1	221 (64%)	301 (88%)	344
Tier 2	30 (37%)	67 (82%)	82
Tier 3	12 (30%)	30 (75%)	40
Tier 4	0 (0%)	8 (44%)	18
Statewide	263 (54%)	406 (84%)	484

Table 3.13 Month of Exit Among 172 Incumbent Farms With and Without Price Supports

	With Price Support (Observed)			Without Price Support (Simulation)		
	Mean	Median	Std. Dev	Mean	Median	S.E.
Tier 1	Jul-08	Sep-07	32.3 (months)	Aug-07	Mar-07	25.6 (months)
Tier 2	Mar-10	Sep-09	25.8 (months)	Nov-08	Jul-08	26.4 (months)
Tier 3	Aug-09	Jul-09	31.2 (months)	Sep-08	Oct-08	29.0 (months)
Tier 4	-	-	-	Sep-08	Aug-08	33.6 (months)

Table 3.13 above displays the average exit time by tier for a 172 farm subset operating at the start of the tier program in June 2004 for which we observed exits. The simulation results suggest tier 1, tier 2, and tier 3 incumbent farms that we observed exit would have exited 11, 16, and 11 months sooner on average, respectively. In each tier, the forecasted exit time average and median were smaller without tier payments than those observed with tier payments. The standard deviation among exit times within each tier was very close between the observed and simulated data.

Table 3.14 Total Variable Profit by Tier 2004-2014

Tier	Simulation	Observed	Difference
1	-$46,751.11	-$1,298,313.97	-$1,251,562.86
2	-$168,660.96	$1,786,929.86	$1,955,590.82
3	$27,358.02	$49,808,321.30	$49,780,963.28
4	$1,751,433.00	$113,706,262.81	$111,954,829.80

Table 3.15 Total Variable Profit per month by Tier 2004-2014

Tier	Simulation	Observed	Difference
1	-$3.30	-$91.59	-$88.30
2	-$54.56	$578.07	$632.63
3	$20.86	$37,971.22	$37,950.36
4	$2,901.28	$188,356.40	$185,455.13

The tier program affects profits in two ways. First, farms exit sooner and more often, meaning fewer months of production. Second, the tier program increases producer milk prices. As can be seen in the two tables above, total industry profits in tier 1 increased from the tier payments. With tier prices, tier 1 farms earned approximately $1.3 million in total industry losses from 2004 to 2014 and approximately $92 in industry losses per month. Total profits in tier 1 fell due to increased farm exits and thus fewer months where tier 1 farms incurred losses. Tiers 2, 3, and 4 all observed an increase in total industry profit from the tier payments. Tiers representing smaller farms had smaller changes in total industry profits than tiers representing larger farms.

3.7. Conclusions

A hybrid approach of simulation modeling was adopted to assess the effectiveness of price supports under Maine's dairy relief program. Using a sample of 204 conventional Maine dairy farms, average variable cost was estimated as a quadratic function of output with a time trend. Using the saved residuals, stochastic variable costs were estimated each for 484 Maine dairy farms from 2004 to 2015. After subsetting observations satisfying the rule-of-thumb filter, a probit was conducted to calculate exit probabilities. For exit probabilities, the probability of exit was equal to the proportion of observations filtered out. Exit decision forecasts were based on these exit probabilities in each iteration of the simulation program.

Incorporating randomness into the cost estimation made the rule-of-thumb filters farther from zero, while categorizing a nearly equal proportion of observations in the deterministic and stochastic settings. The probit coefficients are quite different in the deterministic and stochastic settings. Specifically, the stochastic model had more significant coefficients, with all AVC lags significant at the 5% level with correctly hypothesized signs. Price lags, however, had mixed sign with only one significant term in the stochastic setting. This could conservatively indicate that per-unit costs drive exit decisions more than milk prices.

We compared the forecasted number of farms that exit without price supports to the observed number of farms that exit with price supports for each tier. As expected, smaller tiers received more benefits, as was indicated by the greatest difference in tier 1. Nevertheless, tiers 2, 3, and 4 received substantial benefits as well. The finding that smaller farms receive more benefit from these price supports is intuitive for two reasons. First, smaller farms tend to have higher costs, given the presence of economies of scale in the Maine dairy industry. Second, tiers categorized by small farms are designated higher target prices than tiers with large farms, meaning the subsidies to farms in smaller tiers occur more frequently in larger payments per cwt.

We also compared exit times of incumbent farms that exit. On average farm exits occurred much sooner without tier payments with approximately the same variation in exit time within each tier. This suggests the tier program is not only valuable in that it prevents farm exits, but also in that it enables farms to remain in business longer.

In short, the results indicate the Maine's Dairy Relief Program has considerable value, particularly to smaller Maine dairy farms. By keeping reducing the number of farms that exit and keeping farms in business longer, we find the tier program substantially contributes to the sustainability of the Maine dairy industry. Had the tier program not been adopted in 2004, there would likely be far fewer dairy farms operating in Maine today.

CHAPTER 4

CONCLUDING REMARKS

4.1. Discussion of Findings

This paper is separated into three distinct chapters investigating different aspects of the Maine dairy industry. First, we provided an overview of the United States dairy industry with an emphasis on New England dairy farms. Second, we analyzed farm profitability and economies of scale among Maine dairy farms and compare findings of similar studies from other states and previous studies of Maine dairy farms. Third, we estimated the impact of Maine's Dairy Relief Program in terms of industry sustainability.

Maine dairy farms create several externalities. Positive externalities include land for recreational purposes such as snowmobiling, hunting, and fishing. Additionally, Maine residents have the option to buy milk products from local dairy farms. Negative externalities include odor from manure spreading and pollution from manure disposal.

Federal price support programs such as the FMMO's, MILC, DEIP, and DPPSP have been utilized in the past decade as well as the LGM-Dairy and MPP dairy insurance programs. Additionally, the Maine Dairy Relief Program establishes price floors that Maine dairy farms based on production scale. Despite these legislative bills that aimed to increase industry sustainability, the apparent trend is that farms remaining in business are getting larger, while small farms are exiting the industry more frequently.

We employed a sample 79 total farms from the 2010 and 2013 dairy cost-of-production studies to investigate farm profitability and economies of scale. Our estimation of a per-unit cost function indicated that costs fall at a decreasing rate with output and eventually increase. Further, estimation of a Cobb-Douglas production function suggests increasing returns to scale exist in the Maine dairy industry. These two findings reinforce the hypothesis that small farms have higher per-unit costs, as was indicated in the raw data and in similar cost-of-production studies.

Finally, we used simulations to assess the benefits of Maine's Dairy Relief program. A sample of 204 total farms from four cost-of-production studies was used to estimate Average Variable Cost (AVC). The AVC function was then used in combination with milk price and output data for all Maine dairy farms to estimate variable profit per cwt for all farms in the state from June 2004 to May 2015, which was necessary to run the simulation program. In each iteration, these estimated variable profits were used to establish a rule-of-thumb filter for removing observations for a probit regression. After removal of filtered observations, a binary probit was estimated with exit decision modeled as a function of seasonality, price lags in the previous six months, and AVC lags in the previous six months. Based on the corresponding probit probabilities of exit, a stochastic exit decision was forecasted without price supports for each farm-month combination. The results suggest that approximately 30% more farms would have exited and exits would have occurred sooner if the price floors had not been enacted in 2004. Though tier 1 farms observe the greatest difference in number of exits, the three tiers representing larger farms are substantially impacted as well.

In sum, our data and analyses indicate small farms tend to have higher per unit costs and have lower input productivity. These findings likely explain the trend of average farm size increasing and small farms shutting down that has been observed among US dairy farms in recent decades. This trend has led to increased dairy farm support programs, such as Maine's Dairy Relief Program. Our simulation analysis indicated 30% more Maine dairy farms would have exited without the price floors established by the program. Despite the fact that 263 conventional dairy farms shut down since the program began, our findings suggest the program still has substantial impacts in preventing farm exits.

4.2. Remarks about Future Research

University of Maine Cooperative Extension conducts the cost-of-production study of Maine dairy farms every three years. Sponsored by the Maine Milk Commission, the study collects expenditure and output data for a representative sample of Maine dairy farms. The data collected for the 2013 study included only input expenditures and total annual production. Although this data was sufficient for calculation of average cost per cwt for each tier, additional data would have allowed for more sophisticated econometric analysis. We recommend researchers working on future cost-of-production studies collect data on input quantities, input prices, monthly milk production, and revenues collected. It is useful to inform farmers prior to visits of what information is desired for data collection. Lastly, data on number of laborers would enable a further analysis of economic impact in terms of job creation.

REFERENCES

Aigner DJ, Lovell CAK, Schmidt P (1977) Formulation and estimation of stochastic frontier production function models. J Econ 6:21–37

Alvarez, A., Corral, J. D., Solís, D., & Pérez, J. (2008). Does Intensification Improve the Economic Efficiency of Dairy Farms? *Journal of Dairy Science, 91*(9), 3693-3698. doi:10.3168/jds.2008-1123

Andreyeva, T., Long, M. W., & Brownell, K. D. (2010). The Impact of Food Prices on Consumption: A Systematic Review of Research on the Price Elasticity of Demand for Food. Am J Public Health American Journal of Public Health, 100(2), 216-222. doi:10.2105/ajph.2008.151415

Attonaty, J.M., M.H. Chatelin, and F. Garcia (1999). "Interactive simulation modeling in farm decision-making". Computers and Electronics in Agriculture. Vol. 22, no. 2-3, pp. 157-170.

Balagtas, J.V., and D.A. Sumner. 2003. The effect of the Northeast Dairy Compact on producers and consumers, with implications of compact contagion. Review of Agricultural Economics Rev Agricultural Economics 25(1): 123–144.

Beshore, M. (2003, January 28). Re: Proposal to classify evaporated milk as a Class IV product [Letter to Richard M. McKee]. Harrisburg, Pennsylvania.

Blayney, D., & Normile, M. A. (2004). Economic effects of U.S. dairy policy and alternative approaches to milk pricing. Washington, D.C.: U.S. Dept. of Agriculture.

Bolotova, Y. and A.M. Novakovic. 2012. The Impact of the New York State Milk Price Gouging Law on the Price Transmission Process and Supermarket Pricing Strategies in the Fluid Whole Milk Market. Agribusiness: An International Journal 28: 377-399.

Bozic, M., Newton, J., Thraen, C., & Gould, B. (2012). Mean-reversion in income over feed cost margins: Evidence and implications for managing margin risk by US dairy producers. *Journal of Dairy Science, 95*(12), 7417-7428.doi:10.3168/jds.2012-5818

Bragg, L., G. Criner, and A. Cook. 2009. Final Report on the 2007 Dairy Cost-of-Production Survey. Presented to the Maine Milk Commission. Orono, ME: Dept. of Resource Economics and Policy, University of Maine.

Bragg, L.A., and T.J. Dalton. 2006. The cost of producing milk in Maine: Results from the 2005 dairy cost of production survey. Maine Agricultural and Forest Experiment Station.

Burdine, K.H., R. Mosheim, D. Blaney, and L.J. Maynard. (2014). “Livestock gross margin-dairy insurance: an assessment of risk management and potential supply impacts.” Economic Research Report No. 163, USDA, Economic Research Service, Washington DC.25(1): 123–144.

Byma, Justin and Loren W. Tauer. 2010. Exploring the role of managerial ability in influencing dairy farm efficiency. Agricultural and Resource Economics Review.39(3):505-516.

Cabrera, V., Solís, D., & Corral, J. D. (2010). Determinants of technical efficiency among dairy farms in Wisconsin. *Journal of Dairy Science, 93*(1), 387-393. doi:10.3168/jds.2009-2307

Capps Jr., Oral., and Pablo Sherwell, “Spatial Asymmetry in Fluid-Retail Price Transmission Associated with Fluid Milk Products “ Selected Paper presented at Annual Meeting of the Western Agricultural Economics Association, Providence, Rhode Island. July 24-July 27, 2005.

Carman, H. F., & Sexton, R. J. (2005). Supermarket fluid milk pricing practices in the western United States. Agribusiness, 21(4), 509-530. doi:10.1002/agr.20062

Carree, M. A. (2002). Technological inefficiency and the skewness of the error component in stochastic frontier analysis. *Economics Letters, 77*(1), 101-107. doi:10.1016/s0165-1765(02)00119-2

Chidmi, B., R.A. Lopez, and R.W. Cotterill. 2005. Retail oligopoly power, dairy compact, and Boston milk prices. Agribusiness 21(4): 477–491.

Chite, R., & Shields, D. 2009. Dairy Policy and the 2008 Farm Bill. CRS Report for Congress. Congressional Research Service.

Chouinard, H. H., Davis, D. E., Lafrance, J. T., & Perloff, J. M. (2010). Milk Marketing Order Winners and Losers. *Applied Economic Perspectives and Policy, 32*(1), 59-76. doi:10.1093/aepp/ppp002

Cotterill, R. W. (2005). The impact of the Northeast Dairy Compact on New England consumers: A report from the milk policy wars. Agribusiness, 21(4), 455-471. doi:10.1002/agr.20059

Dairy export incentive program (DEIP). (2007). In W. Goode, *Dictionary of trade policy terms*. Cambridge, United Kingdom: Cambridge University Press. Retrieved from http://www.library.umaine.edu/auth/EZProxy/test/authej.asp?url=http://search.credoreference.com/content/entry/cuptpt/dairy_export_incentive_program_deip/0

Dairy Product Price Support Program (DPPSP) formerly the Milk Price Support Program (MPSP). (2011). Washington, D.C.: U.S. Dept. of Agriculture, Farm Service Agency.

Dalton, T.J., & L.A. Bragg. 2003. The cost of producing milk in Maine: Results from the 2002 dairy cost of production survey. Maine Agricultural and Forest Experiment Station.

Dong, Fengxia, David Hennessy and Helen H. Jensen, "Size, Productivity, and Exit Decision in Dairy Farms" Selected Paper presented at Agricultural & Applied Economics Association's 2013 AAEA & NAREA Joint Annual Meeting, Washington, DC. Aug 4-6, 2013.

Dong, Fengxia, Xiodong Du and Brian W. Gould, "Milk Price Volatility and its Determinants" Selected Paper presented at Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania. July 24- July 26, 2011.

Drake, Tim. 2011. Maine's dairy relief program. Maine Policy Review 20(1): 77–78. http://digitalcommons.library.umaine.edu/ mpr/vol20/iss1/14.

Foltz, J. D. (2004). Entry, Exit, and Farm Size: Assessing an Experiment in Dairy Price Policy. American Journal of Agricultural Economics Am J Agricultural Economics, 86(3), 594-604. doi:10.1111/j.0002-9092.2004.00603.x

Glaser, Lewrene, and Gary D. Thompson, "How Dairy Price Changes Influence Consumer Welfare" Selected Paper presented at Annual Meeting of the Western Agricultural Economics Association, Vancouver, British Columbia. June 29-July 1, 2000.

Grieco, P. L., Li, S., & Zhang, H. (2016). Production Function Estimation With Unobserved Input Price Dispersion. *International Economic Review, 57*(2), 665-690. doi:10.1111/iere.12172

Helmberger, P., & Chen, Y. (1994). Economic Effects of U.S. Dairy Programs. Journal of Agricultural and Resource Economics, 19(2), 225-238.

Holsinger, V., Rajkowski, K., & Stabel, J. (1997). Milk pasteurisation and safety: A brief history and update. Revue Scientifique Et Technique De L'OIE Rev. Sci. Tech. OIE, 16(2), 441-451. doi:10.20506/rst.16.2.1037

Horwitz, R. P. (n.d.). *New England as a Jurisdiction for Supporting Continuity of Dairy Operations: A Reassessment* (United States, United States Department of Agriculture, Animal and Plant Health In spection Service). Retrieved December 30, 2013.

Hovhannisyan, V., & Bozic, M. (2013). Retailer Motivation to Adjust Milk Prices: An Analysis Using Superelasticity of Demand. Agribusiness, 30(2), 195-206. doi:10.1002/agr.21349

Huang, Kuo P., and Don P. Blayney, "Demand for Organic and Conventional Beverage Milk" Selected Paper presented at Annual Meeting of the American Agricultural and Economics Association, Montreal, Canada. July 27-July 30, 2003.

Jiang, N., & Sharp, B. (2015). Technical efficiency and technological gap of New Zealand dairy farms: A stochastic meta-frontier model. *Journal of Productivity Analysis J Prod Anal, 44*(1), 39-49. doi:10.1007/s11123-015-0429-z

Jin, H. J., & Frechette, D. L. (2004). Fractional Integration in Agricultural Futures Price Volatilities. *American Journal of Agricultural Economics, 86*(2), 432-443. doi:10.1111/j.0092-5853.2004.00589.x

Kersbergen, R., G. Anderson, G. Criner, and A. Davis. 2013. Cost of producing milk in Maine: Results from the 2010 Dairy Cost-of-Production Survey. Maine Agricultural and Forest Experiment Station Bulletin 853.

Kim, Taeyoon, Wade Brorsen, and Philip Kenkel, "Estimation of Efficiency with the Stochastic Frontier Cost Function and Heteroscedasticity: A Monte Carlo Study " Selected Paper presented at Annual Meeting of the American Agricultural Economics Association, Orland, Florida. July 27-July 29, 2008.

Kompas, T., & Che, T. N. (2006). Technology choice and efficiency on Australian dairy farms*. *The Australian Journal of Agricultural and Resource Economics Aust J Agric Res Econ, 50*(1), 65-83. doi:10.1111/j.1467-8489.2006.00314.x

Kumbhakar, S.C., Tsionas, E.G., Sipiläinen, T., 2009. Joint estimation of technology choice and technical efficiency: an application to organic and conventional dairy farming. Journal of Productivity Analysis 31, 151-161

Lass, D. A. (2005). Asymmetric response of retail milk prices in the northeast revisited. Agribusiness, 21(4), 493-508. doi:10.1002/agr.20061

Laughton, C. 2013. 2012 Northeast Dairy Farm Summary. Farm Credit East, Farm Credit of Maine, and Yankee Farm Credit.

Laughton, C. 2014. 2013 Northeast Dairy Farm Summary. Farm Credit East, Farm Credit of Maine, and Yankee Farm Credit.

Liu, Donald J., Chin-Hwa Sun, and Harry M. Kaiser. "Market Conduct under Government Price Intervention in the U.S. Dairy Industry." *J. Agr. Res. Econ.* 20 (1995): 301-315.

MacDonald, J. M. (2007). Profits, costs, and the changing structure of dairy farming. Washington, D.C.: U.S. Dept. of Agriculture, Economic Research Service.

Malan, D., Louw, A., & Blignaut, C. (2010). Simulation analysis of risk management for a diversified commercial farm. *Agrekon, 49*(3), 373-395. doi:10.1080/03031853.2010.503389

Manchester, A. C., & Blayney, D. P. (1997). The structure of dairy markets past, present, future. Washington, DC: U.S. Dept. of Agriculture, Economic Research Service.

Neyhard J., Tauer L., Gloy B.: Analysis of price risk management strategies in dairy farming using whole-farm simulations. Journal of Agricultural and Applied Economics, 45, 2013, 313-327.

Nicholson, C. F., & Stephenson, M. W. (2014). Dynamic Market Impacts of the Dairy Margin Protection Program. Journal of Agribusiness, 32(2), 164-195.

Niskanen, O., & Heikkilä, A. (2015, April). The Impact of Parcel Structure on the Efficiency of Finnish Dairy Farms. *Agricultural and Resource Economics Review*.

Packaging Machinery Manufacturing Institute (PMMI). 2013. 2013 Dairy Industry—A Market Assessment: Executive Summary. PMMI, Reston, VA. http://www.pmmi.org/files/Research/ExecutiveSummaries/2013DairyExecSummary.pdf.

Schmit, T., & Kaiser, H. (2006). Forecasting Fluid Milk and Cheese Demands for the Next Decade. Journal of Dairy Science, 89(12), 4924-4936. doi:10.3168/jds.s0022-0302(06)72543-7

Shields, D. 2009. Dairy Market and Policies Issues. CRS Report for Congress. Congressional Research Service.

Shields, D. 2010. Consolidation and Concentration in the US Dairy Industry. CRS Report for Congress. Congressional Research Service.

Shields, D. A. “Dairy Farm Support: Legislative Proposals in the 112th Congress.” CRS Report for Congress R42065, Congressional Research Service, Washington, DC, 2011.

Shields, D. A. “Farm Safety Net Programs: Background and Issues.” CRS Report for Congress R42065, Congressional Research Service, Washington, DC, 2015.

Schnepf, R. 2012. Dairy Policy Proposals in the 2012 Farm Bill. CRS Report for Congress. Congressional Research Service.

Sobson, C. (2004). *2003 Northeast Dairy Farm Summary*. Rep. Farm Credit East, May 2004.

Stokes, J.R. (2006): Entry, Exit, and Structural Change in Pennsylvania's Dairy Sector, Agricultural and Resource Economics Review 35 (2), 357-373.

Sumner, D. A. (1999). Domestic Price Regulations and Trade Policy: Milk Marketing Orders in the United States. Canadian Journal of Agricultural Economics/Revue Canadienne D'agroeconomie Canadian J Agric Econ, 47(5), 5-16. doi:10.1111/j.1744-7976.1999.tb00233.x

Tauer, L. (2001). Efficiency and Competitiveness of the Small New York Dairy Farm. *Journal of Dairy Science, 84*(11), 2573-2576. doi:10.3168/jds.s0022-0302(01)74710-8

Tauer, L., "When to Get In and Out of Dairy Farming: A Real Option Analysis" Selected Paper presented at American Agricultural Economics Association Annual Meeting, Long Beach, CA. July 24-26, 2006.

Tauer, L., & Mishra, A. (2006). Dairy Farm Cost Efficiency. *Journal of Dairy Science, 89*(12), 4937-4943. doi:10.3168/jds.s0022-0302(06)72544-9

United States, United States Department of Agriculture, National Agricultural Statistics Service. (2010, September). *Overview of United States Dairy Industry*.

United States, United States Department of Agriculture, Risk Management Agency. (2015). Livestock gross margin insurance: Dairy cattle.

Valvekar, M., Cabrera, V., & Gould, B. (2010). Identifying cost-minimizing strategies for guaranteeing target dairy income over feed cost via use of the Livestock Gross Margin dairy insurance program. Journal of Dairy Science, 93(7), 3350-3357. doi:10.3168/jds.2009-2815

Valvekar, M., Chavas, J.P., Gould, B.W., and Cabreca, V. E. (2011) Revenue Risk Management, Risk Aversion, and the Use of Livestock Gross Margin for Dairy Cattle Insurance. Agricultural System, 104:671-678

Wang HJ. 2002. Heteroscedasticity and Non-Monotonic Efficiency Effects of a Stochastic Frontier Model. Journal of Productivity Analysis,18: 241-253.

Weimar, M. R., & Blayney, D. P. (1994). Landmarks in the U.S. dairy industry. Washington, DC: U.S. Dept. of Agriculture, Economic Research Service.

Wieck, C., & Heckelei, T. (2007). Determinants, differentiation, and development of short-term marginal costs in dairy production: An empirical analysis for selected regions of the EU. *Agricultural Economics, 36*(2), 203-220. doi:10.1111/j.1574-0862.2007.00199.x

Wolf, C. (2010). Understanding the milk-to-feed price ratio as a proxy for dairy farm profitability. *Journal of Dairy Science, 93*(10), 4942-4948. doi:10.3168/jds.2009-2998

Wolf, C. and G. *Tonsor*. (2013) "*Dairy* Farmer Policy Preferences." *Journal of Agricultural and Resource Economics*. *38*. 220-234.

Xia, T., & Sexton, R. J. (n.d.). Retail Prices for Milk by Fat Content: A New Theory and Empirical Test of Retailer Pricing Behavior. SSRN Electronic Journal SSRN Journal. doi:10.2139/ssrn.1432151

BIOGRAPHY OF AUTHOR

Dylan Bouchard was born in Greenville, Maine. He graduated from Greenville High School in June 2011 and went on to study Economics at the University of Maine. During his undergraduate career, Dylan earned membership in Omicron Delta Epsilon and Pi Mu Epsilon, the Economics and Mathematics Honor Societies, respectively. In August of 2014, he received his Bachelor of Science degree in Economics from the University of Maine. Dylan began graduate school in the fall of 2014, conducting research under Dr. Xuan Chen and has since co-authored a technical bulletin published by the Maine Agricultural and Forest Experiment Station entitled *Cost of Producing Milk in Maine: Results from the 2013 Cost-of-Production Survey*. He is a candidate for the Master of Arts degree in Economics from the University of Maine in August 2016.