Adoption of Total Mixed Ration Practice and Profitability:

The Case of Ontario Dairy Farms

by

Yi Zheng

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ABSTRACT

Adoption of Total Mixed Ration Practice and Profitability:
The Case of Ontario Dairy Farms

Yi Zheng | **Advisor:**
University of Guelph, 2013 | **Dr. Getu Hailu**

This thesis examines determinants of the adoption of total mixed ration (TMR), and the effects of the adoption of TMR on the farm level productivity and profitability of Ontario dairy farms. A sample of 320 farm level data from 2004-2008 is taken from the Ontario Dairy Farm Accounting Project (ODFAP). A probit model is estimated to examine the factors affecting the adoption of TMR; and the propensity score matching analysis is used to explore the influence of the use of TMR on sample farm's productivity and profitability.

Results from the probit model show that farmer's age, herd size, region, breed type and feeding system have significant effect on the adoption of TMR. In turn, the adoption of TMR feeding practice has positive influence on both farm productivity and profitability. Under the propensity score matching method, the use of the TMR feeding practice has an economically significant effect on farm profits (*i.e.*, for average farm with approximately 73 cows, the use of TMR feeding practice increases farm profits by CAD$37,091.30/year approximately) and a statistically significant increase in milk production by 1075.41 hl/cow per year.

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Chapter 1: Introduction

This study examines the effect of the adoption of the total mixed ration (TMR) feeding practice on the productivity and profits of Southern Ontario dairy farms. Throughout this thesis, the TMR feeding practice refers to a practice of weighing and blending all feedstuffs into a nutritionally balanced ration, which provides adequate nourishment that meets the needs of a dairy cow to help it achieve maximum performance. With the TMR feeding, the animals get the same mixture, and the feeding is done group-wise and not individually. The term productivity refers to average milk production per cow per year; and profit refers to dairy enterprise's average profit per cow per year. This study aims to answer the following research question: "Does the use of total mixed ration (TMR) in the feeding of dairy cows influence dairy farm level productivity and profits?"

1.1 Background

With the increasing global competition and pressure on supply management, dairy producers in Canada are being challenged to produce milk more efficiently to be competitive and profitable. One way producers could be competitive is through a low-cost production strategy. Best management feeding practice provides one example of a strategy for feeding efficiency and enhanced productivity and profits. This study assesses the characteristics of farmers who use the TMR feeding practice, and examines whether the use of the TMR feeding practice influences productivity (milk yield) and profits.

A few previous economic studies have been done to empirically estimate the effect of using the TMR feeding practice. For example, Foltz and Chang (2002) in the study of the effect of rbST on milk yield and profit per cow in the U.S., found that the TMR feeding practice did not have an effect on both milk yield and productivity. Meanwhile, in the study of the effect of rbST on milk yield and profits, Schraufnagel (2007) finds that TMR has a positive effect on milk yield and profits. The results of these two studies are inconclusive and partially contradictory as to the effect of the use of the TMR practice on both milk yield and profits, and the result of these studies do not directly target the effect of the use of TMR on milk yield and profits.

Total mixed ration (TMR), also known as complete ration, allows the segregation of animals according to the existing herd size, the layout of the barns and loafing areas, and the practice of feeding cows TMRs. Feeding each group with the required amounts of protein, energy, nutrients, vitamins, and minerals, without overfeeding late-lactation or lower-producing cows, results in a more efficient use of feed (*e.g.*, reduced feed wastage). The TMR feeding practice was introduced in the late 70's in Ontario and popularized around the late 80's (Mongeon 2012[1]). Despite its long history, the adoption of the practice remained modest at around 50-60% of farms. For example, in 2004 only 54.9% of ODFAP sample farmers in Southern Ontario used TMR on their dairy farms. Thus, the purpose of this study is to examine the impact of the use of the TMR feeding practice on farm level productivity and profits.

1.2 Economic Research Problem

Although the scientific studies have shown that the use of TMR has a positive influence on dairy farm productivity (*e.g.*, Neitz, Feeds and Dugmore 2005; Bargo et al. 2002, 2948-2963), the impact of TMR on economic performance (*e.g.*, profit) is limited and unclear. The benefits of the use of the TMR feeding system involves savings from improved feed efficiency (*e.g.*, reduced feed wastage); labour costs (*e.g.*, reduced the number of labour used on farm); transportation and commercial feed manufacturer costs (*e.g.*, avoiding additional costs of transportation and handling required by a commercial feed manufacturer); equipment costs (*e.g.*, long equipment life); forage and grain costs (*e.g.*, less bulk purchases and cheaper feed ingredients); and energy use costs (*e.g.*, low energy use). Meanwhile, the adoption of the TMR feeding practice involves the following costs: TMR mixer initial investment costs, fuel costs from powering the TMR mixer, labour costs (including fringe benefits such

[1] This information is provided on November 21, 2012, by R. Lackey, who works at Ontario Ministry of Agriculture, Food and Rural Affairs.

as social security, medicare, workman's compensation insurance, health insurance, housing allowance etc. for the workers), filling and operating equipment costs associated with the TMR mixer, and repair costs.

The economic research problem addressed in this study is whether the use of the TMR feeding practice has significant impact on the profits of dairy farms. That is, the study addresses the research question: "Does the use of total mixed ration in dairy cows feeding practice influence dairy farm productivity and profits?"

1.3 Purpose and Objectives

The purpose of the study is to examine the economic impact of the use of the total mixed ration (TMR) feeding practice on farm level productivity and profits. The specific objectives of this study are to:

1. examine factors affecting the adoption of the TMR feeding practice by estimating a probit regression; and
2. examine whether and to what extent the adoption of TMR affects farm level productivity and profits of dairy farms by using the propensity score matching approach.

1.4 Chapter Outline

Chapter 2 provides an overview of the Canadian and Ontario dairy industry, feed cost and feeding system. It also focuses on the TMR feeding practice relevant to dairy production. Chapter 3 highlights theories and researches on the impact of technology adoption on farm level economic performance. Chapter 4 develops the conceptual framework which describes what influences farmer's decision to adopt the TMR feeding practice and states the hypothesis of this study. Chapter 5 provides data sources used in this study, and elaborates on the empirical framework employed to empirically test the hypothesis. Chapter 6 provides empirical results, discusses the implication of these results and compares these results with previous literature. Chapter 7 summarizes major findings and their implications for Southern Ontario's dairy production. Limitations of this study and suggestions for future research will also be provided in this chapter.

Chapter 2: Dairy Industry Background and Total Mixed Ration

2.1 Introduction

In order to provide an overview of the dairy industry in Canada and Ontario as well as a general framework of how the feeding system operates in agricultural production, this section will review feeding systems with total mixed ration (TMR) across countries and time periods with an emphasis on the TMR feeding practice for dairy.

2.2 Canada and Ontario Dairy Industry

2.2.1 Overview of Canada and Ontario Dairy Industry

"Canada is among the top twenty dairy countries in the world in terms of dairy cattle production fluid milk and dairy product production and, consumption and exports of dairy genetic material" (Canadian Dairy Industry Profile 2005, 17). Unlike many of the large dairy farming operations in the United States, dairy farms in Canada are family owned and operated (The Ontario Milk Industry 2013, 6). Canada's milk and dairy products are famous around the world for their excellence and are as diverse as its land and people (Canadian Dairy Information Centre 2012a). Enforcement of strict quality standards on dairy farms and processing levels contribute to Canada's strong reputation for high-quality dairy products, along with a strong commitment to sound animal welfare practices and environmental sustainability (Canadian Dairy Information Centre 2012a).

According to the Canadian Dairy Information Centre (2012a), the dairy industry ranks third in the Canadian agricultural sector, following grains and oil seeds, and red meats. In 2011, dairy production in Canada generated a total net farm receipt of $5.8 billion and sales of $13.7 billion, representing 16.4% of the Canadian food and beverage sector. Up to now, 82% of Canadian dairy farms are located in Ontario and Quebec, 13% in the Western provinces and 5% in the Atlantic Provinces. The Canadian dairy cattle population totals 1.4 million, and the typical Canadian dairy farm has 77 cows. The Holstein breed is the most common dairy breed (94% of the dairy herd); Ayrshire, Brown Swiss, Canadienne, Guernsey, Jersey and Milking Shorthorn breeds are also found on Canadian farms.

The Canadian dairy sector operates under a production and marketing system called supply management system. The term “supply management” originated in the 1960s and is used commonly in rural Canada (The Ontario Milk Industry 2013, 3). This system allows producer to produce the exact amount of milk required by Ontario milk processors to meet consumer demand (The Ontario Milk Industry 2013, 3).Supply management is the key to success in Canada’s dairy industry and the poultry sector (*i.e.*, chicken, turkey and eggs), and it eliminates the problem of surpluses and shortages and, instead, provides a steady supply of milk at stable prices for producers (The Ontario Milk Industry 2013, 3).

According to the Dairy Farmers of Ontario (2013), dairy is the largest sector of Ontario agriculture. Under The Milk Act, Ontario’s dairy industry is overseen by a producer organization called “Dairy Farmers of Ontario (DFO)”, which is owned and paid for by dairy farmers (The Ontario Milk Industry 2013, 2), and a government body, the Farm Products Marketing Commission, which acts as a supervisor for the industry (Canadian Dairy Industry Profile 2005, 12).

According to the Canadian Dairy Industry Profile (2005), the Dairy Farmers of Ontario licenses all producers, buys all raw milk produced in the province, sells this milk to processors, and pays producers. The DFO uses the costs of production data to set the prices producers receive, and it reviews and indexes these regularly to reflect changing farm costs and overall economic conditions. In order to derive the prices that processors will pay for various classes of industrial milk, the DFO considers the support prices set by the Canadian Dairy Commission for butter and skim milk powder. The DFO also licenses producers of farm-separated cream (which is used to make butter), and allocates a portion of the provincial share of the Market Sharing Quota (MSQ) to these producers. The DFO arranges for milk transportation and negotiates rates with the Ontario Milk Transport Association, which represents the majority of firms handling milk transportation. Farm-separated cream transport is arranged directly between creameries and producers.

The DFO not only operates the supply management system, but also administers a quota system, which requires dairy farmers to be licensed and to own milk quotas. Producers in Ontario with their quota holdings, receive an average price for all the milk sold to fluid and industrial milk processors (Canadian Dairy Industry Profile 2005, 12). Producers are paid for milk components (*i.e.*, butterfat, protein and solids non-fat) in all the classes of milk sold (Canadian Dairy Industry Profile 2005, 12).

2.2.2 Change in Canada and Ontario Dairy Industry

The production sector has experienced dramatic changes in Canada over the last 41 years. The number of dairy farms has fallen significantly over the past 41 years for both Canada and Ontario (Tables 2.1 and 2.2). During the same period, the number of dairy cows at the national level has declined 55% and the number of Ontario dairy cows has declined 56%, while national milk production per cow and Ontario milk production per cow increased by 78% and 71%, respectively. These changes are due to the benefits of research including improvements in genetics, animal feed control, animal disease control and farm technologies (Canadian Dairy Industry Profile 2005, 17).

Table 2.1: Change in size of the Canadian dairy industry

	2011	2001	1991	1981	1971
Number of Farms	12,746	18,673	31,200	52,567	113,008
Number of Dairy Cows	983,100	1,091,000	1,328,100	1,764,400	2,195,000
Average Milk/cow (kg)	9,774	9,242	7,523	6,254	5,492
Average Cows/farm	77	58	43	34	19

Source: Canadian Dairy Information Centre and self-calculation

Note: Average Milk/cow (kg) is calculated by (Σ Number of Records × Milk(kg)) ÷ (Σ Number of Records), and breed type include Ayrshire, Brown Swiss, Canadienne, Guernsey, Holstein, Jersey, Milking Shorthorn. For 1991, 1981 and 1971, data for Canadienne are unavailable.

Table 2.2: Change in size of the Ontario dairy industry

	2011	2001	1991	1981	1971
Number of Farms	4,137	6,244	10,233	14,471	26,681
Number of Dairy Cows	322,000	372,000	446,700	550,000	739,000
Average Milk/cow (kg)	9,639	8,972	7,304	6,226	5,653
Average Cows/farm	78	60	44	38	28

Source: Canadian Dairy Information Centre and self-calculation
Note: Average Milk/cow (kg) is calculated by (Σ Number of Records × Milk(kg)) ÷ (Σ Number of Records), and breed type include Ayrshire, Brown Swiss, Canadienne, Guernsey, Holstein, Jersey, Milking Shorthorn. For 1991, 1981 and 1971, data for Canadienne are unavailable.

According to Table 2.1, for Canada as a whole, milk per cow per year increased from 5,492 kg in 1971 to 9,774 kg in 2011 (Canadian Dairy Information Centre 1971b, 1981b, 1991b, 2001b, 2011b and self-calculation). Thus, production efficiency, measured as total output per cow, almost doubled over the past 41 years. On the other hand, the total number of cows in Canada dropped from 2,195,000 cows in 1971 to 983,100 cows in 2011 (Canadian Dairy Information Centre 1971c, 1981c, 1991c, 2001c, 2011c). According to the Canadian Dairy Industry Profile (2005), consolidation has been taking place in the dairy processing industry in Canada. The specialization of dairy farms and the reduction of transportation costs contributed to the consolidation of processing enterprises (Canadian Dairy Industry Profile 2005, 30). Because of mergers, firms can reduce plant overcapacity, combine resources and skills and reduce costs by operating fewer but larger and more efficient plants. The decline in the number of companies and processing plants were mostly caused by company mergers and acquisitions (Canadian Dairy Industry Profile 2005, 30).

Similarly, as shown in Table 2.2, for Ontario, milk per cow per year increased from 5,653 kg in 1971 to 9,639 kg in 2011 (Canadian Dairy Information Centre 1971b, 1981b, 1991b, 2001b, 2011b and self-calculation). The total numbers of cows in Ontario dropped from 739,000 cows in 1971 to 322,000 cows in 2011 (Canadian Dairy Information Centre 1971c, 1981c, 1991c, 2001c, 2011c).

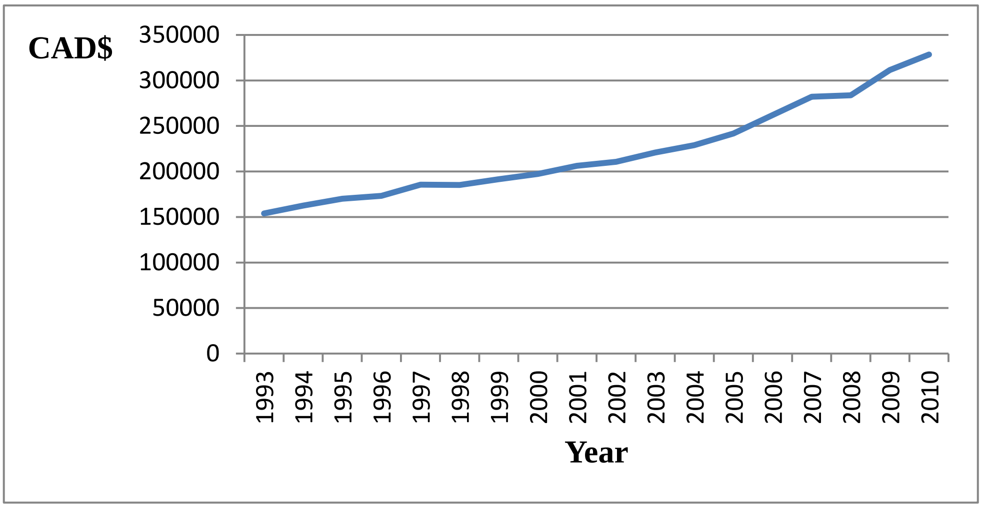
The improvement in productivity is similar to what happened in all of Canada; however, Ontario production still lags behind the national average. In 1971, Ontario production per cow was 5,653 kg. It increased to 9,693 kg per cow in 2011 (Canadian Dairy Information Centre 1971b, 1981b, 1991b, 2001b, 2011b and self-calculation). The 9,693 kg per cow per year milk production lags behind the national average of 9,774 kg of milk per cow per year.

2.3 Feed Cost and Dairy Feeding System

2.3.1 Feed Cost

According to Figure 2.1, input costs of Ontario dairy farms have continued to increase from 1993 to 2010.

Figure 2.1: Input costs of dairy farms in Ontario, 1993-2010



Source: Statistics Canada

Note: 1. Input costs include total operating expenses in dairy farms;

2. All the numbers here are real and are deflated by CPI (index 2002=100).

News was released on August 23, 2012 by Watt Publishing Co. that hog producers in Canada are worrying about increasing animal feed prices caused by the continuing U.S. drought. Hogs are being sold across Canada, America and Europe since feed prices are on the rise and it is too costly to raise animals (Huber 2012). Due to the crises in weather and crop failure in 2012, dairy producers on Vancouver Island have to buy feed rather than growing their own feed, which make it difficult for small operators to survive (Horner 2012). A Dutch-based group who sells feed in 80 countries reports that feed prices in Canada increased an average of 14.7% from July to September in 2012. Current high feed prices have been a new barrier for Canadian beef farmers, just like the prices they faced when BSE outbreak happened nine years ago (Nutreco 2012). “The impacts of the 2012 drought continue to play out in a beef industry, which discouraged by high feed prices and large cattle-feeding losses” (The Farmer’s Exchange 2012). Besides, the expanded demand on the prairies for feed grains by the expanding livestock and poultry industry and Canadian based policy and regulations also contributed to the increase in feed prices (Canadian Agri-Food Policy Institute 2005, 48)

2.3.2 Dairy Feeding System

“A successful dairy feeding system is defined as one that delivers the needed nutrients to each cow at the correct time (stage of lactation) to maintain maximum milk production” (University of Minnesota Extension 2012). There are four feeding systems: forage system, grain system, mineral system and total mixed ration (TMR) system. Each system has its benefits and costs. There is not an ideal one for all dairy farmers. Farmers have to consider forage delivery, grain, protein and minerals when they choose a feeding system (University of Minnesota Extension 2012).

2.4 Total Mixed Ration (TMR)

2.4.1 Total Mixed Ration

Total mixed ration (TMR), or complete ration, is a practice of weighing and blending all feedstuffs into a nutritionally balanced ration, which provides adequate nourishment to meet the needs of dairy cows to help them achieve maximum performance. With TMR feeding, the animals get the same mixture, and the feeding is done group-wise and not individually. Of all feeding systems, TMR supplies a balanced ration to the cow and ensures that every bite consumed by the cow is the same (Snowdon 1991). TMR is commonly used on farms with a large herd size.

2.4.2 Advantages of Total Mixed Ration

The Total Mixed Ration (TMR) system has many potential advantages and it warrants consideration by any farmer anticipating a change in his/hers feeding system. Using TMR improves feed efficiency since every bite consumed by the cow contains the proper amount of ingredients for a balanced ration. TMR provides greater accuracy in formulation and feeding because a cow cannot consume significantly more or less of a forage or concentrate in properly mixed TMR (Lammers, Heinrichs and Ishler 2013). Thus, TMR feeding prevents individual cows from expressing a preference for one kind of forage over another (Snowdon 1991). A greater variety of ingredients allows more flexibility in formulating the ration for various production groups. Commodity ingredients used for TMR can be fed quite cost effectively in the diet as additional costs of transportation and handling are avoided (Lammers, Heinrichs and Ishler 2013). Neitz, Feeds and Dugmore (2005) find that using TMR increased milk production by approximately 5% to 8%. In the study by Bargo et al. (2002), dairy cows fed with TMR are found to have the highest milk production compared to dairy cows fed with pasture plus concentrate (PC) or pasture plus partial TMR (pTMR). They also find that TMR leads to higher milk production, milk fat and protein percentage, and maintenance in body condition score compared to pasture plus concentrate.

Advantages of TMR are that it, 1) allows cows consume the desired proportion of forages; 2) reduces risk of digestive upset; 3) increases feed efficiency; 4) allows usage of byproduct feeds; 5) allows accuracy of diet formulation; and 6) reduces labor needs (Dinsmore and Mark 2011). For farms with a large herd size, TMR will not be labor saving, but it potentially improves feed efficiency and animal health (Snowdon 1991).

2.4.3 Disadvantages of Total Mixed Ration

The main disadvantage of TMR is the inability to feed cows as individuals. TMR can be developed for different animal groups, but if not grouped according to production, cows in late lactation are likely to get too fat (Lammers, Heinrichs and Ishler 2013).

For farms with small herd size, TMR system may not be economical. Lammers, Heinrichs and Ishler say that the process of mixing ration requires accuracy because over mixing can cause serious problems and under mixing can lead to less effective feed utilization by the cows. However, accurate weighing may result in additional costs and maintenance. Some farmers cannot adopt TMR since TMR may not well suit their housing and feeding facilities. Moreover, if the TMR diet is not balanced correctly or mixed properly, the cows will perform worse.

2.5 Summary

This chapter provides the background of Canada's and Ontario's dairy industry, and discusses the advantages and disadvantages of the TMR feeding practice used in dairy farms. Although farms with larger herd size benefit most from TMR, it has been successfully adopted by farms with various types and sizes because of the potential advantages of TMR.

Chapter 3: Literature Review on Technology Adoption and Farm Level Economic Performance

3.1 Introduction

There is currently no economic study that specifically examines the economic impact of the TMR feeding practice on Southern Ontario's dairy sector, but a variety of studies have been done to examine the effect of technology adoption in different areas. This section will provide an overview of literature on the economic impact of technology adoption.

3.2 Economic Impact of Technology Adoption

3.2.1 Technology Adoption

Technology adoption refers to "the choice to acquire and use a new invention or innovation" (Hall and Khan 2003, 1). In 1962, Rogers defined the adoption process as "the mental process an individual passes from first hearing about an innovation to final adoption" (p. 17). Later, Feder, Just and Zilberman (1985) define final adoption as "the degree of use of a new technology in long run equilibrium when the farmer has full information about the new technology and its potential" (p. 257).

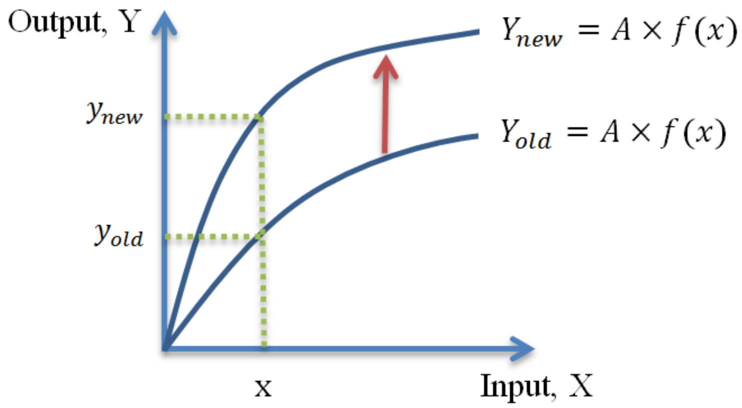
3.2.2 Incentive for Technology Adoption

Rogers (1983) points out that awareness of a need is regarded as a first step in the adoption process. The other steps pointed out by Lionberger (1960) are interest, evaluation, acceptance, trial and technology adoption.

Individuals adopt new technology when the value they expect to receive for the product is greater than the expected cost of producing the product (Hall and Khan 2003). Benefits received by the user and the costs of adoption are two obvious determinants of new technology adoption, and these benefits are the difference in profits when a firm shifts from an older technology to a newer technology (Hall and Khan 2003).

Figure 3.1 shows that new technology adoption shifts the production function up, that is, using the same amounts of inputs one can produce more output after adopting new technology. But new technology adoption is often costly for different kinds of reasons, for example, new machines need to be purchased and employees need to be trained to learn how to use the new technology (Hall and Khan 2003).

Figure 3.1: New technology shifting the production function



3.2.3 Factors Affecting Adoption of Technology/Best Management Practices

Many different technologies have been used in many different segments of the farming industry. Farm level adoption decisions rely on a variety of social and economic factors. Feder, Just and Zilberman (1985) review factors that influence new technology adoption, including farm characteristics, risk and uncertainty, human capital, labor availability, credit constraints, land tenure, and supply constraints.

Labor

New technologies can be regarded as either labor saving or labor intensive. As a result, adoption decisions can be affected by labor quality and availability (Feder, Just, and Zilberman 1985, 255-298; El-Osta and Morehart 2000, 477-498; Gillespie, Davis, and Rahelizatovo 2004, 35-48; Shields, Rauniyar, and Goode 1993, 469-484). Feder, Just and Zilberman (1985) find that labor shortages prevent farmers from adopting technologies that are yield improving. Farmers tend to adopt labor saving technologies if labor availability is decreased (Shields, Rauniyar, and Goode 1993, 469-484). El-Osta and Morehart (2000) find that increased usage of hired labor increases the probability of adopting a combined management and capital-intensive technology. Gillespie, Davis, and Rahelizatovo (2004) find that "producers who rated the quality of labor available as higher were more likely to adopt management-intensive technologies" (p. 35).

Operator's Age

Operator's age is an important factor that affecting technology adoption. Most of adoption literature shows a negative relationship between farmer age and technology adoption. This is because older farmers are sometimes considered to be risk-averse and thus less likely to adopt new technologies than are younger farmers. Operator's age was found to have a negative effect on profit per cow for Connecticut dairy cow by Foltz and Chang in 2002. Johnson and El-Osta (1998) find a significant and negative relationship between age of operator and U.S. dairy farm profitability.

Education

The level of higher education may increase the probability of technology adoption because more education is thought to create a favorable mental attitude for the acceptance of new practices. Most literature shows a positive relationship between education and technology adoption, for example, Zepeda (1994) in the adoption of DHIA by dairy farmers; Saha, Love and Schwart (1994) in the adoption of bST by dairy farmers; and Rahelizatovo and Gillespie (2004) in the adoption of best management practices (BMPs). Moreover, Mekonnen, Dehninet and Kelay (2010) find that the level of technology adoption is highly dependent on farmer's education level in Ethiopia. Higher education level also has a positive impact on farm profits. Mishra and Morehart (2001) find that operator's education positively influences financial success on the U.S. dairy farm.

Herd Size

Farmers who own large herds are more likely to adopt technologies because these farmers prefer new farming systems that are more labor saving. Herd size has been shown to positively and significantly affect farm profits by Foltz and Chang (2002), Winsten, Parsons and Hanson (2000) as well as Gloy, Hyde and LaDue (2002).

Ownership Structure

Farmers that own ratios tend to adoption technologies because the ownership of a ratio may enhance technology via improved access to new varieties released. However, in previous studies, there is no consistent conclusion on the relationship between farm ownership structure and farm level profits. Sole proprietorship has been shown to have a significant and positive impact on farm profits by Kauffman and Tauer (1986). Although some studies find a positive relationship between sole proprietorship and farm profits, more studies showed a negative relationship. Mishra and Morehart (2001) find that sole proprietorships have lower profits than partnerships or corporations. In the studies of Burton and Abderrezak (1998) as well as Garcia, Sonka and Yoo (1982), sole proprietorship has been shown to negatively affect expected profits.

Farm Age

Increase in farm age means increase in farm experience. Increase in experience can increase not only farm profitability, but also the probability of technology adoption. This is because experienced farmers are expected to have more knowledge about the benefits of a new technology which they could use for deciding whether or not to adoption the technology. Foster and Rosenzweig (1995) show that an increase at farmer's own experience increases farm profitability of the adoption of high-yielding seed varieties (HYVs), and farmers who have experienced neighbours are significantly more profitable than those who do not have experienced neighbours.

Debt-to-asset Ratio

Debt-to-asset ratio has been shown to have either no impact or negative impact on farm profitability. Gillespie, Davis and Rahelizatovo (2004) find that debt-to-asset ratio has no impact on the adoption of breeding technologies in U.S. hog production. The impact of the debt-to-asset ratio is uncertain as changes in return depend on the efficient use of borrowed funds (Haden and Johnson 1989, 105-112). Gloy, Hyde and LaDue (2002) and Lazarus, Streeter and Jofre-Giraudo (1990) find that the debt-to-asset ratio is negatively related to farm profitability. Moreover, farm profitability will be negatively affected by higher debt due to the interest costs subtracted from net farm income (Lazarus, Streeter, and Jofre-Giraudo 1990, 267-277).

Milking System

There is a positive relationship between using parlour milking system and farm profitability. El-Osta and Johnson (1998) find that a parlour milking system positively affects U.S. dairy farm profits. Farms with a parlour milking system are expected to generate higher profits than farms with a pipeline, bucket or transfer station milking system (Schraufnagel 2007).

Feeding System

Compared to a manual feeding system, a semi/fully automated feeding system can increase efficiency and financial returns. A semi/fully automated feeding system can increase labour efficiency (Ratnasena 2010). Using an automated feeding system can minimize waste while maximizing nutrition and returns (DeLaval 2013).

3.2.4 Impact on Farm Level Economic Performance

The literature on the relationship between technology adoption and economic performance is uncertain. For example, Foltz and Chang (2002) find no significant relationship between TMR and milk yield and profit per cow. But Schraufnagel (2007) finds that Wisconsin dairy farms that use the TMR feeding practice have significantly higher milk per cow and income per cow. El-Osta and Morehart (2000) as well as Stoneman and Kwon (1994) show that technology adoption has a positive effect on farm profitability. Stoneman and Kwon (1994) further find that non-adopters experience reduced profits compared to the adopters of new technologies. Lusk (2007) in a study of the economic value of genetic selection and marketing cattle, points out that the value of using leptin information to select optimal cattle is high, and the difference in per head profit between the best and the worst performing genotype is over $28. Although the above studies show that the adoption of technology leads to a better farm performance or increased farm profits, there is limited study on the impact of using TMR on farm profitability in general, and in Ontario, in particular.

Technology adoption has a positive impact on farmers. Asfaw (2010)'s study reveals that the adoption of improved agricultural technologies (*i.e.*, improved chickpea and pigeonpea technologies) has a significantly positive impact on crop income, which confirms the potentially direct role of technology adoption on improving rural household welfare. On the other hand, technology adoption may have a negative impact on farms at the same time. Yesuf, Kassie, and Köhlin (2009) find that "fertilizer adoption reduces yield variability, but increases the risk of crop failure. However, adopting soil and water conservation technology has no impact on yield variability, but reduces the downside risk of crop failure" (p. 8). As a result, different types of farm technology adoption lead to different risk implications.

Berry (2008) finds that the use of molecular genetics in the selection of breeding animals increases genetic gain for productivity and profitability in Irish dairy farms. Another study of the implementation of genomic technology by Mumford (2010) shows that the Australian dairy industry has seen vast genetic improvements and that these advancements in the industry have had a significant impact on the dairy enterprise. Farming families, communities, societies and the governments' GDP, as well as the potential for genomic selected animals in New Zealand, are expected to deliver a net worth of between $1.9 billion and $3.9 billion in extra profit to New Zealand dairy farmers over the next 20 years. Moreover, Murray (2012) points out that genomics leads to a faster rate of progress for all traits and brings more profit to the dairy producers in Canada. By using genetic testing, the research period is sharply shortened when compared with the traditional method. Consequently, the costs of manpower and resources are reduced correspondingly.

3.3 Summary

This chapter provides a literature review on the determinants of technology adoption and the economic impact of technology adoption. Most conclusions have shown that technology adoption has positive impacts on farm level economic performance. However, there is limited information on whether the effect of technology adoption on farm level economic performance is significant or not.

Chapter 4: Theoretical Framework

4.1 Introduction

In this chapter, the theoretical model of this study is provided to describe what influences farmer's decision to adopt the TMR feeding practice.

4.2 The Model

Assume a farmer who produces a single output is q. Let p denote output price. f(.) is a continuous and twice differentiable production function, X is a vector of inputs, and r is the vector of associated input prices. Fuel along with TMR mixer (input X_{TMR}) is assumed to be an input in the production process. Efficiency in the use of TMR mixer, assumed to vary between farms, is taken into account by incorporating the function $h(\alpha)$, which represents farmer's characteristics. The production function will thus be written

$$q = f(h(\alpha)X_{TMR}, X_{-TMR}), \tag{4.1}$$

where X_{-TMR} is the vector of all inputs except TMR. Farms are assumed to be price-takers both in the input and output markets.

A risk-averse dairy producer will maximize the expected utility of profits[2]. The choice variable is X, over which farmers maximize the expected utility of profit. In Canada, the dairy industry operates under the national supply management system.

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2 In the absence of uncertainty, one can use a cost minimization framework. Cost minimization problems are closely related to utility maximization problems. Expected utility maximization implies cost minimization in the absence of production uncertainty (Chavas 2004, 97). That is:

$$Max_q \left\{Max_x\{EU(pq - r'X: q = f(h(\alpha)X_{TMR}, X_{-TMR}))\}\right\}$$

$$= Max_q\{EU(pq + Max_x\{-r'X: q = f(h(\alpha)X_{TMR}, X_{-TMR})\})\}$$
$$= Max_q\{EU(pq - Min_x\{r'X: q = f(h(\alpha)X_{TMR}, X_{-TMR})\})\}$$
$$= Max_q\{EU(pq - C(r, q))\}$$

where $C(r, q) = Min_x\{r'X: q = f(h(\alpha)X_{TMR}, X_{-TMR})\}$ is the cost function in a standard cost minimization problem under uncertainty.

The supply management system limits each farm producing a fixed amount of milk according to the quota each farm purchases. As a result, in this study, farmers maximize the expected utility of profit subject to output q. These can be expressed as

$$Max\, E[U(\Pi)] = \text{Max}\, U(pq - r'X) \text{ subject to } q = f(h(\alpha)X_{TMR}, X_{-TMR}), \quad (4.2)$$

where U(.) is the Von Neuman-Morgenstern utility function.

The farmer will adopt TMR if the expected utility of profits after adoption is greater than the expected utility of profits before adoption. Assume now that a farmer can choose to adopt or not to adopt the TMR feeding practice. Denote X^1 for the optimal input choices if the technology is adopted, and X^0 for the optimal input choices if the technology is not adopted. Adopting the technology implies a fixed cost ($I_1 > 0$ and $I_0 = 0$). Expected utility of profits under adoption is

$$E[U(\Pi^1)] = U(pf(h_1(\alpha)X^1_{TMR}, X^1_{-TMR}) - r^1_{TMR}X^1_{TMR} - r'_{-TMR}X^1_{-TMR} - I_1), \quad (4.3)$$

and expected utility of profits with no adoption is

$$E[U(\Pi^0)] = U(pf(h_0(\alpha), X^0_{-TMR}) - r'_{-TMR}X^0_{-TMR}). \quad (4.4)$$

The farmer will choose to adopt the TMR technology if

$$E[U(\Pi^1)] - E[U(\Pi^0)] > 0. \quad (4.5)$$

Farmer's choice thus depends on input and output prices, the fixed cost of the new technology, technology parameters and the farmer's characteristics.

4.3 Hypothesis

According to the conceptual framework, the null hypothesis that will be tested in the empirical framework can be written as the following:

H_0: The farm level profitability/productivity is not affected by the use of TMR feeding practice.

H_a: The use of the TMR feeding practice has significant impact on farm level profitability/productivity.

If the null hypothesis is rejected, the use of the TMR feeding practice should have a statistically significant impact on farm profitability/productivity, that is, the adoption of the TMR feeding practice may increase/decrease at dairy farm's profits/productivity. If failing to reject the null hypothesis, TMR may not have statistically significant impact on farm level profitability/productivity.

4.4 Summary

A theoretical framework was developed to determine factors affecting the adoption of the TMR feeding practice. Based on the theoretical framework, the null hypothesis addressed as TMR does not have significant impact on farm level profitability/productivity, while the alternative hypothesis is that farm level profitability/productivity is significantly affected by TMR. The null hypothesis has been tested empirically as described in the following chapter.

Chapter 5: Empirical Framework

5.1 Introduction

With an aim to empirically test the null hypothesis that TMR does not have a significant influence on farm profitability, an econometric model is specified with the introduction of variables that represent the adoption of the TMR feeding practice. The econometric model will be set up and discussed in this chapter. Sources and description of data, definitions of dependent variable and independent variables will also be provided.

5.2 Econometric Model

5.2.1 Adoption Model

Whether or not farmers decide to adopt TMR is dependent on the farms and farmers' characteristics. The decision of a farmer to adopt TMR is based on each farmer's self-selection instead of random assignment. As a result, a dummy variable for TMR adoption should be endogenized by using an index function model. The index function to estimate farmers' TMR adoption is:

$$PTMRC_i = Z_i'\gamma + u_i, \quad (5.1)$$

where $PTMRC_i$ is an unobservable index variable denoting the difference between the utility of using TMR (U_{i1}) and the utility of not using TMR (U_{i0}). If $PTMRC_i = U_{i1} - U_{i0} > 0$, then the individual farmer i will use TMR. The term $Z_i'\gamma$ provides an estimate of $U_{i1} - U_{i0}$, using farms and farmers characteristics. The term Z_i are explanatory variables and u_i is an error term unobserved by the researcher and assumed to be distributed normally with mean zero and variance one, that is, $u_i \sim N(0,1)$. This model can then be estimated with a standard probit log-likelihood function.

5.2.2 Propensity Score Matching

According to Khandker, Koolwal, and Samad (2010), instrumental variable (IV) methods allow for endogeneity in individual participation, program placement, or both. With panel data, IV methods can allow for time-varying selection bias. Measurement error that results in attenuation bias can also be resolved through this procedure. However, the IV approach involves finding a variable (or instrument) that is highly correlated with program placement or participation but that is not correlated with unobserved characteristics affecting outcomes, which is hard to find in this study. Double-difference (DD) methods assume that unobserved heterogeneity in participation is present—but that such factors are time invariant. DD essentially compares treatment and comparison groups in terms of outcome changes over time relative to the outcomes observed for a pre-intervention baseline (Khandker, Koolwal, and Samad 2010, 53-68). However, the data used in this study lacks initial baseline survey of both nonparticipants and participants. That is, a two-period setting is invalid.

In order to avoid self-selection bias, Foltz and Chang (2002) use the probit model to determine the factors affecting the adoption of rbST and to examine the effect of rbST on productivity and profitability for Connecticut dairy farms. This probit model is also known as adoption model with self-selectivity. However, there may be a problem if using the self-selection model for examining the effect of TMR adoption on farm level productivity and profits in this study. That is, the outcome cannot tell whether the adoption of TMR affects farm profit or there are other reasons that lead to this outcome (*e.g.*, does TMR adoption increase dairy farm's profits, or is the positive correlation we observe due to the fact that richer farmers are able to adopt TMR technology?). In other words, we should take into consideration not only the correlation between TMR adoption and farm profits, but also the underlying causation. As a result, with an aim to find out the extent that the net difference in outcomes between the treated group (*i.e.*, TMR users) and the non-treated group (*i.e.*, TMR non-users), this study uses the propensity score matching (p-score matching, or PSM) method. This method constructs a statistical comparison group by modeling the probability of participating in the program on the basis of observed characteristics unaffected by the program (Khandker, Koolwal, and Samad 2010). The observations of the treated groups and the non-treated groups are attributed to the use of TMR, given that all other things (*e.g.*, operator's age, education, herd size, other technologies used, breed type, etc.) are held constant.

The reasons for choosing this method are as follows: 1) PSM can help remove selection bias; 2) PSM does not require functional form assumptions for outcome equation. Regression model impose a form on relationship which may or may not be accurate and which PSM avoid; 3) PSM reduces the number of dimensions on which to match participants and comparison units; and 4) unlike Ordinary Least Square (OLS) and Instrumental Variable (IV) estimations (which impose linear functional form that will be biased and inconsistent), the PSM method makes it possible to develop a counterfactual or control group (*i.e.*, TMR non-users) that is as similar to the treatment group (*i.e.*, TMR users) as possible in terms of observed characteristics (*e.g.*, operator's age, education, herd size, other technologies used, breed type, etc.) (Khandker, Koolwal, and Samad 2010, 53-68). That is, each participant (a TMR user) is matched with an observationally similar non-participant (a TMR non-user), and then the average difference in outcomes across the two groups (TMR users and non-users) is compared in order to get the program treatment effect (which is the effect of TMR adoption on farm profits).

TMR adoption is assumed to be a function of a wide range of observable farm and farmer characteristics. The PSM procedure balances distributions of observed covariates between a treatment group (TMR users) and a control group (TMR non-users) based on the similarity of their predicted probabilities of adopting TMR technology (their 'p-score') (Mendola 2007, 372-393). There are four steps for examining the effect of TMR adoption on farm level productivity and profits by using the PSM approach in this study.

1st Step: Estimating the Propensity Score

Propensity score is the probability of adopting TMR given a vector of observed variables (*e.g.*, operator's age, education, herd size, other technologies used, breed type, etc.).

$$p(x) = Pr[D = 1|X = x], \quad (5.2)$$

where D=1 means the individual is in the treatment group (*i.e.*, TMR users group). x[3] is a subset of X. Following Rosembaum and Rubin (1983), the propensity score is estimated using a logit model. In other words, this step involves running a logit model to estimate the probability of a dairy farmer being in the TMR users group, and this step is used for all dairy farmers in the TMR users and non-users group.

2nd Step: Matching the TMR Users and Non-users Using Propensity Score

Once the propensity score is estimated, each TMR user can be matched with an identical TMR non-user based on farm characteristics by using matching methods[4] (Nearest Neighborhood Matching, Kernel Matching and Radius Matching).

3rd Step: Estimating the Average Treatment Effect on the Treated (ATT)

Since in reality, a farmer cannot be observed both under treatment and without treatment at the same time, so the counterfactual condition has to be made to get the difference in the outcomes of interest (*i.e.*, productivity and profits). This study uses average treatment effect for the treated (ATT) to represent the program treatment effect, that is, the effect of TMR adoption on farm level productivity and profits. The equation for calculating the ATT value can be expressed as

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[3] There is a common support stating that "the overlap condition for persons with the same x value in X are allowed to have a positive probability of being in treated and control group" (Chen and Zeiser 2007).

[4] Nearest Neighbor Matching (NNM): a unit in control group is matched to a treated unit based on the closest propensity score (Chen and Zeiser 2007). There are two ways using this method: matching "with replacement" and "without replacement". In the matching with replacement case, an untreated unit can be used more than once. The average matching quality will be increased, but fewer cases will be used as well. In the matching without replacement case, an untreated unit can be used only once. NNM method faces the risk of bad matches if the closest neighbor is far away.

Kernel Matching (KM): using weighted averages of all units in the control group to construct the counterfactual match for each treated unit (Grill and Rampichini 2011). The closest control units are given the greatest weight (Chen and Zerser 2007). This method lowers variance as more information is used. However, this method will include possibly bad matches at the same time.

Radius Matching (RM): using a tolerance level on the maximum propensity score distance (caliper) to avoid the risk of bad matches (Chen and Zeiser 2007). All the units in control group within the caliper will be used. If none of the units in control group is within the pre-specified distance from the treated unit, this treated unit is excluded from the analysis (Grilli and Rampichini 2011). Compared to NNM, this method has a better matching quality. However, it is difficult to choose a reasonable tolerance level.

$$|P_i - P_j| < \delta$$

where P is the propensity score and δ is the caliper of width.

There is no "winner" of all situations. Thus this study explores a number of approaches to see which one works best.

$$E(Y^1 - Y^0|D = 1) = E(Y^1|D = 1) - E(Y^0|D = 1), \quad (5.3)$$

where Y^1 denotes outcomes after treatment (*i.e.*, productivity/profit after TMR adoption) and Y^0 denotes outcomes without treatment (*i.e.*, productivity/profit without TMR adoption).

4th Step: Assessing the Quality of Matching

The last step is to see whether there are any significant differences in the weighted mean of X_s' between TMR users group and non-users group. If the balance is good, none of the X_s' should be significantly different between the two groups. That is, the two groups should be very similar. This can be checked by using a t-test. If the p-value is above 0.1 (*i.e.*, the null hypothesis of equal means cannot be rejected at the 10 percent level for all variables), it can be confidently concluded that the results concerning the differences between TMR users and non-users are based on similar dairy farms (Gadd, Hansson and Mansson 2009).

5.3 Data

Farm level data from 2004-2008 is taken from the Ontario Dairy Farm Accounting Project (ODFAP), which consists of extensive disaggregated information on revenue and costs, and also consists of the physical and financial structures of each sample farm. It is unbalanced panel data[5], which maintains a sample of farms representing typical Ontario dairy situations and different technology levels, regional differences and other significant factors. Consumer price index (CPI) deflator used in this study is the CPI for all items in Ontario, index 2002=100. The CPI data range from 2004 to 2008 and are taken from Statistics Canada.

As this study aims to examine the economic impact of the use of total mixed ration (TMR) on farm level productivity and profitability, a sub-sample of farms was selected with the revenue greater or equal to 80% of farm's revenue is derived from dairy enterprise[6] (Moschini 1988, 187-206). As a result, the sample consists of 320 dairy farms that are fairly specialized in milk production.

5.4 Variable Description

The main variables of interest are productivity and profits. The independent variables include variables for 1) the adoption of TMR; 2) farm operator's characteristics; 3) farm management characteristics; 4) the adoption of other technologies and 5) the time trend. Variable selection is guided by previous studies[7].

5.4.1 Dependent Variable

Profit per cow: Profit (Y) is defined as the difference between the total revenue received by a firm and its total cost of production (Nicholson and Snyder 2011). Total revenue is defined as the direct revenue from a farm's cow enterprise, which includes milk revenue and livestock (cull cows, breeding cows and bulls) sold. According to ODFAP annual report (2011), dairy enterprise consists of dairy cows, the raising of

[5] Panel data is also called longitudinal data or cross-sectional time series data. For an unbalanced data, the number of observations per time period varies.
[6] There are seven enterprises in the ODFAP database: general farm, cows (dairy herd), replacement, small grain, hay/haylage/pasture, corn/corn silage and overhead.
[7] Foltz and Chang, 2002; Gloy, Hyde and LaDue, 2002; Schraufnagel, 2007.

replacements and/or any related livestock born of the dairy cow herd, and the supporting crop production associated with both. Total cost includes total direct expenses from the farm's cow enterprise (such as milking supplies, milk trucking, cattle marketing, livestock registration, livestock insurance, and quota rental, etc.), total allocation expenses from the farm's cow enterprise (such as heating, taxes, labor, and barn equipment repair, etc.), and intermediate expenses from the farm's crops (including small grain, hay and corn) and replacement enterprises[8]. Profit per cow (Y_{it}) is calculated as

$$\begin{aligned}&(\text{direct revenue from the farm's cow enterprise}\\&- \text{direct expenses from the farm's cow enterprise}\\&- \text{total allocation expenses from the farm's cow enterprise}\\&- \text{intermediate expenses from the farm's crops and replacement enterprises})\\&\div \text{total number of cows.} \qquad (5.4)\end{aligned}$$

Profit per cow (CAD$/head) is calculated by using total revenue minus total cost, and then deflated by CPI (index 2002=100).

Milk per cow: Milk per cow (Y), a measure for productivity, is defined as milk shipped per lactating cow (hl/head) per year.

5.4.2 Independent Variables

The independent variables are hypothesized to influence Ontario dairy farms' profit consisting of five parts: 1) the adoption of TMR fed to milk cow; 2) farm operator's characteristics; 3) farm management characteristics; 4) the adoption of other technologies and 5) the time trend.

The use of TMR: To examine the effect of TMR on dairy farm level profit, a dummy variable is used to represent TMR fed to milk cows ($DUM.TMRC_{it}$). The dummy variable is equal to 1 for the farms observed during 2004-2008, representing the adoption of TMR fed to milk cows, and 0 otherwise. This can be expressed as

[8] Intermediate costs from crops (including small grain, hay and corn) and replacement enterprises = total allocation expenses from crops (including small grain, hay and corn) and replacement enterprises + total direct expenses from crops (including small grain, hay and corn) and replacement enterprises – total direct revenue from crops (including small grain, hay and corn) and replacement enterprises

$$DUM.TMRC_{it} = 1 \; if \; TMR \; fed \; to \; milk \; cows; 0 \; otherwise. \tag{5.5}$$

Farm operator's characteristics: Farm operator's characteristics include farm principal operator's age (AGE_{it}) and operator's formal education ($DUM.EDU_{it}$).

Age is a factor thought to affect technology adoption. Most of the adoption studies show a negative relationship between farmer's age and adoption. For example, Johnson and El-Osta (1998) find a significant and negative relationship between age of operators and U.S. dairy farm profitability. Foltz and Chang (2002) find that age has a negative effect on profit per cow in Connecticut dairy farms. Older farmers are considered to be risk-averse and thus less likely to adoption new technologies than younger farmers, operator's age is hypothesized to affect farm level profit negatively in this study.

Education reflects the ability to adopt new technology (Nelson and Phelps 1966, 69-75; Wozniak 1984, 70-79). More education is expected to create a favorable mental attitude for the acceptance of new practices. Education is considered a factor affecting the use of TMR feeding practice. Higher level of education has been found to increase the probability of technology adoption by Zepeda (1994) in the adoption of DHIA by dairy farmers; Saha, Love and Schwart (1994) in the adoption of bST by dairy farmers; and Rahelizatovo and Gillespie (2004) in the adoption of best management practices (BMPs). Moreover, Mekonnen, Dehninet and Kelay (2010) find that the level of technology adoption is highly dependent on farmer's education level in Ethiopia. Mishra and Morehart (2001) find that operator's education positively influences financial success in U.S. dairy farm. As a result, operator's education is hypothesized to have a positive effect on farm profit level. A dummy variable is set equal to 1 if the principal operator has a formal education higher than high school (*i.e.*, Agricultural Diploma, Community College, B.Sc. Degree or Post Graduate Degree), and 0 otherwise. These can be expressed as

$$DUM.EDU_{it} = 1 \; if \; greater \; than \; high \; school \; level \; education; \; 0 \; otherwise. \tag{5.6}$$

Farm management characteristics: Farm management characteristics consist of herd size ($COWS_{it}$), farm ownership structure ($DUM.BTYPE_{it}$), adoption of record-keeping technology adoption ($DUM.RECORD_{it}$), farm age ($FAGE_{it}$), debt-to-asset ratio (DAR_{it}), South-Western region ($DUM.SW_{it}$), South-Eastern region ($DUM.SE_{it}$), breed type of herd ($DUM.BREED_{it}$).

Since farmers with large herd size would prefer new farming systems that are more labor saving, herd size, which is measured as total number of cows per farm, is considered in this study. Herd size has been shown to positively and significantly affect farm profits by Foltz and Chang (2002), Winsten, Parsons and Hanson (2000) as well as Gloy, Hyde and LaDue (2002). Thus, herd size is expected to have a positive influence on farm profits, that is, the coefficient of herd size is hypothesized to be positive.

Farmers that own ratios tend to adopt technologies because the ownership of a ratio may enhance technology via improved access to new varieties. As a result, ownership structure is taken into account. Farm ownership structure consists of sole proprietorship, partnership and corporation. Different types of farm ownership structure may lead to different farm management. There is no consistent conclusion on the relationship between farm ownership structure and farm level profits. Sole proprietorship has been shown to have a significant and positive impact on profits by Kauffman and Tauer (1986). However, Mishra and Morehart (2001) find that sole proprietorships have lower profits than partnerships or corporations. In the studies of Burton and Abderrezak (1998) and Garcia, Sonka and Yoo (1982), sole proprietorship has been shown to negatively affect expected profits. In this study, a dummy variable is set to equal 1 if a farm is a sole proprietor and 0 if a farm is a partnership/corporation. These can be expressed as

$$DUM.BTYPE_{it} = 1 \; if \; sole \; proprietor, and$$
$$DUM.BTYPE_{it} = 0 \; if \; partnership/corporation. \quad (5.7)$$

Record-keeping technologies provide farmers with necessary information in animal feeding and breeding (Foltz and Chang 2002, 1021-1032; Gloy, Hyde, and LaDue 2002, 233-247). Thus, the adoption of record-keeping technologies is expected to have a positive impact on farm profits. A dummy variable is set to equal 1 if a farm adopts record-keeping technologies and 0 otherwise. These can be expressed as

$$DUM.RECORD_{it} = 1\ if\ adopt\ record\text{-}keeping; 0\ otherwise. \tag{5.8}$$

Farm age, which captures farm experience, refers to the number of years since a farm starts shipping milk. Since experienced farmers are expected to have more knowledge about the benefits of a new technology, increase in experience can increase the probability of technology adoption. Increase in farmer's own experience increases farm profitability of high-yielding seed varieties (HYVs) adoption and farmers who have experienced neighbors are significantly more profitable than those who do not have experienced neighbors (Foster and Rosenzweig 1995, 1176-1209). Increase in farm age/farm experience leads to better knowledge about correct management of technology adoption, which results in higher farm profits. Thus, the coefficient of farm age is hypothesized to be positive.

The debt-to-asset ratio[9], a measure of a farm's financial management, reflects the proportion of a farm's assets which are financed through debt. The impact of the debt-to-asset ratio is uncertain as changes in return depend on the efficient use of borrowed funds (Haden and Johnson 1989, 105-112). However, Gloy, Hyde and LaDue (2002) and Lazarus, Streeter and Jofre-Giraudo (1990) find that the debt-to-asset ratio is negatively related to farm profitability. Farm profitability will be negatively affected by higher debt due to the interest costs subtracted from the net farm income (Lazarus, Streeter, and Jofre-Giraudo 1990, 267-277). Thus, the debt-to-ratio is expected to negatively influence farm profitability.

Geographical characteristics affect adoption. Kaliba, Verkuijl and Mwangi (2000) find that geographical characteristics significantly influenced the adoption process of

[9] The debt-to-asset ratio is calculated as total farm debts divided by total farm assets. If the debt-to-asset ratio is less than one, most of the farm's assets are financial through equity. If the debt-to-asset ratio is greater than one, most of farm's assets are financial through debt.

improved maize seeds and inorganic fertilizers. Mekonnen, Dehninet and Kelay (2010) find that the level of technology adoption highly depends on the location of farmers. Not only are population heterogeneous and is individual behaviour dynamic, but there are also numerous differences in farm characteristics among regions. Due to this, regional area should be taken into consideration. The results from an adoption study on a feeding practice in one geographical setting do not always apply to another geographical setting. Moreover, even within a geographical setting, different regions have varying adoption patterns for the same type of feeding practice. As a result, region is considered in this study.

According to the ODFAP annual report (2011), samples are collected from grid areas in Southern Ontario. These grid areas are divided into six regions[10] on the basis of similar land capabilities, climatic factors and non-dairy opportunities. In this study, the six regions are further grouped into three main regions: South-Western region, South-Central region and South-Eastern region. Location dummy variables ($DUM.SW_{it}$ and $DUM.SE_{it}$) are created to represent different regions. The effect of regions on farm profitability is indeterminate. Due to the different agricultural environments, the coefficient of each region could be positive, negative or zero.

Different types of species can affect the level of adoption. For example, Mapiye et al. (2006) find that the adoption of forage and browse legumes in Zimbabwe dairy farms is affected by the type of species. In this study, approximately 95% of cows in the sample collected by ODFAP are Hosltein, which generates higher milk yield than any other breeds (such as Jersey, Ayrshire, Guernsey and mixed breeds). The breed of cows is expected to have a positive impact on farm profitability. A breed dummy variable is set to equal 1 if the breed is Holstein and 0 otherwise. These can be

[10] The countries included in each region are as follows:

Region 1: Elgin, Essex, Kent, Lambton, Middlesex, Norfolk (South-western region)
Region 2: Brant, Huron, Oxford, Perth, Waterloo (South-western region)
Region 3: Bruce, Dufferin, Grey, Simcoe, Wellington (South-central region)
Region 4: Durham, Haldimand, Halton, Niagara, Northumberland, Ontario, Peel, Prince Edward, Wentworth, York (South-central region)
Region 5: Frontenac, Hastings, Lanark, Leeds, Lennox and Addington, Peterborough, Victorria (South-eastern region)
Region 6: Carleton, Dundas, Glengarry, Grenville, Prescott, Renfrew, Russell, Stormont (South-eastern region)

expressed as

$$DUM.BREED_{it} = 1 \; if \; Holstein, and$$
$$DUM.BREED_{it} = 0 \; if \; Jersey, Guerney \; or \; mixed \; breeds. \qquad (5.9)$$

Adoptions of other technologies: Other technologies associated with the dairy production include the milking system ($DUM.MS_{it}$) and the feeding system ($DUM.FS_{it}$).

There are four types of milking systems: parlour, pipeline, bucket and transfer station. El-Osta and Johnson (1998) find that the parlour milking system positively affects U.S. dairy farm profits. Farms with the parlour milking system are expected to generate higher profits than farms with pipeline, bucket or transfer station milking system (Schraufnagel 2007). Thus, the coefficient of the parlour milking system is hypothesized to be positive. A dummy variable is set to equal 1 if a farm uses the parlour milking system and 0 otherwise. These can be expressed as

$$DUM.MS_{it} = 1 \; if \; parlour, and$$
$$DUM.MS_{it} = 0 \; if \; pipeline, bucket \; or \; transfer \; station. \qquad (5.10)$$

A semi/fully automated feeding system can increase labour efficiency (Ratnasena, 2010). Using an automated feeding system can minimize waste while maximizing nutrition and returns (DeLaval, 2013). Thus, an automated feeding system is expected to have a positive impact on farm profitability. A dummy variable is set to equal 1 if a farm uses a semi/fully automated feeding system and 0 if a farm uses a manual feeding system. These can be expressed as

$$DUM.FS_{it} = 1 \; if \; semi/fully \; automated, and$$
$$DUM.FS_{it} = 0 \; if \; manual. \qquad (5.11)$$

Time trend: The time period used in this study is from 2004 to 2008. Time trend variables account for any time-variant factors (such as weather, technology, etc.) that are not captured in the regression.

A summary of variable descriptions is showed in Table 5.1.

Table 5.1: Variable descriptions

Variables	Unit	Description
Dependent Variables		
Dairy profit per cow (Y_{it})	CAD$/head	(Total direct revenue from cow enterprise − total direct expense from cow enterprise − total allocation expense from cow enterprise − intermediate expenses from small grain, hay, corn and replacement enterprises) ÷ Number of cows
Milk production per cow (Y_{it})	Hectoliter/head	Average milk production per cow per year
Independent Variables		
Total Mixed Ration (TMR) fed to milk cows ($DUM.TMRC_{it}$)	1/0	1 = TMR fed to milk cows; 0 otherwise
Probit Total Mixed Ration (TMR) fed to milk cows ($PTMRC_{it}$)	Number	Adoption of probit TMR fed to milk cow
Farm Operator Characteristics		
Age (AGE_{it})	Year	Number of Years
Education ($DUM.EDU_{it}$)	1/0	1 = Greater than high school level education; 0 otherwise
Farm Characteristics		
Herd size ($COWS_{it}$)	Number	Number of milk cows
Ownership structure ($DUM.BTYPE_{it}$)	1/0	1 = Sole proprietor; 0 = partnership or corporation
Milk record-keeping system ($DUM.RECORD_{it}$)	1/0	1 = Adopt record-keeping technologies; 0 otherwise
Farm age ($FAGE_{it}$)	Number	T = 1 if Year = 1951, T = 2 if Year = 1952,…, T = 56 if Year = 2006
Debt-to-asset ratio (DAR_{it})	Ratio	Total liabilities ÷ total assets
South-Western region ($DUM.SW_{it}$)	1/0	1 = South-Western region; 0 otherwise
South-Eastern region ($DUM.SE_{it}$)	1/0	1 = South-Eastern region; 0 otherwise

Continued

Table 5.1: Variable descriptions (Continued)

Variables	Unit	Description
Breed type of herd ($DUM.BREED_{it}$)	1/0	1 = Holstein; 0 otherwise
Other Technologies		
Milking system ($DUM.MS_{it}$)	1/0	1 = Parlour; 0 otherwise
Feeding system ($DUM.FS_{it}$)	1/0	1 = Semi/Fully automated; 0 = manual
Time Trend		
Time trend (T_i)	Number	T = 1 if Year = 2004, T = 2 if Year = 2005,…, T = 5 if Year = 2008

5.5 Descriptive Statistics

Table 5.2 shows the numbers and proportions of sample Ontario farms using the TMR feeding practice between 2004 and 2008. The data that I would like to highlight is the number of farms that fed TMR to milk cows. The percentage of dairy farms adopting TMR fed to milk cows slightly fluctuated from 2004 to 2008; however, it shows a general increasing trend, from 54.9% (2004) to 66.1% (2008).

Table 5.2: Numbers and proportions of sample farms using TMR feeding practice, 2004-2008

Year	Number of Farms Observed	Farms that Fed TMR to Milk Cows	Farms that Separated Milk Cows and Fed TMR according to Production	Farms that Fed TMR to Replacement
2004	71	39 (54.9%)	31 (43.7%)	25 (35.2%)
2005	60	37 (61.7%)	30 (50.0%)	18 (30.0%)
2006	59	39 (66.1%)	25 (42.4%)	25 (42.4%)
2007	68	48 (70.6%)	35 (51.5%)	29 (42.6%)
2008	62	41 (66.1%)	29 (46.8%)	21 (33.9%)

Source: Ontario Dairy Farm Accounting Project (2004-2008)

Note: 1. Farms that Fed TMR to Milk Cows: numbers and proportions of dairy farms that only use TMR feeding practice on their milk cows;

2. Farms that Separated Milk Cows and Fed TMR according to Production: numbers and proportions of dairy farmers that separate milk cows first and feed each group of milk cows TMR according to their milk production. Fed TMR according to production is differentiated based on milk production, which is usually done by grouping cows by stage of lactation in a free stall;

3. Farms that Fed TMR to Replacement: numbers and proportions of dairy farmers that only use TMR feeding practice on their replacement cows.

Table 5.3 shows a comparison of profits and productivity before and after a particular sample farm used the TMR feeding practice. This farm was the only farm in the samples that switched to using TMR feeding practice during the 2004-2005 time periods. The results show that after using TMR feeding practice, the farm generated more profits (CAD$306.92) per cow per year and also milk production was increased by 421.74 hl/cow per year.

Table 5.3: Comparison between using and not using TMR feeding practice on a sample farm

	Using	Non-using	Difference
Profit per cow (CAD$/head)	2,105.48	1,798.56	306.92
Milk per cow (hl/head)	9,228.55	8,806.81	421.74
Year	2005	2004	

Source: Ontario Dairy Farm Accounting Project (2004-2005), Statistics Canada (2004-2005)

Note: Data have been deflated by CPI for all items in Ontario, index 2002=100.

With an aim to better understand the economic performance of dairy farms with and without TMR, Table 5.4 and Table 5.5 provide average milk production per cow and profit per cow, respectively. Comparisons between dairy farms with and without TMR are conducted for 2004, 2005, 2006, 2007 and 2008, respectively. The t-test is used to see whether the outcomes are significantly different at 1, 5, or 10% level. Table 5.4 shows that, for each year, average milk production per cow of TMR users is greater than average milk production per cow of TMR non-users. Especially for 2004, 2005, 2006 and 2008, the numbers of average milk production per cow for TMR users and TMR non-users are significantly different at the 1% level. Compared to other years (*i.e.*, 2004, 2005, 2006, and 2008), the number of TMR non-users who used parlour milking system doubled in 2007. Herd size of TMR non-users increased by 14% in 2007, which is 1.2% higher than the increased percentage of TMR users' herd size. These may contribute to the insignificant difference in productivity in 2007.

Table 5.5 shows that the average profit per cow (deflated by CPI, index 2002=100, for all items in Ontario) of TMR users is greater than the average profit per cow of TMR non-users. This result is significantly different at 5% level in 2005. Moreover, average profit per cow of TMR users continued to increase from 2004 (CAD$1,575.74/head) to 2008 (CAD$1,707.12/head).

Table 5.4: Productivity of TMR fed to milk cows (both users and non-users)

Milk shipped per lactating cow per year (hl)	Cows of TMR Users		Cows of TMR Non-Users		Difference	
2004	8819.97	(1214.36)	7528.62	(1476.53)	1291.35***	(319.26)
2005	9127.95	(1227.93)	7563.63	(1547.15)	1564.32***	(360.55)
2006	9199.73	(1263.02)	8112.45	(1480.99)	1087.27***	(368.44)
2007	9459.07	(1302.55)	8873.48	(2240.35)	585.59	(433.51)
2008	9246.37	(1288.40)	8021.06	(1592.00)	1225.32***	(374.87)

Source: Ontario Dairy Farm Accounting Project (2004-2008)

Note: 1. Standard deviation statistics are in the parentheses;

2. Difference is calculated by using the T-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.5: Profitability of TMR fed to milk cows (both users and non-users)

Profit per cow (CAD$/head)	Cows of TMR Users		Cows of TMR Non-Users		Difference	
2004	1575.74	(109.27)	1320.92	(132.38)	254.82	(170.07)
2005	1806.52	(100.75)	1352.82	(152.26)	453.70**	(175.20)
2006	1772.00	(100.22)	1533.59	(201.51)	238.41	(200.57)
2007	1773.04	(91.15)	1679.01	(176.51)	94.04	(181.18)
2008	1707.12	(136.53)	1385.68	(207.86)	321.43	(241.80)

Source: Ontario Dairy Farm Accounting Project (2004-2008), Statistics Canada (2004-2008)

Note: 1. Data have been deflated by CPI for all items in Ontario, index 2002=100;

2. Standard deviation statistics are in the parentheses;

3. Difference is calculated by using the T-test;

4. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.6 to 5.11 provide descriptive statistics of independent variables defined in Table 5.1 for each year between 2004 and 2008 and the aggregate level, respectively, to investigate if statistics of sample farms in ODFAP are consistent with the hypotheses in section 5.4.2.

For each single year (*i.e.*, 2004, 2005, 2006, 2007 and 2008) and the aggregate level (2004-2008), operator's age, milk record-keeping, farm age, and breed type do not show significant differences between TMR users and non-users. Herd size, ownership structure, milking system and feeding system, however, show significant differences between TMR users and non-users for each single year and the aggregate level. That is, compared to farms without TMR feeding practice, farms with TMR feeding practice have characteristics of larger herd sizes, partnership/corporation business types, parlour milking systems and semi/fully automated feeding systems. The education of operators is significantly different between TMR users and non-users for 2004, 2005 and aggregate level. The South-Western region shows significant differences between TMR users and non-users for 2004, 2005, 2006 and the aggregate level. The South-Eastern region shows significant differences between TMR users and non-users for 2004, 2005 and the aggregate level. The debt-to-asset ratio shows significant differences between TMR users and non-users for 2006, 2008 and the aggregate level.

Table 5.6: Characteristics of Ontario dairy farms using and not using TMR fed to milk cow in 2004

Variables	TMR Users		TMR Non-Users		Difference	
Farm operator's age	46.21	(1.61)	47.88	(1.54)	-1.67	(2.26)
Farm operator' education (1 = greater than high school level education; 0 otherwise)	0.69	(0.07)	0.41	(0.09)	0.29**	(0.11)
Herd size	78.71	(9.23)	46.03	(2.15)	32.67***	(10.39)
Ownership structure (1 = sole proprietor; 0 otherwise)	0.10	(0.05)	0.25	(0.08)	-0.15*	(0.09)
Milk record-keeping system	0.87	(0.05)	0.94	(0.04)	-0.07	(0.07)
Farm age	34.26	(1.89)	33.53	(2.09)	0.73	(2.82)
Debt-to-asset ratio	0.27	(0.03)	0.21	(0.03)	0.06	(0.05)
South-Western region (SW)	0.44	(0.08)	0.13	(0.06)	0.31***	(0.10)
South-Eastern region (SE)	0.23	(0.07)	0.47	(0.09)	-0.24**	(0.11)
Breed type of herd (1 = Holstein; 0 otherwise)	0.95	(0.04)	0.97	(0.03)	-0.02	(0.05)
Milking system (1 = parlour; 0 = otherwise)	0.28	(0.07)	0.06	(0.04)	0.22**	(0.08)
Feeding system (1 = semi/fully automated; 0 = manual)	0.97	(0.03)	0.81	(0.07)	0.16**	(0.07)

Source: Ontario Dairy Farm Accounting Project (2004)

Note: 1. Standard deviation statistics are in the parentheses;

2. Differences for continuous variables (*i.e.*, Farm operator's age, Herd size, Farm age, and Debt-to-asset ratio) are calculated by using the T-test; and differences for dummy variables (*i.e.*, Farm operator's education, Ownership structure, Milk record-keeping, South-western region, South-eastern region, Breed type of herd, Milking system and Feeding system) are calculated by using the P-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.7: Characteristics of Ontario dairy farms using and not using TMR fed to milk cow in 2005

Variables	TMR Users		TMR Non-Users		Difference	
Farm operator's age	46.86	(1.37)	47.61	(1.56)	-0.74	(2.13)
Farm operator' education (1 = greater than high school level education; 0 otherwise)	0.70	(0.08)	0.43	(0.10)	0.27**	(0.13)
Herd size	83.31	(10.15)	44.04	(2.60)	39.27***	(13.08)
Ownership structure (1 = sole proprietor; 0 otherwise)	0.05	(0.04)	0.22	(0.09)	-0.16*	(0.09)
Milk record-keeping system	0.81	(0.06)	0.87	(0.07)	-0.06	(0.10)
Farm age	35.43	(1.85)	35.96	(2.47)	-0.52	(3.04)
Debt-to-asset ratio	0.28	(0.03)	0.22	(0.04)	0.07	(0.05)
South-Western region (SW)	0.43	(0.08)	0.22	(0.09)	0.22*	(0.12)
South-Eastern region (SE)	0.19	(0.06)	0.39	(0.10)	-0.20*	(0.12)
Breed type of herd (1 = Holstein; 0 otherwise)	0.95	(0.04)	0.96	(0.04)	-0.01	(0.06)
Milking system (1 = parlour; 0 = otherwise)	0.43	(0.08)	0.09	(0.06)	0.35***	(0.10)
Feeding system (1 = semi/fully automated; 0 = manual)	0.95	(0.04)	0.61	(0.10)	0.34***	(0.11)

Source: Ontario Dairy Farm Accounting Project (2005)

Note: 1. Standard deviation statistics are in the parentheses;

2. Differences for continuous variables (*i.e.*, Farm operator's age, Herd size, Farm age, and Debt-to-asset ratio) are calculated by using the T-test; and differences for dummy variables (*i.e.*, Farm operator's education, Ownership structure, Milk record-keeping, South-western region, South-eastern region, Breed type of herd, Milking system and Feeding system) are calculated by using the P-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.8: Characteristics of Ontario dairy farms using and not using TMR fed to milk cow in 2006

Variables	TMR Users		TMR Non-Users		Difference	
Farm operator's age	47.46	(1.43)	45.65	(1.64)	1.81	(2.31)
Farm operator' education (1 = greater than high school level education; 0 otherwise)	0.64	(0.08)	0.45	(0.11)	0.19	(0.14)
Herd size	86.96	(9.93)	43.5	(2.86)	43.46***	(14.07)
Ownership structure (1 = sole proprietor; 0 otherwise)	0.05	(0.04)	0.20	(0.09)	-0.15*	(0.10)
Milk record-keeping system	0.87	(0.05)	0.90	(0.07)	-0.03	(0.09)
Farm age	37.18	(2.00)	39.15	(2.58)	-1.97	(3.35)
Debt-to-asset ratio	0.30	(0.04)	0.24	(0.04)	0.06	(0.06)
South-Western region (SW)	0.49	(0.08)	0.25	(0.10)	0.24*	(0.13)
South-Eastern region (SE)	0.21	(0.06)	0.35	(0.11)	-0.14	(0.12)
Breed type of herd (1 = Holstein; 0 otherwise)	0.95	(0.04)	0.95	(0.05)	0.00	(0.06)
Milking system (1 = parlour; 0 = otherwise)	0.41	(0.08)	0.10	(0.07)	0.31**	(0.10)
Feeding system (1 = semi/fully automated; 0 = manual)	0.97	(0.03)	0.70	(0.10)	0.27***	(0.11)

Source: Ontario Dairy Farm Accounting Project (2006)

Note: 1. Standard deviation statistics are in the parentheses;

2. Differences for continuous variables (*i.e.*, Farm operator's age, Herd size, Farm age, and Debt-to-asset ratio) are calculated by using the T-test; and differences for dummy variables (*i.e.*, Farm operator's education, Ownership structure, Milk record-keeping, South-western region, South-eastern region, Breed type of herd, Milking system and Feeding system) are calculated by using the P-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.9: Characteristics of Ontario dairy farms using and not using TMR fed to milk cow in 2007

Variables	TMR Users		TMR Non-Users		Difference	
Farm operator's age	47.92	(1.35)	44.40	(1.52)	3.52	(2.32)
Farm operator' education (1 = greater than high school level education; 0 otherwise)	0.65	(0.07)	0.55	(0.11)	0.10	(0.13)
Herd size	97.24	(9.16)	49.53	(2.73)	47.71***	(14.36)
Ownership structure (1 = sole proprietor; 0 otherwise)	0.06	(0.03)	0.40	(0.11)	-0.34***	(0.11)
Milk record-keeping system	0.96	(0.03)	0.95	(0.05)	0.01	(0.06)
Farm age	38.25	(1.83)	40.05	(2.85)	-1.80	(3.38)
Debt-to-asset ratio	0.36	(0.04)	0.30	(0.05)	0.06	(0.06)
South-Western region (SW)	0.40	(0.07)	0.30	(0.10)	0.10	(0.12)
South-Eastern region (SE)	0.27	(0.06)	0.45	(0.11)	-0.18	(0.13)
Breed type of herd (1 = Holstein; 0 otherwise)	0.96	(0.03)	0.90	(0.07)	0.06	(0.07)
Milking system (1 = parlour; 0 = otherwise)	0.48	(0.07)	0.20	(0.09)	0.28**	(0.11)
Feeding system (1 = semi/fully automated; 0 = manual)	0.96	(0.03)	0.75	(0.10)	0.21***	(0.10)

Source: Ontario Dairy Farm Accounting Project (2007)

Note: 1. Standard deviation statistics are in the parentheses;

2. Differences for continuous variables (*i.e.*, Farm operator's age, Herd size, Farm age, and Debt-to-asset ratio) are calculated by using the T-test; and differences for dummy variables (*i.e.*, Farm operator's education, Ownership structure, Milk record-keeping, South-western region, South-eastern region, Breed type of herd, Milking system and Feeding system) are calculated by using the P-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.10: Characteristics of Ontario dairy farms using and not using TMR fed to milk cow in 2008

Variables	TMR Users		TMR Non-Users		Difference	
Farm operator's age	47.24	(1.58)	47.48	(1.76)	0.23	(2.55)
Farm operator' education (1 = greater than high school level education; 0 otherwise)	0.63	(0.08)	0.52	(0.11)	0.11	(0.13)
Herd size	91.40	(9.62)	49.36	(2.81)	42.03***	(13.64)
Ownership structure (1 = sole proprietor; 0 otherwise)	0.12	(0.05)	0.33	(0.10)	-0.21**	(0.11)
Milk record-keeping system	0.93	(0.04)	1.00	(0.00)	-0.07	(0.04)
Farm age	40.73	(1.73)	39.71	(2.66)	1.02	(3.07)
Debt-to-asset ratio	0.38	(0.04)	0.27	(0.05)	0.12*	(0.06)
South-Western region (SW)	0.38	(0.08)	0.25	(0.10)	0.13	(0.12)
South-Eastern region (SE)	0.23	(0.07)	0.35	(0.11)	-0.12	(0.13)
Breed type of herd (1 = Holstein; 0 otherwise)	0.93	(0.04)	0.86	(0.08)	0.07	(0.09)
Milking system (1 = parlour; 0 = otherwise)	0.51	(0.08)	0.10	(0.06)	0.42***	(0.10)
Feeding system (1 = semi/fully automated; 0 = manual)	0.98	(0.04)	0.57	(0.12)	0.40***	(0.11)

Source: Ontario Dairy Farm Accounting Project (2008)

Note: 1. Standard deviation statistics are in the parentheses;

2. Differences for continuous variables (*i.e.*, Farm operator's age, Herd size, Farm age, and Debt-to-asset ratio) are calculated by using the T-test; and differences for dummy variables (*i.e.*, Farm operator's education, Ownership structure, Milk record-keeping, South-western region, South-eastern region, Breed type of herd, Milking system and Feeding system) are calculated by using the P-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

Table 5.11: Characteristics of Ontario dairy farms using and not using TMR fed to milk cow in aggregate level (2004-2008)

Variables	TMR Users		TMR Non-Users		Difference	
Farm operator's age	47.18	(0.65)	46.77	(0.72)	0.41	(1.02)
Farm operator' education (1 = greater than high school level education; 0 otherwise)	0.66	(0.03)	0.47	(0.05)	0.20***	(0.06)
Herd size	88.03	(4.28)	46.41	(1.16)	41.62***	(5.75)
Ownership structure (1 = sole proprietor; 0 otherwise)	0.08	(0.02)	0.28	(0.04)	-0.20***	(0.05)
Milk record-keeping system	0.89	(0.02)	0.93	(0.02)	-0.04	(0.03)
Farm age	37.27	(0.84)	37.22	(1.12)	0.05	(1.40)
Debt-to-asset ratio	0.32	(0.02)	0.24	(0.02)	0.08***	(0.03)
South-Western region (SW)	0.43	(0.03)	0.22	(0.04)	0.21***	(0.05)
South-Eastern region (SE)	0.23	(0.03)	0.41	(0.05)	-0.18***	(0.05)
Breed type of herd (1 = Holstein; 0 otherwise)	0.95	(0.02)	0.93	(0.02)	0.02	(0.03)
Milking system (1 = parlour; 0 = otherwise)	0.43	(0.03)	0.10	(0.03)	0.32***	(0.04)
Feeding system (1 = semi/fully automated; 0 = manual)	0.97	(0.01)	0.70	(0.04)	0.27***	(0.04)

Source: Ontario Dairy Farm Accounting Project (2004-2008)

Note: 1. Standard deviation statistics are in the parentheses;

2. Differences for continuous variables (*i.e.*, Farm operator's age, Herd size, Farm age, and Debt-to-asset ratio) are calculated by using the T-test; and differences for dummy variables (*i.e.*, Farm operator's education, Ownership structure, Milk record-keeping, South-western region, South-eastern region, Breed type of herd, Milking system and Feeding system) are calculated by using the P-test;

3. ***, **, *sample means of TMR users and non-users are significantly different at 1, 5, or 10% level.

5.6 Summary

This chapter provides an econometric model to empirically estimate factors affecting the use of TMR feeding practice and to introduce the PSM approach to examine the effect of using TMR feeding practice on farm level productivity and profits. The definitions of both the dependent variables and independent variables, along with descriptive statistics, are elaborated in this chapter with a focus on the dummy variable representing the adoption of TMR fed to milk cows. The variables included in the model are selected based on both previous studies and availability of variables in the ODFAP database.

Empirical estimates of the regression model will be provided and discussed in detail in the next chapter. This is to determine whether or not and to what extent the farm level productivity and profits are influenced by the adoption of TMR feeding practice in Southern Ontario.

Chapter 6: Empirical Results and Discussions

6.1 Introduction

In this chapter, the regression model provided in Chapter 5 is run by following the procedure below: 1) examine factors affecting the use of TMR feeding practice by estimating probit regression; 2) examine the impact of the use of TMR feeding practice on profits and productivity by using propensity score matching (PSM) method; 3) check the robustness of the PSM results by running regression models; 4) give empirical results from the regression models; 5) compare results with previous literature. Discussion of the empirical results are developed by explaining the estimate parameter coefficients for independent variables, illustrating the implications of these estimates and investigating factors that may influence the estimates. IBM SPSS Statistics 20 is used for data aggregation and STATA 11 SE is used for estimation in this study.

6.2 Parameter Estimates of the Regression Models

6.2.1 TMR Adoption

Table 6.1 shows the marginal effects of adopting TMR feeding practice. Marginal effects represent the expected changes in utility index if explanatory variables change one unit, $\frac{\partial PTMRC_i}{\partial Z_i}$. From the coefficients shown in the last column, older farmers are less likely to use the TMR feeding practice, which suggests that older farmers are less likely to try new management practices than younger farmers. Larger farms are more likely to use TMR feeding practice, and the effect is statistically significant at the 1% level. The negative coefficient on the South-Eastern region implies that farms in the South-Eastern region are less likely to adopt the TMR feeding practice. The negative coefficient on the Holstein breed type implies that farms with Holstein breed are less likely to practice the use of TMR, suggesting that the TMR feeding practice and breed type are substitute technology. The coefficient of feeding system (*i.e.*, semi/fully automated) is statistically significant and positive, suggesting that feeding system and the use of TMR are complementary.

Table 6.1: Factors affecting TMR adoption

Characteristics	Coefficients		Marginal Effect	
Farm operator’s age	-0.02*	(0.01)	-0.01*	(2.90E-03)
Farm operator’ education (1 = greater than high school level education; 0 otherwise)	-0.11	(0.20)	-0.03	(0.05)
Herd size	0.03***	(0.01)	0.01***	(1.20E-03)
Sole proprietor ownership structure	-0.43	(0.26)	-0.11	(0.06)
Farm age	-0.01	(0.01)	-2.70E-03	(2.30E-03)
Debt-to-asset ratio	0.32	(0.47)	0.08	(0.12)
South-Western region (SW)	0.04	(0.20)	0.01	(0.05)
South-Eastern region (SE)	-0.66***	(0.23)	-0.17***	(0.05)
Holstein breed type of herd	-1.11***	(0.42)	-0.23***	(0.10)
Milk record-keeping system	-0.42	(0.30)	-0.10	(0.07)
Parlour milking system	0.23	(0.24)	0.06	(0.06)
Semi/Fully automated feeding system	1.19***	(0.29)	0.32***	(0.06)
Time Trend	0.04	(0.06)	0.01	(0.02)
Pseudo R^2	0.33			

Note: 1. Robust standard errors are in the parentheses;

2. ***, **, * significant at 1%, 5%, and 10%.

6.2.2 TMR and Profitability/Productivity

The idea behind the propensity score matching (PSM) approach is to match each participant (*i.e.*, TMR user) with an identical nonparticipant (*i.e.*, TMR non-user), and then to measure the average difference in the outcome variable (*i.e.*, profitability/productivity) between the participants (*i.e.*, TMR users) and the nonparticipants (*i.e.*, TMR non-users) (Khandker, Koolwal, and Samad 2010).

Prior to semi-parametrically[11] estimating the TMR adoption impact, we need to specify the propensity scores for treatment variables (*i.e.*, TMR adoption variable). This study uses a logit model to predict the probability of adopting the TMR feeding practice and includes different ranges of farm characteristics as regressors. The result of logit formulation of the propensity score is reported in Table 6.2 (which is similar to the probit results in Table 6.1).

[11] Propensity score matching in this study is a semi-parametric method since the p-scores are estimated using parametric model (*i.e.*, logit model).

Table 6.2: Estimation of the propensity score

Characteristics	Coefficients		Marginal Effects	
Farm operator’s age	-0.04*	(0.02)	-0.01*	(2.90E-03)
Farm operator’ education (1 = greater than high school level education; 0 otherwise)	-0.22	(0.35)	-0.03	(0.05)
Herd size	0.05***	(0.01)	0.01***	(1.30E-03)
Ownership structure (1 = sole proprietor; 0 otherwise)	-0.71	(0.44)	-0.11	(0.06)
Farm age	-0.02	(0.02)	-2.80E03	(2.40E-03)
Debt-to-asset ratio	0.45	(0.84)	0.07	(0.12)
South-Western region (SW)	0.08	(0.34)	0.01	(0.05)
South-Eastern region (SE)	-1.12***	(0.40)	-0.17***	(0.06)
Breed type of herd (1 = Holstein; 0 otherwise)	-1.70**	(0.80)	-0.21***	(0.12)
Milk record-keeping system	-0.71	(0.52)	-0.10	(0.07)
Milking system (1 = parlour; 0 = otherwise)	0.38	(0.40)	0.06	(0.06)
Feeding system (1 = semi/fully automated; 0 = manual)	2.03***	(0.54)	0.32***	(0.07)
Time Trend	0.07	(0.11)	0.01	(0.02)
Constant	0.81	(1.72)		
Pseudo R^2	0.33			

Note: 1. Robust standard errors are in the parentheses;

2. ***, **, * significant at 1%, 5%, and 10%.

Different matching algorithms can be used to assign TMR users to non-users on the basis of the propensity score. The only way to find out which matching method is appropriate to use for a specific situation is to try a number of matching algorithms. In this study, the effect of using TMR feeding practice on profit per cow and/or productivity (measured as milk per cow) is estimated through five different matching algorithms: *the nearest neighbour method (NNM); the kernel matching method (KM); and radius matching (RM) method with 0.01, 0.05, 0.10 caliper*[12]. After many trials (Table 6.3), this study uses RM (0.01) as it provides the lowest after matching mean bias and it provides good overall matching quality result compared to the other four methods. Thus, this study mainly focuses on the RM (0.01) method to estimate the effect of TMR adoption on profitability and productivity. We also make references to alternative matching algorithms as the difference in the after matching mean bias is very small between, for example, KM, RM (0.01) and RM (0.05), suggesting the results in Table 6.3 should be interpreted cautiously. The results for KM and RM (0.05) indicate that the adoption of the TMR feeding practice has statistically significant effect on profit per cow. Even under the RM (0.01) method, the effect of the adoption of TMR practice is economically significant (*i.e.*, CAD$508.10/cow per year). For an average farm with 73 cows in Ontario, this amounts to approximately CAD$37,091.30 per year, despite the statistical insignificance of the result from RM (0.01) – the preferred matching algorithm.

[12] For previous studies that only do different tests using RM methods, they usually use RM with 0.01 caliper, RM with 0.05 caliper and RM with 0.10 caliper. Although the smaller radius leads to better quality of matches, it also leads to a higher possibility that some treated units are not matched (Grilli and Rampichini 2011). Thus, it is difficult to know which tolerance level is reasonable to use.

Table 6.3 shows the estimates of TMR adoption effect (ATT[13]) from the five matching algorithms obtained, using the *psmatch2* command in STATA 11 SE. The outcome variables are profit per cow and milk per cow. The results from both KM and RM (0.05) matching algorithms indicate that the use of TMR feeding practice significantly and positively increases profits and productivity. Under the RM (0.01) matching algorithm, the ATT value for profit per cow is 508.10, that is, farms using the TMR feeding practice generate more profits (CAD$508.10/cow per year) than farms not using the TMR feeding practice. Although the result for profits under the RM (0.01) matching algorithm is not statistically significant, as mentioned above, it is economically significant. For sample dairy farms (N=320) in Ontario, the average herd size is 73 cows. As indicated earlier, based on the result, dairy farms with the TMR feeding practice generate CAD$37,091.30/year (approximately) more than dairy farms without the TMR feeding practice. The ATT value for milk per cow is 1075.41hl/cow and is statistically significant at the 10% level; that is, farms using the TMR feeding practice produce more milk (1075.41 hl/cow per year) than farms not using TMR feeding practice. This is consistent with the theoretical prediction that adoption of best management practice enhances farm productivity.

Table 6.4 shows the propensity score and the covariate balance using the RM (0.01) method. A t-test is used to assess the quality of the match. That is, using t-test to examine the means of the treated and matched control group to see whether the two groups are indeed similar. The last column in Table 6.4 presents the results of a t-test

[13] ATT is short for average treatment effect on the treated group (TMR users), which is useful to explicitly evaluate the effects on those for whom the programme is actually intended.

that shows the equality of means between the treated group (*i.e.*, TMR users) and the control group (*i.e.*, TMR non-users). If the p-value is greater than 0.1, the null hypothesis of equal means cannot be rejected at the 10% level for all variables. That is, the results in terms of the differences between the treated and the control are based on similar dairy farms in the study (Gadd, Hansson and Mansson 2009). Results show that before matching, several variables (*i.e.*, education, herd size, ownership structure, debt-to-asset ratio, South-Western region, South-Eastern region, and feeding system) exhibit statistically significant differences, however after matching, these variables exhibit non-significant differences, that is, the two groups are indeed similar (*i.e.*, covariates are balanced well). This means the balance is good and the ATT values under RM (0.01) method are reliable.

The estimation of treatment effects with matching estimators is based on the selection on observable characteristics. However, if there are unobserved variables which affect assignment into treatment and the outcome variable simultaneously, a `hidden bias' might arise. It should be clear that matching estimators are not robust against this 'hidden bias.' Since it is not possible to estimate the magnitude of selection bias with non-experimental data, the bounding approach is used to address this problem (Rosenbaum 2002). Table 6.5 gives the result of the Rosenbaum bounds sensitivity analysis obtained using the *rbounds* command in STATA 11 SE. γ is the effect of unobserved variable. γ will be zero if the result is free of hidden bias, that is, unobserved variables have no influence on the probability of adopting the TMR feeding practice. Following Rosenbaum (2002), e^{γ} is a measure of the degree of departure from a study that is free of hidden bias. $e^{\gamma} = 1$ means the "base" scenario of no hidden bias. For the statistically significant effects, this study increased the value of e^{γ} until the inference about the treatment effect changed under the assumption of no hidden bias $e^{\gamma} = 1$. The p-critical values represent the upper bound of the p-value from the Wilcoxon signed rank test for estimated TMR adoption effect (ATT) for each level of unobserved selection bias e^{γ}.

Since the estimated treatment effect is positive, the lower bounds under the assumption that the true treatment effect has been underestimated were not reported in this study. The critical value is e^{γ}, at which point I would have to question my conclusion of a positive effect of TMR adoption. For profit per cow, critical value of hidden bias is $e^{\gamma} = 1.60$. That is, between the bounds $e^{\gamma} = 1.00$ and $e^{\gamma} = 1.60$, the unobserved bias effect of TMR adoption on profits is not significant at the 10% level. For milk per cow, critical value of hidden bias is $e^{\gamma} = 2.90$. That is, between the bounds $e^{\gamma} = 1.00$ and $e^{\gamma} = 2.90$, the unobserved bias effect of TMR adoption on productivity is not significant at the 10% level. The critical levels of hidden bias for KM and RM (0.05) are also reported in Table 6.5.

Compared to previous literature, the result for the impact of the TMR feeding practice on profits is consistent with Foltz and Chang (2002): there is no statistically significant relationship between the TMR feeding practice and farm profits. The result for the impact of TMR feeding practice on productivity is consistent with Schraufnagel (2007): the TMR feeding practice significantly increases milk per cow.

Table 6.3: Matching estimates of TMR effects on profit per cow/milk per cow (ATT)

Dependent Variable	Matching Method				
	NNM	KM	RM (0.01)	RM (0.05)	RM (0.10)
Profit per cow	395.40 (302.28)	533.81*** (177.30)	508.10 (307.39)	529.22*** (184.21)	492.63*** (159.26)
Milk per cow	520.97 (515.48)	928.56*** (345.65)	1075.41* (566.89)	917.31** (354.98)	704.78** (326.51)
Summary of the distribution of the abs(bias)					
After matching mean bias	21.54	13.75	12.75	13.95	14.29
Number of matched pairs (on support)	30	88	39	88	98

Note: 1. ATT is short for average treatment effect on the treated group (TMR users);

2. * Significant at 10%; ** Significant at 5%; *** Significant at 1%;

3. Bootstrap standard errors with 1000 replications are in the parentheses;

4. Numbers in observations parentheses were not used in the estimate due to the common support condition;

5. Data has been deflated by CPI for all items in Ontario, index 2002=100.

Table 6.4: Propensity score and covariate balance (N=39 matched pairs)

Variable	Sample	Mean		% bias	% reduction |bias|	t-test	
		Treated (TMR users)	Control (TMR non-users)			t	p > |t|
Operator's age	unmatched	47.18	46.64	6.3	21.6	0.52	0.60
	matched	46.97	47.40	-4.9		-0.21	0.83
Education	unmatched	0.66	0.46	41.5	62.0	3.58	**0.00**
	matched	0.41	0.49	-15.8		-0.68	0.50
Herd size	unmatched	88.42	46.44	94.8	97.3	7.25	**0.00**
	matched	48.42	49.58	-2.6		-0.39	0.70
Ownership structure	unmatched	0.07	0.28	-57.1	79.5	-5.28	**0.00**
	matched	0.08	0.12	-11.7		-0.63	0.53
Milk record-keeping system	unmatched	0.90	0.93	-12.2	25.5	-1.02	0.31
	matched	0.95	0.97	-9.1		-0.58	0.56
Farm age	unmatched	37.31	37.34	-0.3	73.5	-0.02	0.98
	matched	35.28	35.27	0.1		0.00	1.00
Debt-to-asset ratio	unmatched	0.32	0.24	37.0	83.6	3.09	**0.00**
	matched	0.24	0.26	-6.1		-0.26	0.80
South-Western region (SW)	unmatched	0.43	0.22	45.6	65.1	3.81	**0.00**
	matched	0.33	0.26	15.9		0.70	0.49
South-Eastern region (SE)	unmatched	0.23	0.41	-39.5	45.7	-3.46	**0.00**
	matched	0.26	0.35	-21.4		-0.94	0.35
Holstein breed type	unmatched	0.95	0.93	6.2	-296.0	0.54	0.59
	matched	0.97	0.91	24.7		1.15	0.25

Continued

Table 6.4: Propensity score and covariate balance (N=39 matched pairs) (Continued)

Variables	Sample	Mean		% bias	% reduction |bias|	t-test	
		Treated (TMR users)	Control (TMR non-users)			t	p > |t|
Milking system	unmatched	0.42	0.10	76.8	48.7	6.21	**0.00**
	matched	0.05	0.21	-39.4		-2.15	0.04
Feeding system	unmatched	0.97	0.70	74.8	96.7	7.16	**0.00**
	matched	0.95	0.94	2.4		0.16	0.87
Time Trend	unmatched	3.05	2.77	20.2	42.4	1.74	0.08
	matched	2.72	2.55	11.6		0.50	0.62

Note: Figures (for unmatched) in **bold** are significant variables

Table 6.5: Rosenbaum bound sensitivity analysis test for hidden bias

Matching algorithm	Outcome	ATT	Critical level of hidden bias
RM (0.01)	Profit per cow	508.10 (307.39)	1.60
	Milk per cow	1075.41* (566.89)	2.90
KM	Profit per cow	533.81***	2.60
	Milk per cow	928.56***	2.60
RM (0.05)	Profit per cow	529.22***	2.55
	Milk per cow	917.31**	1.25

6.3 Regression Model

The following regressions are run with an aim to check the robustness of the PSM results. The linear regression in this study is written as:

$$
\begin{aligned}
Y_{it} = {} & \beta_0 + \beta_1 DUM.TMRC_{it} + \beta_2 AGE_{it} + \beta_3 DUM.EDU_{it} + \beta_4 COWS_{it} \\
& + \beta_5 DUM.BTYPE_{it} + \beta_6 DUM.RECORD_{it} + \beta_7 FAGE_{it} + \beta_8 DAR_{it} \\
& + \beta_9 DUM.SW_{it} + \beta_{10} DUM.SE_{it} + \beta_{11} DUM.BREED_{it} \\
& + \beta_{12} DUM.MS_{it} + \beta_{13} DUM.FS_{it} + \beta_{14} T_i \\
& + u_{it} \qquad (6.1)
\end{aligned}
$$

where

i indexes i^{th} farm, $i = 1, 2, \dots, 262$;

t is time variable, which indexes year, $t = 2004, 2005, 2006, 2007, 2008$;

Y_{it} is the profit of farm i at time period t (CAD$/head) or average milk production per cow per year (hl/head);

$DUM.TMRC_{it}$ is a 0 or 1 dummy variable for TMR fed to milk cow adoption of farm i at time period t (1 = adopt TMR feeding practice; 0 otherwise);

AGE_{it} is the principal operator's age of farm i at time period t;

$DUM.EDU_{it}$ is a 0 or 1 dummy variable for operator's formal education of farm i at time period t (1 = greater than high school level education; 0 otherwise);

$COWS_{it}$ is the total number of cows of farm i at time period t;

$DUM.BTYPE_{it}$ is a 0 or 1 dummy variable for farm ownership structure of farm i at time period t (1 = sole proprietor; 0 = partnership/ corporation);

$DUM.RECORD_{it}$ is a 0 or 1 dummy variable for using record-keeping system of farm i at time period t (1 = adopt record-keeping technologies; 0 otherwise);

$FAGE_{it}$ is the farm age of farm i at time period t;

DAR_{it} is the debt-to-asset ratio of farm i at time period t;

$DUM.SW_{it}$ is a 0 or 1 location dummy variable for South-western region of farm i at time period t (1 = South-Western region; 0 otherwise);

$DUM.SE_{it}$ is a 0 or 1 location dummy variable for South-eastern region of farm i at time period t (1 = South-Eastern region; 0 otherwise);

$DUM.BREED_{it}$ is a 0 or 1 dummy variable for herd breed type of farm i at time period t (1 = Holstein; 0 otherwise);

$DUM.MS_{it}$ is a 0 or 1 dummy variable for milking system of farm i at time period t (1 = parlour; 0 = buckets, pipeline or transfer station);

$DUM.FS_{it}$ is a 0 or 1 dummy variable for feeding system of farm i at time period t (1 = semi/fully automated; 0 = manual);

T_i is time trend of farm i;

u_{it} is the error term, which assume to be an independent identically-distributed random variable with a normal distribution $N\sim(0,\sigma^2)$;

β_0 is the intercept term;

β_1, β_2, $\beta_3 \ldots \beta_{14}$ are coefficients.

All variables are defined in Table 5.1.

6.3.1 Fixed Effects Model versus Random Effects Model

Panel data is used for estimating the regression models. Since the assumptions[14] of ordinary least squares (OLS) regression for panel data applications are too strong, this study focuses on two panel data analyses: fixed effects (FE) model and random effects (RE) model.

According to Wooldrige (2002), the basic unobserved effects model can be written as

$$Y_{it} = X_{it}\beta + c_i + u_{it}, i = 1, \ldots, N; t = 1, \ldots, T, \quad (6.2)$$

where Y_{it} is the dependent variable observed for individual i at time period t; X_{it} is an $N \times K$ matrix with observable time-variant independent variables; β is a $K \times 1$ coefficient vector. c_i is the unobserved time-invariant individual effect; and u_{it} is an idiosyncratic error that is uncorrelated with all explanatory variables.

[14] Classical assumptions for OLS are: 1. regression is linear in parameters; 2. error term has a zero population mean; 3. error term is uncorrelated with explanatory variables; 4. no serial correlation; 5. no heteroscedasticity; 6. no perfect multicollinearity; 7. error term is normally distributed. However, with panel data, it is possible to control for omitted variables that are time-variant but constant between farms (Stock and Watson 2003).

Either the FE model or the RE model can be used to analyze panel data. The decision on which model to use depends on the correlation between c_i and other observable independent regressors. In a RE model, c_i is assumed to be independent of other observed explanatory variables (Wooldridge 2002):

$$\text{Cov}\ (c_i, X_{it}) = 0; \text{t} = 1,2, \ldots, \text{T}. \quad (6.3)$$

The FE model, however, allows arbitrary correlation between c_i and other observed explanatory variables (Wooldridge 2002):

$$\text{Cov}\ (c_i, X_{it}) \neq 0; \text{t} = 1,2, \ldots, \text{T}. \quad (6.4)$$

In 1978, Hausman proposed a test to see whether c_i and X_{it} are correlated, that is, whether to choose a RE model or a FE model. A FE model is consistent and preferable when c_i is correlated with X_{it}, while a RE model is consistent and preferable when c_i is independent of X_{it}. The null hypothesis of the Hausman specification test is that there is no correlation between the unobserved effect c_i, and the observed explanatory variables X_{it}.

As the FE regression model requires having at least two observations per farm, farms with only one observation in the dataset are excluded from the regression. Thus, 262 farms are left in the regression, with 58 farms being excluded.

The statistic of the Hausman specification test computed in the regression (dummy TMR and profit per cow) is 16.95 (χ^2) with a p-value of 0.0755, suggesting that there is no significant correlation between unobserved time-invariant individual effect and other observed explanatory variables. Therefore, the RE model is estimated for this regression. The statistic of the Hausman specification test computed in the regression (dummy TMR and productivity) is 23.87 (χ^2) with a p-value of 0.0079, suggesting that there is a significant correlation between unobserved time-invariant individual effect and other observed explanatory variables. Therefore, the FE model is estimated for this regression.

6.3.2 Diagnostics: Test for Heteroscedasticity, Serial Correlation and Multicollinearity

The robustness of data to heteroscedasticity, serial correlation and multicollinearity are tested in this section. A modified Wald test is used to test group-wise heteroscedasticity for the FE model and cluster-robust covariance estimators[15] are used to compute heteroscedasticity-robust standard errors and are reported to correct the potential presence of heteroscedasticity for the RE model. The Wooldridge test for autocorrelation is used for testing serial correlation. Variance inflation factor (VIF) values are measured to indicate the severity of multicollinearity.

Heteroscedasticity: Since no test has been found so far to identify the heteroscedasticity in the RE model, cluster-robust covariance estimators are used to fix the potential presence of heteroscedasticity in the RE model (dummy TMR and profit per cow). Since the dummy TMR and productivity model is a FE model, modified Wald test is used to test the heteroscedasticity. The modified Wald test statistic value for group-wise heteroscedasticity in the FE model (dummy TMR and productivity) is 1.9e+58[16] with a p-value of 0.000. Thus, the null hypothesis of homoscedasticity is rejected. The estimated FE model is corrected for heteroscedasticity using robust standard error.

Serial correlation: The Wooldrige test for autocorrelation in panel data is used to test if there is serial correlation. The test statistic for the Wooldrige test follows an F distribution. The null hypothesis under this test is that there is no first order autocorrelation.

For the model of dummy TMR and profit per cow, the calculated statistic is 1.565 with a p-value of 0.2171. Thus, I fail to reject the null hypothesis of no serial correlation at the 5% significance level.

For the model of dummy TMR and productivity, the calculated statistics is 2.072 with a p-value of 0.1565. Thus, I fail to reject the null hypothesis of no serial correlation at the 5% significance level.

---

[15] Cluster-robust covariance estimates are generalizations of the “sandwich” method used to compute heteroscedasticity-robust standard errors (Stata’s robust option), as developed by White (2001).

[16] Too large a value of the test statistic is taken as evidence that the null is false.

Multicollinearity: Variance inflation factor (VIF) quantifies the severity of multicollinearity. It measures the degree of multicollinearity of an independent variable with the other independent variables in a regression model. In both scholarly articles and advanced statistical textbooks, multicollinearity is considered as a sign of severe or serious multicollinearity if the VIF value is greater than 10 (O'Brien 2007, 673-690). This study uses *collin* command in STATA to compute collinearity diagnostic measure (*i.e.*, VIF). Table 6.6 shows the VIF values for independent variables in the regression. All the VIF values in the regression (dummy TMR and profit/milk per cow) are below 10, implying that the collinearity of all the variables in the regression should not be a concern based on the cut-off value of 10 in most previous studies.

Table 6.6: Variance Inflation Factor (VIF)

Variable	VIF
TMR adoption	1.45
Farm operator’s age	1.66
Farm operator’ education (1 = greater than high school level education; 0 otherwise)	1.36
Herd size	1.63
Ownership structure (1 = sole proprietor; 0 otherwise)	1.39
Milk record-keeping System	1.08
Farm age	1.64
Debt-to-asset ratio	1.42
South-Western region (SW)	1.44
South-Eastern region (SE)	1.45
Breed type of herd (1 = Holstein; 0 otherwise)	1.19
Milking system (1 = parlour; 0 = otherwise)	1.74
Feeding system (1 = semi/fully automated; 0 = manual)	1.46
Time Trend	1.14
Mean VIF	1.43

6.3.3 TMR and Profitability/Productivity

Table 6.7 shows profit per cow and productivity regression estimates. For comparison purpose, the pooled OLS with time fixed effects models are included in this table. The R^2 are 0.22 for profit per cow and 0.40 for productivity in pooled OLS, and 0.23 for profit per cow in the RE model and 0.10 for productivity in the FE model. The results from the pooled OLS with time fixed effects models show that for the productivity, the use of the TMR feeding practice, debt-to-asset ratio, breed type, milk record-keeping system, and year 2007 are all statistically significant at the 1% level, and herd size, milking system, year 2006 and year 2008 are statistically significant at 5% level. This finding suggests that the use of the TMR feeding practice has a statistically significant impact on productivity. The productivity estimates also provide some insights into the relationship between productivity and technologies for dairy farms. Clearly, the uses of the TMR feeding practice, the milk record-keeping system, and parlour milking system have significantly positive impact on farm productivity.

The results for profit per cow show that the use of the TMR feeding practice, farm age, debt-to-asset ratio, and breed type are statistically significant at the 1% level, and the operator’s education and year 2007 are statistically significant at the 5% level. This finding suggests that the use of the TMR feeding practice has a statistically significant impact on profit per cow. The parameter estimates for profit regression show that farms with more experience and using the Holstein breed type are more profitable, effectively demonstrating one of the key reasons for why Holstein breed is the most common dairy breed in Ontario. The results from random effects model also show that the use of the TMR feeding practice has a statistically significant impact on profit per cow.

Table 6.8 shows profit per cow and productivity regression estimates with Heckman sample selection. The results from the pooled OLS with time fixed effects models show that for the productivity, the debt-to-asset ratio, breed type, milk record-keeping system, and year 2007 are all statistically significant at the 1% level, and the probit TMR[17], herd size, milking system and year 2006 are statistically significant at 5% level. This finding suggests that the use of the TMR feeding practice has a statistically significant impact on productivity. The results for profit per cow show that the farm age, debt-to-asset ratio, and breed type are statistically significant at the 1% level, and the probit TMR and year 2007 are statistically significant at the 5% level. This finding suggests that the use of the TMR feeding practice has a statistically significant impact on profit per cow.

In sum, from the regression models, the impact of the use of the TMR feeding practice on productivity has statistically significant impacts on both profits and productivity. These results are consistent with the result shown in the PSM approach. In the PSM approach, the effect of the use of the TMR feeding practice on productivity is statistically significant. Even though the use of the TMR feeding practice does not show a statistically significant impact on profits under the RM (0.01) method, it has an economically significant effect on profits.

[17] Probit TMR is calculated by using operator's age, operator's education, herd size, ownership structure, farm age, debt-to-asset ratio, South-Western region, South-Eastern region, milking system, feeding system and time trend variables. Breed type and milk record-keeping variables are excluded from the model because of exclusion restrictions. That is, the exclusions of breed type and milk record-keeping variables provide better fit to the model (*i.e.,* R^2 increases from 0.2330 to 0.2473).

Table 6.7: Productivity and profit per cow for Ontario dairy farms

	Pooled OLS with time fixed effect			
	Profit per cow	Milk per cow	Profit per cow (random effects)	Milk per cow (fixed effects)
TMR adoption	347.4***	750.7***	350.9***	179.8
	(3.68)	(4.24)	(2.62)	(0.18)
Farm operator’s age	-13.04*	-16.33*	-9.683	-4.696
	(-1.93)	(-1.66)	(-1.19)	(-0.49)
Farm operator’ education	-178.0**	11.37	-166.8	-912.5***
	(-1.98)	(0.07)	(-1.43)	(-3.53)
Herd size	1.073	3.436**	-0.207	-40.07***
	(1.36)	(2.27)	(-0.19)	(-2.64)
Ownership structure	153.4	-131.1	103.7	.
	(1.32)	(-0.51)	(0.66)	.
Farm age	14.16***	-12.40*	8.999	-8.822
	(3.38)	(-1.66)	(1.54)	(-1.11)
Debt-to-asset ratio	-1052.3***	1356.1***	-734.5	-189.9
	(-3.03)	(4.06)	(-1.58)	(-0.22)
South-Western region (SW)	-154.7	246.0	-158.2	.
	(-1.63)	(1.47)	(-1.24)	.
South-Eastern region (SE)	-151.6	-95.59	-175.7	.
	(-1.58)	(-0.51)	(-1.30)	.

Continued

Table 6.7: Productivity and profit per cow for Ontario dairy farms (Continued)

	Profit per cow (Pooled OLS)	Milk per cow (Pooled OLS)	Profit per cow (random effects)	Milk per cow (fixed effects)
Holstein breed type	904.9***	1849.0***	840.1***	662.5***
	(5.70)	(4.22)	(4.14)	(4.20)
Milk record-keeping system	-98.44	972.9***	-240.5	-67.37
	(-0.81)	(3.20)	(-1.59)	(-0.07)
Milking system	163.2*	371.8**	108.5	.
	(1.82)	(2.07)	(0.86)	.
Feeding system	-67.47	-57.58	19.08	949.8***
	(-0.45)	(-0.20)	(0.10)	(4.95)
Year 2005	127.3	231.4		
	(1.21)	(1.10)		
Year 2006	171.9	414.9**		
	(1.53)	(2.03)		
Year 2007	248.5**	667.5***		
	(2.29)	(2.84)		
Year 2008	191.9	417.6**		
	(1.42)	(2.01)		
Time trend			80.20***	203.3**
			(3.08)	(2.04)
Constant	1011.2**	5777.7***	1073.7*	10721.0***
	(1.99)	(6.55)	(1.76)	(4.97)

Continued

Table 6.7: Productivity and profit per cow for Ontario dairy farms (Continued)

	Profit per cow (Pooled OLS)	Milk per cow (Pooled OLS)	Profit per cow (random effects)	Milk per cow (fixed effects)
Observations	317	317	317	317
Adjusted R^2	0.216	0.400	0.234	0.097

Note: 1. ***, **, * significant at 1%, 5%, and 10%;

2. *t* statistics in parentheses;

3. Data have been deflated by CPI for all items in Ontario, index 2002=100;

4. Variables are omitted because of collinearity.

Table 6.8: Productivity and profit per cow for Ontario dairy farms with Heckman sample selection

	Pooled OLS with time fixed effect			
	Profit per cow	Milk per cow	Profit per cow (random effects)	Milk per cow (fixed effects)
Probit TMR	427.0**	727.0**	332.2	2200.7
	(2.59)	(2.47)	(1.55)	(0.88)
Farm operator's age	-9.290	-10.60	-6.363	71.69
	(-1.25)	(-0.99)	(-0.69)	(0.91)
Farm operator' education	-171.6*	22.27	-149.0	-681.2*
	(-1.88)	(0.14)	(-1.27)	(-1.85)
Herd size	1.136	3.864**	-0.0883	-41.98***
	(1.45)	(2.58)	(-0.08)	(-2.72)
Ownership structure	251.7*	8.958	170.0	.
	(1.83)	(0.03)	(0.91)	.
Farm age	16.18***	-9.472	10.46*	-9.633
	(3.63)	(-1.25)	(1.73)	(-1.37)
Debt-to-asset ratio	-1040.7***	1402.4***	-695.5	-262.9
	(-3.10)	(3.84)	(-1.51)	(-0.32)
South-Western region (SW)	-160.8*	241.4	-158.0	.
	(-1.69)	(1.40)	(-1.22)	.
South-Eastern region (SE)	-64.58	26.80	-128.3	.
	(-0.55)	(0.13)	(-0.81)	.

Continued

Table 6.8: Productivity and profit per cow for Ontario dairy farms with Heckman sample selection (Continued)

	Profit per cow (Pooled OLS)	Milk per cow (Pooled OLS)	Profit per cow (random effects)	Milk per cow (fixed effects)
Holstein breed type	806.4***	1639.2***	765.3***	623.9***
	(5.00)	(3.55)	(3.82)	(4.21)
Milk record-keeping system	-130.9	900.4***	-288.6*	-112.8
	(-1.03)	(2.83)	(-1.87)	(-0.15)
Milking system	147.6	357.7**	90.37	.
	(1.62)	(2.04)	(0.68)	.
Feeding system	-174.3	-170.8	-23.42	930.2***
	(-1.09)	(-0.49)	(-0.12)	(4.88)
Year 2005	109.7	210.6		
	(1.00)	(0.96)		
Year 2006	168.4	419.3**		
	(1.47)	(1.99)		
Year 2007	231.1**	653.5***		
	(2.04)	(2.85)		
Year 2008	165.4	384.7*		
	(1.18)	(1.75)		
Time trend			76.30***	117.3
			(2.82)	(0.95)
Constant	882.2	5669.6***	978.7	6196.2
	(1.59)	(6.12)	(1.44)	(1.16)

Continued

Table 6.8: Productivity and profit per cow for Ontario dairy farms with Heckman sample selection (Continued)

	Profit per cow (Pooled OLS)	Milk per cow (Pooled OLS)	Profit per cow (random effects)	Milk per cow (fixed effects)
Observations	317	317	317	317
Adjusted R^2	0.202	0.376	0.217	0.118

Note: 1. ***, **, * significant at 1%, 5%, and 10%;

2. *t* statistics in parentheses;

3. Data have been deflated by CPI for all items in Ontario, index 2002=100;

4. Variables are omitted because of collinearity.

6.4 Summary

This chapter investigates whether the use of the TMR feeding practice has a significant effect on dairy farm profitability and productivity; and it uses the PSM approach to examine the impact of the use of the TMR feeding practice on profitability and productivity. Regression models are used to check the robustness of the PSM results. The results from the PSM approach reveal that the use of the TMR feeding practice has a statistically and significantly positive impact on productivity, and has an economically significant effect on profits. The results from regression models are consistent with the findings in the PSM approach.

Chapter 7: Summary and Conclusions

7.1 Introduction

This chapter summarizes motivation for this study, theoretical framework used for analysis, empirical results, discussions of the empirical estimates, while pinpointing limitations of this study as well as suggestions for future research.

With the increasing global competition and pressure on supply management, dairy producers in Canada are being challenged to produce milk more efficiently to be competitive and profitable. One way producer could be profitable is through a low-cost production strategy. Fortunately, the TMR feeding practice allows farmers to separate milk cows and feed them according to their milk production, which can benefit dairy farmers by improving feed efficiency, reducing costs (labour, transportation and commercial feed manufacturer, equipment, forage and grain) and lowering energy use. However, adopting the TMR feeding practice requires an initial investment in a TMR mixer, along with fuel costs from powering the TMR mixer, and the added cost of accurate weighing with calibrated scales. Although TMR can help increase milk production, it may also cause an increase in costs. As a result, the impact of TMR on profit is not clear.

The percentage of Ontario dairy farms adopting TMR fed to milk cows increased from 54.9% in 2004 to 66.1% in 2008. This study examines whether the use of total mixed ration (TMR) in the feeding of dairy cows influences dairy farm productivity and profits.

The objectives of this study are to examine factors affecting the adoption of TMR by estimating a probit regression and to examine whether and to what extent the use of TMR affects farm level profits and productivity by using the PSM method. Data for 320 sample dairy farms used in this analysis were obtained from the Ontario Dairy Farm Accounting Project (ODFAP) from 2004 to 2008.

A probit model and the propensity score matching analysis were used to examine the factors affecting the adoption of TMR on farm productivity and profitability.

Regression models were used to check the robustness of the results from the PSM approach.

Results from the probit model show that the adoption decision is affected by the operator’s age, herd size, region, breed type and feeding system. That is, in Ontario, younger dairy farmers are more likely to use the TMR feeding practice. Dairy farmers who have larger herds and use a semi/fully automated feeding system in their farms are more likely to adopt the TMR feeding practice. Location in South-Eastern region and Holstein breed type decrease the probability of using the TMR feeding practice. The use of the TMR feeding practice is found to have positive impacts on both farm productivity and profitability. Under the PSM method, the use of the TMR feeding practice is shown to have an economically significant effect on farm profits (*i.e.*, using the TMR feeding practice increases farm profits by CAD$37,091.30/year approximately) and have a statistically significant increase in milk production by 1075.41 hl/cow per year.

As there are few TMR studies done in previous economic literature, the study contributes to the literature by empirically examining factors affecting the adoption of TMR and the impact of TMR on dairy farm productivity and profitability. Moreover, compared to other technology adoption studies using adoption with the self-selectivity method, this study uses the PSM analysis to examine the impact of TMR on farm productivity and profitability. The findings of this study further contribute to the literature on the potential strategies that can be used to increase farm profitability.

7.2 Policy Implications

The analysis of the effect of the TMR adoption on the profitability of the sample dairy farms in Ontario has a number of policy implications. The TMR adoption is found to have an economically significant impact on dairy farm profitability. Policy makers may build a program for TMR adoption and help/support farmers with lower milk production/farm profits.

7.3 Limitations and Suggestions for Future Research

This study focused on examining the effect of TMR adoption on the productivity and profitability of Ontario dairy farms. According to previous studies, economic impacts of TMR on farm profits are different for different areas, and are different for different years (*e.g.*, Foltz and Chang (2002) find no significant relationship between TMR and milk yield and profit per cow in Connecticut dairy farms. However, Schraufnagel (2007) find significantly positive relationship between TMR and milk yield and income per cow in Wisconsin Dairy Farms.) The results from this study may not fully apply to other provinces in Canada due to different policies and the different agricultural environment in each province. Therefore, it may be important to examine how TMR adoption has affected the dairy farm profitability in other provinces.

From the PSM method perspective, there are six things that should be taken into consideration for future research using the PSM method. First, PSM is a good technique and will provide good comparison if the selection bias from unobserved characteristics is insignificant. Second, if data used in a study are scarce, one should carefully analyze whether this technique is appropriate to use. Third, in order to meet the common support requirement, non-participant observations need to be dropped, which may lead to a problem of bias. Fourth, sufficient data on nonparticipants are essential to ensure a large enough sample from which to draw matches. Fifth, the choice of matching algorithm is important when there are very few control units remaining after having discarded the irrelevant controls. Based on previous studies, Radius Matching algorithm and Kernel Matching algorithm are recommended when the number of individuals in control group is large. Sixth, there is always a trade-off between bias and variance arises when choose matching algorithms. However, there is not a best matching algorithm in the PSM method for all situations, which algorithm to choose depends on the situation at hand. It is better to try a number of approaches.

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