IMPLICATIONS OF BOVINE SOMATOTROPIN ON PERFORMANCE AND STRUCTURE FOR WESTERN CANADIAN DAIRY FARMS

By Kenny K.H. Chow

A Thesis
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Abstract

BST is experimentally found that it could increase milk production by 10 percent. This bio-technology may be attractive for dairy farmers to adopt. The objective of this study is to examine some of the potential effects of BST administration on western Canadian dairy farms. The effects include: BST profitability on gross margins of the farm operation; short-run adjustments on milk production levels, herd size, and input combinations for the dairy and cropping enterprises; milk quota values; milk prices; and likely long-term impacts in terms of structural changes in the dairy and related agricultural sectors.

Some farms representative of dairy farms in prairie region are classified in this study. A linear programming model is developed to examine BST effects to the representative farms. Two scenarios are assumed regarding BST adoption: milk quota and no milk quota purchase scenarios. Modelling results show that BST is profitable to be adopted on western Canadian dairy farms under either assumed quota scenarios. Both quota scenarios have unique advantages, in terms of gross margins and assets investment of the farms, regarding BST adoption. Input combinations for the dairy and cropping enterprises do change. The respective share of each feed used for rations are changed, although the types of feed remain constant. Cash crops acreage and labour hours hired on the farm are also affected by BST adoption. The respective changes on cash crop acreage and hired labour hours depend on the type of quota scenario assumed.

Results also show that milk quota values would increase after BST is introduced to the sector. Conversely, milk prices would be insignificantly affected in the intermediate-term. In the short-run, BST is likely to have some small effects on dairy farm and cow numbers. However, the long-term implications of BST adoption may be more significant. The bio-technology would reinforce the trend of fewer but larger dairy herds in the sector. Furthermore, the impacts of BST adoption on related sectors such as; beef, cropping, and farm inputs are likely to be minor.

Table of Contents

Page

List of Tables **Page**

Page

Page

List of Figures **Page**

CHAPTER ONE INTRODUCTION

1.1 Background

1.1.1 Nature of the Dairy Industry in Western Canada

The dairy sector in western Canada (i.e., Manitoba, Saskatchewan, Alberta and British Columbia) has a small share of the total national dairy sector, relative to central Canada (i.e., Ontario and Quebec). The value of milk production in the region represents approximately 22 percent of the total for the Canadian dairy sector. However, the value of dairy production in western Canada is significant (i.e., $ 673 million in 1988, Agriculture Canada, Communication Branch 1989).

There is a significant amount of government intervention in Canada's dairy industry. In particular, dairy farmers operate under a policy of supply management. At the national level, the Canadian Dairy Commission regulates the industrial milk[1] market, determines the targeted production level, and the amount of Market Sharing Quota (MSQ) for industrial milk in Canada. At the provincial level, milk marketing boards or milk control boards are responsible for controlling fluid milk market production and marketing. These provincial agencies regulate fluid milk production, the prices paid to producers for fluid milk, distribute the provincial share of MSQ among dairy farmers and manage the marketing of dairy products.

On the producer side, dairy farmers have to acquire milk quota (for both industrial and fluid milk) in order to sell milk. Although milk quotas are allocated by provincial

[1] Industrial milk is a term used to represent milk that is utilized in the production of cheese, yogurt, ice cream, etc.

milk boards, farmers can transfer the rights to sell milk through quota transactions. Therefore, herd size expansion or contraction is closely related to quota transactions.

While milk is produced in all provinces, the structure of the dairy sector differs significantly between regions in Canada. The dairy sector in western Canada is unique, relative to other parts of Canada. As noted earlier, the dairy sector in this region is smaller than that in central Canada (i.e., Quebec and Ontario). Table 1.1 provides a historical record of the number of Canadian dairy farms, by province. The total number of dairy farms in either Ontario or Quebec is almost ten times as great as the number in each western Canadian province. Similarly, the total numbers of dairy cattle in western Canada are less than in central Canada. Due to the size differences for the dairy sectors in various regions, the allocation of industrial milk production varies substantially among different regions, with the central region having a proportionally larger share (Appendix A, Tables A-1 and A-2). A comparison between MSQ shares and provincial population is provided in Table A-7.

There are many other structural differences between dairy sectors in different regions of the country. Cropping patterns for dairy farms vary because of climatic and soil type differences between regions. The soil and climate conditions in Quebec and Ontario are appropriate for growing corn for use in dairy rations. Conversely, dairy farmers in western Canada rely on cereal grains such as wheat, oats and barley.

1.1.2 Structural Trends in the Western Canadian Dairy Sector

The Canadian dairy sector has been undergoing structural adjustments for many years. In particular, the trend has been towards fewer but larger dairy farms (The Canadian Dairy Commission 1975-1990; Agriculture Canada, Communication Branch 1989; Statistics Canada 1971-1986a). This trend has been exhibited in all regions. In western Canada, the numbers of dairy farms and dairy cattle (including cows and heifers) have decreased during the last ten years (Tables 1.1 and 1.2). However, the percentage decrease in cattle numbers is smaller than the decrease for farms numbers, except in Saskatchewan. As a result, the average herd size in the region has increased throughout the period of 1977-87.

The productivity of the western Canadian dairy sector, measured in terms of milk produced per cow per year, has also increased over the same period (Table 1.3). Over the period of 1976-87, milk production (measured as milk sold per cow per year) increased between 35 and 102 percent in the provinces, representing an annual average increase of 2.9 to 8.6 percent. These increases in milk production have been due to better herd and health management, increased use of artificial insemination and improved farm equipment and milking technologies.

1.2 Economic Problem Statement

A new factor may soon be introduced that will affect the dynamics of the western Canadian dairy sector. In particular, farmers may soon have access to synthetically produced bovine somatotropin (BST). This hormone is produced by the pituitary gland

Table 1.1 Historical Numbers of Dairy Farms, by Province

Year	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	Eastern Canada[a]
1977	1334	2081	960	1742	15880	25838	2119
1978	1274	2014	995	1593	14698	24662	2038
1979	1230	1992	990	1528	12943	23848	1994
1980	1174	1882	910	1413	12217	21785	1887
1981	1183	2026	877	1378	12065	21921	1901
1982	1141	1890	870	1292	11752	20485	1879
1983	1131	1841	862	1231	11483	19811	1852
1984	1095	1760	834	1234	11190	19179	1807
1985	1080	1707	830	1199	10890	18569	1777
1986	1063	1628	822	1158	10231	17898	1705
1987	1061	1614	756	1130	10238	16984	1690

[a] Eastern Canada consists of Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick.

Source: The Canadian Dairy Commission, 1975 to 1990.

Table 1.2 Historical Numbers of Dairy Cows and Heifers (000's), by Province

Year	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	Eastern Canada[a]
1976	114.0	214.0	111.0	126.0	915.0	1110.0	122.9
1977	116.0	210.0	112.0	125.0	903.0	1018.0	122.8
1978	118.5	209.0	114.0	121.0	872.0	991.0	126.0
1979	124.0	215.0	104.5	112.0	844.0	960.0	122.5
1980	129.0	224.0	107.5	113.0	820.0	965.0	124.8
1981	127.5	220.5	109.0	115.0	835.0	988.0	132.3
1982	132.5	209.0	107.0	112.0	844.0	980.0	130.9
1983	128.0	194.0	100.0	107.0	809.0	938.0	129.3
1984	125.0	190.0	95.0	105.0	809.0	922.0	128.4
1985	122.5	181.0	86.0	99.5	782.0	881.0	126.6
1986	113.5	175.0	73.5	94.5	723.0	830.0	125.8
1987	112.5	178.0	73.0	94.0	705.0	807.0	123.9
1988	115.0	176.0	73.0	95.5	705.0	816.0	124.0

[a] Eastern Canada consists of Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick.
Source:The Canadian Dairy Commission, 1975 to 1990.

Table 1.3 **Milk Sold Per Dairy Cow (Litres/Year) less Farm Separated Cream, by Province**

Year	Manitoba	Saskatchewan	Alberta	British Columbia
1976	2990	2120	3030	4880
1977	3050	2200	3160	4920
1978	3140	2230	3170	4860
1979	3410	2350	3140	4970
1980	3510	2390	3140	5050
1981	3477	2514	3359	5334
1982	3624	2746	3709	5174
1983	3794	2998	3885	5203
1984	3964	3329	4167	5580
1985	4140	3386	4298	5754
1986	4482	4233	4756	6475
1987	4718	4299	4715	6597
Total Percentage Increase	57.8%	102.8%	55.6%	35.2%
Annual Average Increase	4.8%	8.6%	4.6%	2.9%
Annual Average Increase (l/year)	144	181.6	140.4	143.1

Source: Agriculture Canada, Policy Branch 1985 to 1988.

in cattle. The hormone has several effects, one of which is to stimulate milk production. It has long been known that injections of BST will cause increased milk production in cattle, with experiments by Asimov and Krouze dating back to 1937. However, until recently the hormone could only be extracted using glands from slaughtered animals, making commercial use of BST impractical (Bauman and Epperd 1985; McNaughton 1988).

During the last decade, genetic engineers have successfully used recombinant DNA technology to produce bacteria that are capable of synthesizing BST in large quantities at a relative low cost (Kennelly and DeBoer 1988; Legates 1989). This development has significantly increased the commercial feasibility of the biotechnology.

Commercial introduction of BST for use by Canadian and American dairy producers has been delayed pending approval by the appropriate regulatory agencies in each country. However, the potential economic effects of commercial introduction have been examined in several studies. These studies have addressed issues related to potential adoption rates (e.g., Zepeda 1990), effects on farm level profitability (e.g., Trelawny and Stonehouse 1989) and impacts on sector performance and structure (e.g., Fallert et al 1987). However, most of the studies have addressed these issues from the perspective of the American dairy sector, or in the case of Canadian studies, the Ontario dairy sector.

Assuming that BST is made available to dairy producers in western Canada, there are some unanswered questions related to several issues. One very important question relates to the short-term profitability of the new technology. At the present time, there is some uncertainty concerning the potential impact on farm level profits. The impact on profit will be determined by the production response resulting from use of BST, as well as the cost of the technology and changes in any other costs.

A second question relates to the impact on production decisions if BST is adopted by producers. It is likely that producers will alter their decisions concerning the level of total milk production and the combination of inputs used to produce that output. This situation is further complicated by the presence of supply management. Given that additional milk quota may be required in order to increase production for a particular farm, it is not clear whether BST will result in changes to the optimal level of milk production by farmers, or simply a reallocation of inputs while maintaining current production levels.

A related question concerns the impact of BST on quota values. In the Canadian dairy industry, milk quota can be considered as a non-substitutable input in the production of milk. Although quota is not actually a productive input, milk production will not occur in practice without it. If milk production is profitable, quota takes on a positive value to producers. Economic theory would suggest that if adoption of BST improves farm level profitability, there will be a corresponding effect on quota value and price. At present, this impact is unknown.

A final question relates to the impact of BST adoption on the long-run structure of the western Canadian dairy sector. Any changes to profitability at the farm level will have effects on the optimal structure of dairy farms in this region. Whether BST use will result in changes to the ongoing structural adjustments in this sector, or simply reinforce these trends, is not known at the present time.

1.3 Study Objectives

The economic questions considered in the previous section provide the focus for the research plan of this study. In particular, the overall goal of this study is to examine the economic impacts of BST adoption by dairy producers in western Canada. These impacts include changes in profitability (in terms of farm profit margins), milk production levels, input use, and long-term structural adjustments. Within this overall goal, there are several specific research objectives.

The first objective of this study is to develop and construct an economic model that is capable of reproducing the physical and financial performance of representative western Canadian dairy farms over a multiple year planning horizon. This model is used throughout the study to examine the impacts of BST adoption.

The second objective of this study is to define several dairy farm operations that are representative of dairy farms located in western Canada. Important physical and/or financial characteristics are used in defining these farms. These representative farms are modelled using the economic model, as indicated above.

The third study objective is to model the adoption of BST by the representative dairy farms. In particular, the short-term impacts of BST adoption on farm gross margins, optimal production levels, herd size, ration composition, crop mix, etc., will be assessed using the results of the economic modelling procedure. A related objective of the study is to assess the impact of BST adoption on values for milk quota.

The fourth objective is to examine whether BST has any impacts on dairy production costs and milk prices. In Canada, milk prices are set by milk control boards at the federal and provincial level and are based on production costs for a sample of dairy farms. Assuming a significant adoption rate for the technology, if BST has an effect on production costs, the changed would be reflected in farm level milk prices.

The final objective of the study is to assess the potential long-run impacts of BST adoption. These impacts include possible structural changes in the dairy and related agricultural sectors that arise from the short-term adjustments attributable to BST adoption.

1.4 Hypotheses

Given the specific research objectives specified above, several hypotheses are tested in this study, as follows:

1. It is hypothesized that if adopted, BST increases the total gross margin for western Canadian dairy farms.
2. It is hypothesized that, in the short-run, BST adoption will result in farmers changing input combinations (e.g., feed and labour) for dairy production. In addition, farm cropping enterprises would be adjusted accordingly.
3. It is hypothesized that the value of milk quota will be affected by BST adoption. In particular, quota values will increase.
4. It is hypothesized that BST will have impacts on dairy production costs and therefore milk prices.
5. It is hypothesized that the long-run structure of the dairy sector and related agricultural industries in western Canada will be affected by BST, as both the number and size of dairy farms will change.

1.5 Outline of the Study

The remainder of this thesis is divided into five chapters; that is, Chapters Two through Six. Chapter Two presents a review of literature dealing with the BST technology itself and the effects of BST adoption. Chapter Three provides a discussion of the conceptual framework (i.e., economic theory and analytical technique) from which the empirical methodology used in this study is developed. Chapter Four is devoted to a discussion of the representative farms, data sources and specification of the empirical model for analysis. Chapter Five presents the results of the analysis and a discussion of their implications. Both short-run and long-run economic implications of BST adoption will be examined based on the results for the representative farms. Finally, the conclusions for the study are summarized in chapter Six. In this chapter, limitations of the study and suggestions for further research are also provided.

CHAPTER TWO LITERATURE REVIEWS

2.1 Introduction

This chapter provides a review of literature relevant to this study. As noted in the last chapter, there are two sections in this chapter. The first section reviews previous studies concerning the experimental results of BST injection and the effects of BST on cows and milk. The second section includes reviews of economic analyses of BST adoption in previous studies.

2.2 Bovine Somatotropin[2]

Bovine Somatotropin (BST), also referred to as bovine growth hormone (bGH), is a protein produced by the anterior pituitary gland, and is composed of 191 amino acids. BST, like a "chief director" in the endocrine (glandular) system, instructs the cow's internal mechanism to give priority to milk production rather than physical growth. BST stimulates milk production through an increase in lactose. Increased BST levels result in a slight increase in the level of insulin in the cow's blood. The insulin works with an enzyme called glucagon to produce more glucose. Meanwhile, there is also an increase in the level of alpha-lactalbumin, which is part of the enzyme lactosynthese that helps convert glucose into lactose. Increased lactose levels result in increased milk production.

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[2] A discussion concerning the biological effects of BST is provided by several sources, including Bauman (1990), Bauman and Eppard (1985), Council for Agricultural Science and Technology (1989), Kennelly and DeBoer (1988), Legates (1989), McNaughton (1988) and Petitclerc and Pelletier (1985).

Previous researchers believed that BST works directly on the mammary cells of the cow. However, this has recently been proven to be wrong. Instead, increased BST results in increased levels of the "insulin-like growth factor #1", or IGF-1, that is located in the mammary. It is this factor that causes the cow to produce more milk. In addition, BST is also a homeorhetic control, which shifts the partitioning of nutrients for the purpose producing milk. Therefore, the biological effect of BST is to direct the use of absorbed nutrients. Adjustments in metabolism of body tissue would also occur due to the effects of BST.

Despite understanding the biological effects of BST on the cow's body, BST use on dairy farms is impractical because of the significant cost. In order to produce a dose of BST for injection, many slaughtered cattle are required. Therefore, the associated production costs are very high. Nevertheless, genetic researchers have discovered that recombinant DNA technology is able to synthesize large amounts of BST at a low cost. The success of this bio-technological development could make BST a viable technology for the dairy industry in the near future.

The production of recombinantly-derived growth hormone can be summarized into a few steps (Legates 1989). To begin with, some natural pituitary bovine growth hormone genes are extracted from cows. They are then cloned, and inserted into a bacterium (Euscherichia Coli). The next step is to seed the bacteria in fermentation vats. The genetically altered bacteria will reproduce and produce more BST. Finally, the recombinant BST is purified and ready for injection in cows to increase milk production.

2.2.1 Milk Production Response during BST Treatment Period

Experimental results indicate that the range of milk yield increases attributable to BST are between 6 percent and 41 percent for long-term treatment and between 10 percent and 30 percent for short-term treatment. Milk yield responses depend on several factors, including dosage, starting date, duration of treatment and quality of management. A summary of short-run and long-run experimental results of BST treatment on lactation cows is presented in Tables B-1 and B-2 in Appendix B.

Under normal herd management conditions, the most reasonable milk yield increases from use of BST should be between 10 percent and 25 percent for long-term BST treatment (Council for Agricultural Science and Technology 1989; University of Massachusetts, Cooperative Extension 1989). Milk yield increases gradually in the first few days of treatment, and reaches a peak level in about five to eight weeks following treatment. As the lactating cycle progresses, milk production declines as it does for untreated cows. However, the level of production is still above the milk production level for untreated cows (Bauman 1990; McCutcheon and Bauman 1985; Schieldt 1989). Some studies claim that the milk production responses from BST are likely to be higher for genetically superior or higher producing cows (e.g., Bauman 1990, University of Massachusetts, Cooperative Extension 1989).

The level of dose and timing of treatment are important in determining the level of response. The optimal dose appears to be between 30 to 40 mg. per day (Bauman 1990). The optimal time to start treatment with BST is after milk yield has peaked. The production response to BST appears to be very small or negligible if BST is used early in the lactation period, because endogenous production of the hormone by the cow is at its highest. This will cause exogenous application of BST to have limited effect (Trelawny and Stonehouse 1989; Bauman 1990). Another reason for delaying use of BST is that the energy needs for the additional milk may delay fertility and produce longer calving intervals. Therefore, researchers recommend initial use of BST between 60 and 100 days after calving, to allow the cow to breed back without any side effects (Schieldt 1989; Council for Agricultural Science and Technology 1989).

With regard to the treatment duration, BST can be used for occasional short-term treatment. Treatment can be as short as 7 days, or as long as the last three quarters of the lactation cycle (Bauman 1990; Bauman and Eppard 1985). Experimental results suggest that occasional short-term use of BST provides a slightly lower milk yield increase in both absolute and percentage terms. However, some dairy farmers will likely use BST to increase milk production in order to meet their milk quota in the very short term. After the quota is filled, they will stop using BST on the farm. One of the advantages of using BST is that no specific treatment duration is required.

2.2.2 Effect of BST on Feed Requirements and Efficiency

During the first few days of treatment with BST, cows use their body reserves to support extra milk production. This results in a negative energy balance for the cow. Nevertheless, with long-term treatment the cow will increase feed intake (Bauman 1990; Kennelly and DeBoer 1988; Schieldt 1989). McNaughton and Schieldt also suggest that treated cows require higher quality of feed in order to compensate for loss of body reserves during the early period of treatment. However, Kennelly and DeBoer argue that, "even increase in feed intake generally is not sufficient to balance the change in milk yield" (p.6). Therefore, the animal is likely to have lower body reserves throughout the treatment period. On the other hand, if feed supply is restricted, the cow will continue to use body reserves to produce milk. This will definitely harm the health of the cow. Researchers do agree that if care is taken in formulating rations, there will be no harmful effects to the health and longevity of the cow.

BST does not change the efficiency of converting feed into milk. The efficiency of converting absorbed nutrients into milk remains the same as before treatment. In absolute terms, the nutrition requirements for body maintenance also remain unchanged. The extra feed intake required with BST treatment is used to produce more milk. The degree to which feed intake increases depends on the milk yield response, the energy density and the ratio of concentration to forage in the ration (Bauman 1990; Petitclerc and Pelletier 1985). For example, a 10 to 15 percent increase in milk yield would require only 6 to 10 percent more feed, respectively. The increased efficiency results from a reduced maintenance requirement per unit of milk.

2.2.3 Effect of BST on Milk Composition

The gross composition of milk from treated cows is not altered by BST. Monsanto Company scientists report that a significant increase in protein percentage (approximately 6 percent) occurs for milk from treated cows. However, this occurs only during a short period of the lactation cycle. Overall, the protein percentage is not altered by any level of BST administration. Other researchers claim that no significant change of protein percentage is detected (Bauman 1990; McNaughton 1988; University of Massachusetts, Cooperative Extension 1989).

Average fat concentration in milk over the entire lactation is also similar for treated and untreated cows. Fat percentage increases, however, only if the cow is in negative energy balance during the first few days of treatment. Once the cow returns to normal energy balance, the milk fat percentage returns to normal levels (Monsanto Agricultural Company 1988; Bauman 1990; University of Massachusetts, Cooperative Extension 1989).

The mineral content of milk from treated cows is not altered by BST use. Calcium, phosphorous and ash levels for milk from treated cows are similar or even greater than (up to 12 percent) levels in milk from untreated cows (Bauman 1990; Monsanto Agricultural Company 1988).

Lactose content in milk is also relatively unchanged by BST treatment. Milk lactose concentrations are found to be elevated due to BST injection during the first eight weeks of the treatment (Bauman 1990; Monsanto Agricultural Company 1988), but return to normal levels afterward.

Finally, manufacturing characteristics of milk from BST-supplemented cows do not differ from those for untreated cows. The characteristics that are important for manufacturing purposes include freezing point, pH, alcohol stability and thermal properties. The flavour and odour of milk also do not change due to BST injection. Similarly, no difference is observed "in cheese making properties, the yield, the composition or sensory properties of the various types of cheese" (Bauman 1990, p.17).

Conversely, some studies show that BST will have slight effects on the storage stability of milk and milk derived products (Monsanto Agricultural Company 1988; McCutcheon and Bauman 1985). These effects are due to slight changes in fatty acid content during the initial treatment period. However, since the overall fatty acid composition of milk is not changed by BST, the effects of changing fatty acid on the storage stability of milk and milk derived products are small.

2.2.4 Effects of BST on Animal Health and the Safety of Milk for Human Consumption

Some researchers claim that BST injections will result in possible side-effects such as Ketosis, fatty liver, crippling lameness, mastitis and infertility. However, there is a lack of actual data or experimental evidence to support these claims. Catastrophic health effects in treated cows have not been observed for either short or long-term experiments in chronic or acute toxicity studies (Bauman 1990; Legates 1989; Monsanto Agricultural Company 1988; University of Massachusetts, Cooperative Extension 1989). Any metabolic disorders would most likely occur during the first few days of BST treatment due to increased use of body reserves for milk production. If sufficient feed is supplied to the cow, however, the disorder will be temporary and mild in nature.

Stress problems are also not found in treated cows. Researchers evaluate stress problems based on two considerations; milk production and heat expended. If the cow were under stress or adverse health conditions, it would produce less milk or be less efficient. However, researchers have not found this to occur with BST treatments. Also, if the cow were under stress or adverse conditions, the energy expended as heat would be greater than expected by researchers. Again, this is not the case. Therefore, stress problems are not likely occur for BST treated cows (Bauman 1990; Schieldt 1989).

Reproduction is an important concern to dairy farmers. Many BST studies demonstrate that major reproduction problems are not observed (Legates 1989; Schieldt 1989). However, Kennelly and DeBoer (1988) claim that there are a lack of long-term BST studies with use of the biotechnology extended over more than one lactational period. They argue that definitive conclusions should be drawn on results from studies that extend beyond a single lactation. In addition, Bauman (1990) claims that BST supplementation will result in decreased pregnancy rates. Council for Agricultural Science and Technology researchers (1989) observe that a delay in breeding back after lactation is commonly observed in high-producing dairy cows. Although the pregnancy rate decreases, the conception rate of the treated cow is not changed. Decreases in the pregnancy rate, or equivalently increases in days open, are associated with increased milk yield. Therefore, the decrease in pregnancy rate is not unpredictable, but is not directly related to the use of BST (Bauman 1990).

Milk from BST cows is safe for human consumption. Sufficient evidence is provided by several studies to support this statement. Although a few studies report that milk from treated cows has slightly higher levels of growth hormone in it, administration of expected commercial doses of BST to dairy cows will not increase the level of growth hormone in milk (Bauman 1990; McNaughton 1988; Kennelly and DeBoer 1988; Legates 1989; Monsanto Agricultural Company 1988).

Even if milk is found to have higher levels of the growth hormone, the hormone is not harmful to human body. BST has been proven to be biologically inactive when orally ingested. Since it is a protein which can be digested enzymatically like other proteins, it will not have any effects to human. Experiments also indicate that bovine growth hormone is different from human growth hormone. Only growth hormone from humans or monkeys can stimulate growth in humans. This is called the "species-specific" activity of BST. Therefore, even if humans drink milk which contains higher levels of bovine growth hormone, there will be no biological growth effects (Bauman 1990; Kennelly and DeBoer 1988; Monsanto Agricultural Company 1988).

BST also does not result in any harmful residues being left in milk. Recombinantly-derived BST is a highly purified hormone. The minor impurities present in the dose are only degraded forms of BST and other proteins. Therefore, like BST itself, the excipents are easily degraded by proteolytic enzymes in the gastrointestinal tract (Monsanto Agricultural Company 1988).

As noted earlier, the fat percentage in milk may increase in the first few days of BST treatment. However, the percentage will return to normal levels once additional and higher quality feed is supplied to the cow. Since the higher percentage of fat is temporary, the overall composition of milk does not change. In short, there will not be any adverse effects for human health unless the effects are caused by milk from untreated cows too (Bauman 1990; Monsanto Agricultural Company 1988; Kennelly and DeBoer 1988).

Finally, milk from treated cows will not cause allergenicity to human. This is because BST is present in the milk at a much lower level than other proteins such as casein, B-lactoglobulin and serum albumins, which are responsible for much of milk allergy in children (Monsanto Agricultural Company 1988).

2.2.5 Methods of Treatment and Required Management

There are basically two methods for BST treatment. To date, the most common method has been by injection. A few chemical companies are trying to develop subcutaneous slow-release implants for BST. This slow-release implant method still has many uncertainty associated with it, however, such as the cost of using implants and possible side effects for the cows.

More intensive management of the dairy herd is required if BST is adopted (Bauman 1990; Schieldt 1989; Kennelly and DeBoer 1988; University of Massachusetts, Cooperative Extension 1989). However, BST appears to be herd size neutral. There are essentially no economies of size associated with the technology. Nevertheless, it does require better and more intensive farm management in order to obtain the desired responses. Injections of BST require extra labour hours. Feed nutrition and energy density in the diets also require special care. In some cases, farmers already have intensive breeding programs to breed high-producing cows. Using BST on these cows requires extra care and special management, as they are more prone to health problems and longer calving interval (McNaughton 1988).

Farmers in financial difficulty who hope BST will save their farms from bankruptcy could worsen their financial situation if they do not use adequate management techniques. Poor management of the farm may cause no milk yield increase even if BST is used. This will result in suffering for both the farm's finance and the cow's health. In short, milk increase responses due to BST depend very much on the farm's management. Better management will result in higher milk yield responses.

2.2.6. Timing of BST Introduction and Cost of BST

BST is ready for use on commercial dairy farms in the near future. However, commercial introduction requires official permission from the appropriate regulatory bodies. To date, four major companies: Monsanto; Cyanamid; Elanco and Upjoin, are lobbying to get their products licensed for use by the American Bureau of Veterinary Drugs and the U.S. Federal Drugs Agency (FDA). This has not occurred yet. The regulatory agencies have concerns about the safety of the milk from treated cows for human consumption, the effects of BST on the health of the cows and the efficacy of BST to the milk production. Moreover, they require research results from BST treatment at least two lactations for their consideration. While the American government considers this issue, the Canadian government is also considering whether to issue BST licences. The likely timing for BST licences in Canada will be in the coming 2 to 3 years.

The actual commercial cost of BST is presently unknown. Estimates by researchers have been based on the likely costs of production for firms producing BST. The estimated expense per cow from these studies is U.S. $ 0.25 to $ 0.30 daily, or equivalently $ 3.50 bi-weekly or $ 67.50 per cow on an annual basis (Schieldt 1989; Legates 1989; Oxley 1988).

2.3 Review of Other Studies on Economic Impacts of BST Adoption

2.3.1 Farm-level Impacts of BST Adoption in Previous Studies

A number of studies have addressed the issue of BST adoption at the farm level. These studies primarily focus on the short-run economic impacts for BST use. The empirical approaches used by these studies involve primarily simulation analysis of mathematical programming[3]. Econometrics has also been used to investigate certain aspects of the BST issue, such as factors affecting adoption rates (e.g., Zepeda. 1990).

In these studies, the main focus is to relate BST use to financial performance of dairy farms. All of the studies (i.e., Kalter et al 1985; Fallert et al 1987; Shin et al 1987; Oxley 1988; Trelawny and Stonehouse 1989; Kliebenstein and Shin 1990; Deloitte and Touche 1990; Jeffrey and Eidman 1992) conclude that it is profitable for farms to adopt BST. These benefits arise primarily because of reduced units costs of production for milk. The actual benefits from BST use depend on many factors, such as milk response rates to BST treatment, dairy farm characteristics, management skills, etc. Moreover, BST adoption is found to be more beneficial to dairy farms when total milk production is allowed to expand (Jeffrey and Eidman 1992; Deloitte and Touche 1990).

In some cases, these studies suggest that large dairies have greater increases in net returns than do small farms, if BST is adopted (e.g., Fallert et al 1987; Trelawny and Stonehouse 1989; Kliebenstein and Shin 1990; and Shulman 1990). Moreover, farms with lower milk production per cow have better gains from BST use if total production is

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[3] Examples of studies using a simulation approach include Deloitte and Touche (1990); Fallert et al (1987); Jeffrey and Eidman (1992) and Oxley (1988). Mathematical programming has been utilized by Deloitte and Touche (1990); Kalter et al (1985); Magrath and Tauer (1988); Shin et al (1987) and Trelawny and Stonehouse (1989).

maintained (Deloitte and Touche 1990; Shin et al 1987). In contrast, higher producing herds would benefit to a greater extent from BST adoption when milk sales are allowed to expand. Nevertheless, profitability of adopting BST depends on government milk price support policy for both Canadian and U.S. studies (Shin et al 1987; Magrath et al 1985; Fallert et al 1987; Oxley 1988). Without price supports, BST appears to be significantly less attractive.

The effects of BST on inputs and crop enterprises depend on the assumption concerning total production. If milk production is constrained to pre-BST levels, overall input use by the dairy enterprise declines due to the requirement of fewer cows (Trelawny and Stonehouse 1989; Deloitte and Touche 1990). Commercial feed purchases decline and cash crop activities increase. Conversely, if total milk production is expanded, total input use increases, including inputs such as hired labour and feed (Deloitte and Touche 1990; Fallert et al 1987; Kalter et al 1985). The effects on cropping enterprises vary, depending on the types of crops and the relative costs of producing feed versus purchasing it.

2.3.2 Sectoral Impacts of BST Adoption in Previous Studies

Several previous BST studies have assessed the sector level impacts of the biotechnology. These include studies by Kalter et al (1985), Fallert et al (1987), Shin et al (1987), Magrath et al (1988), Oxley (1988), and Kliebenstein and Shin (1990). With the exception of Oxley's work, these studies all deal with the U.S. dairy sector. Given the institutional structure associated with the Canadian dairy sector, the impacts are likely to be less significant.

Given the farm-level impacts reviewed in the previous section, it is not surprising that the sector-level studies suggest that BST will result in increased milk supplies. This is particularly true for the U.S. studies. However, this aggregate supply response will be price dependent (i.e., milk prices and BST price), as noted by Magrath and Tauer (1988). This increased milk supply will be provided by fewer cows, with less productive cows likely being replaced.

Milk prices are expected to drop in response to increased aggregate milk supply, aside from any institutional factors (Kalter et al 1985; Shin et al 1987; Fallert et al 1987; Magrath and Tauer 1988; Trelawny and Stonehouse 1989; Deloitte and Touche 1990). However, the magnitude of milk price changes may not directly related to changes in the aggregate supply, due to the government dairy policies in the United States and Canada. Fallert et al (1987), Shin et al (1987) and Magrath and Tauer (1988) examine the social welfare benefits for the U.S. after BST use, assuming various government milk price support policies. In order to maintain current milk price levels, government purchases of milk products, and thus government expenditures, would have to increase. As a result, both American and Canadian governments are expected to reduce support for milk prices in response to BST, so that the benefits may be shared by both producers and consumers.

Oxley (1988) and Deloitte and Touche (1990) also examine the effects of BST on milk quota values in Canada. Both studies suggest that milk quota values would increase between 4 percent and 50 percent, after BST is introduced and adopted.

The magnitude of BST effects on the dairy sector depends on the rate with which BST is adopted. Some researchers believe that the adoption rate will be high. For example, adoption rate estimates of over 50 percent in the first five years have been made by Kalter et al (1985), McNaughton (1988) and University of Masschusetts, Cooperative Extension (1989). However, other studies suggest that not all farmers will adopt BST quickly. Neither will they apply BST to all cows in the herds. For example, Zepeda (1990) claims that researchers may easily ignore some important factors that affect the adoption rate, and thus overestimate the adoption rate for a region. Zepeda finds that herd size and management levels are associated with higher probabilities of early adopting of BST. Conversely, age of the farmer and production level for the herd would be negatively related to the probability of early adoption for BST.

2.4 Conclusion

Despite the number of economic studies related to BST use, there are still some issues that have not been satisfactorily addressed. First, most of the previous studies focused on the effects of BST for the American dairy industry. However, the structure of the American dairy sector is significantly different from the dairy sector in Canada, especially with respect to Canadian supply management policy. The milk quota system is a unique characteristic of the Canadian dairy sector. The American studies, therefore, do not examine BST impacts for quota values.

Not all Canadian studies address this issue either. For example, Trelawny and Stonehouse (1989) assume a constant level of milk production and do not incorporate milk quota considerations into their analysis. Oxley (1988) and Deloitte and Touche's (1990) studies do examine the impacts of BST on milk quota values. However, these studies do not focus on western Canadian dairy farms. Given the unique characteristics of the western Canadian dairy sector, BST impacts may vary from those presented for central Canada.

Finally, the models used in previous studies have tended to be single period linear programming models. Adoption of BST will have some impacts that are dynamic in nature. Therefore, the issue of BST adoption by western Canadian dairy farms is addressed from another perspective in this study. It is also necessary to examine the BST issue using an approach that is based on the characteristics of the western Canadian dairy sector.

CHAPTER THREE THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter focuses on the theoretical and conceptual basis for the study. There are two sections in this chapter. The first of these provides a discussion of the theoretical framework for this study. The production economic theory underlying this study is discussed in detail. The second section addresses the analytical framework. In particular, linear programming is used to empirically implement the theoretical model.

3.2 Theoretical Framework

3.2.1 The Theory of the Firm

The behaviour of firms with respect to production decisions can be explained within a microeconomic framework by the theory of the firm. Typically, it is assumed that firms are operated in a manner so as to maximize profits. Moreover, the objective is not only to maximize short-run profits, but also long-run profits (Mansfield 1991). Profit is measured as revenue less the total costs of production which can include variable and fixed costs in the short-run, and variable costs in the long-run.[4] The mathematical expression for profit is as follows :

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[4] Variable costs are expenses for inputs that can be varied in quantity during the production period. An example of a variable is feed cost for livestock. Fixed costs are expenses for inputs that cannot be changed in production. Examples are depreciation and interest on long-term debt. In a long-run analysis, there are no fixed factors of production, and therefore no fixed costs.

$$\Pi = P\ F(X)\ -\ W\ X \tag{3.1}$$

where Π represents profit, while P and W are the vectors of output and input prices, respectively. X is the vector of input factors. F(X) represents a vector of physical production, which is a function of X.

In maximizing profits, the firm faces two sets of constraints; technological constraints and market constraints. The technological constraints refer to those considerations that affect the technical feasibility of the production plan, particularly in the short-run. Not all levels of production can be achieved (i.e., are feasible) by the firm. For example, an agricultural firm may be limited by land and/or labour availability. Therefore, in making output and input decisions, a farm operator has to consider technological constraints for the firm.

Market constraints relate to the effects of decisions by other agents in the market. A firm must consider the market structure and the possible reactions of other firms in the same industry before making production decisions. Different market structures give rise to different market constraints for the firm. This affects the production and pricing strategies of the firm.

The economic issue of BST adoption by dairy farmers can be considered within a short-run profit maximization framework. More rigorously, use of recombinant BST could be considered as supplementing an existing input for milk production. Since the growth hormone that stimulates milk production already exists inside the cow's body, injection of recombinant BST simply increases the hormone level of the cow. In a sense, BST affects the biological gene of a milking cow, increasing the cow's capacity to produce milk. Owing to the increase in production capability, the cow requires higher levels of other inputs such as feed and labour hours. Nevertheless, adoption of BST does not require additional investment in fixed inputs. As a result, the use of a short-run analytical framework is appropriate.

Assuming that a multi-product multi-input profit maximization framework, mirco-economic theory suggests two conditions for optimality. The first condition concerns the output perspective. For a multi-product firm with n allocable inputs[5], the producer should choose an output level such that the marginal revenue for product j (MR_j) is equal to the marginal cost for producing the j^{th} product (MC_j); that is, $MR_j = MC_j$ for j=1,2, etc. In other words, additional units of the j^{th} product should be produced up to the point where the additional costs of production just equal the additional revenue generated by the output.

From the input perspective, the value of the marginal productivity for the i^{th} input in production of the j^{th} product should be equal to the price of the input, or its marginal factor cost (MFC); that is, $VMP_{ij} = W_i$.[6] Since W_i is constant in a perfectly competitive

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[5] Inputs used in the production of multiple outputs are considered to be allocable if the total amount of input used can be allocated between the various products being produced.

[6] Since $\frac{\partial PF(x)}{\partial X_i} = Pf_i(X) = VMP_i$ where $f_i(X)$ is the marginal physical product for input i, and $\frac{\partial WX}{\partial X_i} = W_i = MFC_i$, the partial derivative of equation 3.1 with respect to X_i is VMP_i - MFC_i. Setting the derivative to zero and rearranging terms provides the result: $VMP_i = MFC_i$.

market, this condition implies that $VMP_{ij} = VMP_{ik}$, for all products j and k. If there are non-allocable inputs[7] used in the production process, an additional condition is required. This condition states that the sum of the values of marginal productivity for non-allocable input z should equal the marginal factor cost of z. Mathematically, this expression is as follows : $\sum_j VMP_{zj} = W_z$ for all products j = 1,2, etc. Both the second and third conditions suggest that it is not economical to use an additional unit of an input, whether allocable or non-allocable, if the additional revenue generated by that unit is less than its cost. To this end, these two conditions together guarantee optimal usage and allocation of inputs.

It should be noted if production is at the optimal level (i.e., profit maximizing), the output and input conditions will be consistent. In other words, if $MR_j = MC_j$ for all j, then $VMP_{ij} = W_i$ for all combinations of output j and allocable input i, and $\sum_j VMP_{zj} = W_z$ for all non-allocable inputs (Beattie and Taylor 1985).

3.2.2 Application of the Theory to the Western Canadian Dairy Sector

The theory of the firm (multi-output, multi-input) can be applied to western Canadian dairy farms. However, because of special characteristics associated with the dairy market structure, some slight adjustments are required for application of the theory. Dairy farmers are assumed to have profit maximization from farm enterprises as their objective. These profits are assumed to be maximized over a short to intermediate-term time horizon (i.e., three years).

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[7] An input is non-allocable if the total amount of input used in production of multiple outputs cannot be allocated between the various products.

As noted earlier, dairy producers are subject to both technological and market constraints. There are certain technologies available for dairy and crop production. These technologies, combined with constraints on productive inputs, determine the set of feasible production plans for the farm. Given the short-run nature of this study, some inputs are assumed to be fixed. These inputs include machinery and building capacity, land and labour.[8] If BST is adopted, the bio-technology allows the farm to expand the set of feasible milk production plans for the herd. However, the farm still faces the same set of technical constraints.

In regard to the market constraints, Canadian dairy farmers constitute a purely competitive market in terms of milk supply. In a pure competitive market[9], there are a large number of firms. Each firm's output is small, relative to total industry output. Therefore, the firm does not have any significant influence on price through expansion or contraction of its own output. Each firm is a price-taker, which means that it receives a given price, determined by the market. There are no barriers to entry or exit in the industry (Call and Holahan 1983).

Dairy farmers are assumed to be operating in a purely competitive market, for several reasons. There are a large number of dairy farmers in western Canada. More

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[8] Land and labour are actually only quasi-fixed, as additional inputs may be rented or hired.

[9] In economics, a pure competitive market structure is different from a perfectly competitive market in that all firms in a perfectly competitive market are assumed to be identical in terms of technology, management skills, location, etc. A detailed discussion concerning the definitions of these two market structures is provided by Call and Holahen (1983).

importantly, however, these farmers are price-takers. Although one of the objectives of the Canadian Dairy Commission and provincial marketing boards is to provide a reasonable milk price for dairy farmers, the farmers themselves have little influence on pricing policies of these institutions. Finally, individual farms do not have a significant share of the total milk market. The only limiting assumption from a purely competitive market perspective is the significant barrier to entry represented by the quota system.

In the Canadian dairy industry, farmers require milk quota to enable them to sell milk to the milk boards. However, no legal constraints prevent farmers from ceasing milk production. In other words, there are no barriers to exit. Quota may be disposed of and allocated to other producers, if a farmer wishes to leave the industry. Meanwhile, the quota barrier to entry into the industry does not provide any monopolistic power to farmers. In addition, the characteristics of milk that a farmer supplies are no different from milk supplied by other producers. All of these factors combine to provide a competitive environment within which individual dairy farmers make decisions (Moschini 1989).

The farms classified in this study are multi-product firms with several allocable and non-allocable inputs. Production activities for the farms include dairy, livestock[10] and cropping enterprises. Dairy and cropping enterprises are separate production processes sharing allocable inputs such as labour and capital. Conversely, dairy and livestock enterprises are joint production activities. Non-allocable inputs include rations, labour and

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[10] Livestock includes production of cattle for sale such as calves, heifers and cull cows.

capital. BST is obviously an allocable input for dairy production only. The production functions for these three enterprises may be mathematically specified as follows:

$$milk = f^{m}(ration_i,\ lab_c,\ capital_c,\ BST/livestock) \tag{3.2}$$

$$livestock = f^{l}(ration_i,\ lab_c,\ capital_c\ /\ milk) \tag{3.3}$$

$$crop_o = f^{o}(lab_o,\ capital_o,\ land_o) \tag{3.4}$$

where m and l represent milk and livestock production, respectively. Notation o represents the various crops that are produced by the farm. Rations are comprised of i types of feed. Allocable inputs between dairy and crop production are labour and capital. The subscript c in equations 3.2 and 3.3 denotes the inputs for cattle in the respective production functions. Moreover, the livestock enterprise can be considered as a by-product of the dairy enterprise. Livestock are produced in conjunction with milk production, whether the farmer wishes it or not. This relationship is represented by the slash in the equations. It should also be noted that there is an interaction between milk and crop production, as some of the output from crop production may be used as an input in the milk production process, as ration components.

If the mathematical objective function and production function are defined, the optimal levels of inputs and outputs can be determined by constructing and solving a constrained profit maximization problem. Within the context of this problem (i.e., dairy farm production decisions), some resources are available in fixed amounts at a zero cash (i.e., explicit) cost. These resources include labour and land. This does not change the nature of the analysis, however. The definition of profit is, thus, adjusted as follows:

$$\textbf{Max } \pi = \mathbf{P_m \times milk + P_l \times livestock + \sum_o P_o \times crop_o - total\ capital\ cost}$$
$$\mathbf{- \sum_i total\ expense\ on\ the\ i^{th}\ ration - BST\ cost}$$

subject to:

$$\mathbf{capital_m + capital_o \leq own\ capital + financing\ capital}$$
$$\mathbf{labour_m + labour_o \leq labour\ available}$$
$$\mathbf{\Sigma_o\ land_o \leq land\ available}$$
$$\mathbf{milk \leq f^m\ (ration_i,\ lab_c,\ capital_c,\ BST\ /\ livestock)}$$
$$\mathbf{livestock \leq\ f^l\ (ration_i,\ Lab_c,\ capital_c\ /\ milk)}$$
$$\mathbf{crop_o \leq f^o\ (lab_o,\ capital_o,\ land_o)} \qquad \textbf{(3.5)}$$

3.3 Conceptual Methodology
3.3.1 Linear Programming Technique

Linear Programming (LP) is the technique used for analysis in this study. The basic form of a linear programming model is as follows (Hazell and Norton 1986):

$$Maximize \quad cy$$

subject to

$$Ay \leq b$$

$$y \geq 0 \qquad \textbf{(3.6)}$$

where y represents a vector of activities (e.g., crop production, milk production, labour hiring), while c represents the marginal contribution of each unit of activity to the decision-maker's objective (e.g., net returns). The matrix A contains input or output coefficients that provide the structure of the resource constraints of the economic problem (e.g., land and labour utilization per unit of activity), while b is a vector of resource endowments. Note that this basic form of the linear programming model is consistent with the profit maximization problem presented in equation 3.5.

Linear programming is only one alternative for use in the analysis of BST adoption. Econometrics or simulation analysis may also be used. Econometrics provides "numerical values for the parameters of economic relationship and verifies economic theory" (Koutsoyiannis 1977, p.3). Econometrics deals with the statistical measurement of economic relationships. In fact, econometrics is a useful analytical technique for analyzing aggregate farm problems. However, the technique provides little information about optimal decisions for individual farm-level analysis.

Simulation methods deal with problems which "cannot be represented in the concise model forms due to stochastic relationships or complexity. It is a means for deriving measures of performance about a complex system by conducting sampling experiments on a mathematical model of the system over periods of time" (Lee, Moore and Taylor 1985, p.551). For the issue of BST adoption, the unanswered questions can be addressed by using linear programming models for representative dairy farms. Linear programming models are much easier to construct and use than simulation models, which tend to be more complicated.

3.3.2 Property of Optimization of Linear Programming Analysis

As just explained, linear programming has advantages over other analytical techniques for use in analyzing the BST issue. In particular, linear programming provides an optimal solution, given the structure of the economic model. The optimization property of linear programming solutions is characterized by satisfaction of Kuhn-Tucker conditions (Lee, Moore and Taylor 1985; Hazell and Norton 1986; Intriligator 1971). The conditions are derived from application of the Lagrangian method to mathematical programming models with inequality constraints. Since linear programming is a special case of non-linear programming, Kuhn-Tucker conditions also apply to the linear model.

The Kuhn-Tucker conditions are briefly discussed below. A more detailed discussion (and derivation) of the Kuhn-Tucker conditions can be found in Intriligator (1971). To preserve the original explanation of Kuhn-Tucker conditions, a non-linear model is assumed. A model similar to equation 3.6, but in non-linear form, is presented as follows:

$$\underset{y}{Max}\ F(y)$$

subject to

$$g(y) \leq b \tag{3.7}$$

where F(y) is the objective function defined in terms of all y decision variables, and g(y) is a vector of constraint functions. Again, b is a vector of resource endowments. A Lagrangian function can be constructed, as follow:

$$L_{\Pi}(y,\lambda) = F(y) - \lambda\,[g(y) - b] \tag{3.8}$$

where λ is a vector of Lagrangian multipliers. Each element of λ represents an implicit value for the corresponding resource that is equal to the change in F(y) attributable to an one unit change in the resource endowment (Hazell and Norton 1986).

The Kuhn-Tucker conditions[11] for this problem are:

$$\frac{\partial L_{\Pi}}{\partial y_j} \leq 0; \; but \; = 0 \; if \; y_j > 0. \tag{3.9a}$$

$$\frac{\partial L_{\Pi}}{\partial \lambda_l} \geq 0; \; but \; = 0 \; if \; \lambda_l > 0. \tag{3.9b}$$

and non-negative values of y_j and λ_l for all j activities and l constraints.

If the objective function (F(y)) is concave and constraints (g(y)) are convex, then the y vector that solves 3.9a and 3.9b will be a global optimal solution to the original non-linear problem. Since the objective function and constraints in linear programming models are all linear (i.e., both concave and convex), the solution to the problem will be a global optimum.

3.3.3 Linear Programming and the Theory of the Firm

As noted above, a linear programming solution satisfying the Kuhn-Tucker conditions is a global optimal (either maximized or minimized) solution. Moreover, if the linear program is modelling profit maximization for a multi-output, multi-inputs firm, the solution also satisfies the two optimality conditions discussed in the theoretical section. An example is provided to illustrate the consistency of the analytical technique and the theoretical model. The model defined by 3.5 is used as an illustration. Given the assumptions of the competitive structure in both input and output markets, the general form of a linear programming model is constructed as follows:

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[11] The resulting Kuhn-Tucker conditions are taken from Intriligator 1971 p.56.

$$Max\ \Pi = \sum_j P_j y_j - \sum_i W_i^v x_i^v - \sum_z W_z x_z$$

subject to constraints:

$$\sum_j a_{ij} y_j - x_i^v \leq 0 \qquad \forall\, i$$

$$\sum_j a_{kj} y_j \leq b_k^f \qquad \forall\, k$$

$$y_j - d_{zj} x_z^v \leq 0 \qquad \forall\, z, \forall\, j$$

$$y_j, x_i^v, x_z^v \geq 0 \qquad \forall\, j, \forall\, i, \forall\, z \qquad \textbf{(3.10)}$$

where P_j is defined as the price of the j^{th} product (j = milk, livestock and crops). Allocable variable inputs are denoted by x_i^v (i = BST, capital, hired labour and rented land for dairy and cropping enterprises). Non-allocable variable inputs are denoted by x_z^v (z = labour, rations and capital used for dairy and livestock enterprises). Maximum available fixed resources are denoted by b_k^f. Notations a_{ij} and a_{kj} are input coefficients, which represent the amount of variable and fixed resources, respectively, required to produce one unit of the j^{th} product. For non-allocable input z, output coefficients d_{zj} is defined as the amount of the j^{th} output that can be produced by one unit of the z^{th} non-allocable input.

The Lagrangian function for this problem is as follows:

$$L_{II}(y, x^v, \lambda) = (\sum_j P_j y_j - \sum_i W_i^v x_i^v - \sum_z W_z^v x_z^v) - \sum_i \lambda_i (\sum a_{ij} y_j - x_i^v)$$

$$- \sum_k \lambda_k (\sum_j a_{kj} y_j - b_k^f) - \sum_z \sum_j \lambda_{zj} (y_j - d_{zj} x_z^v) \qquad \textbf{(3.11)}$$

where λ again represents Lagrangian multipliers, and all other notations in equation 3.11 are defined as before.

Partial derivatives of the Lagrangian function are taken with respect to y_j, x_i^v, x_z^v and multipliers λ. They are:

$$\frac{\partial L_{II}}{\partial y_j} = P_j - \sum_i \lambda_i (a_{ij}) - \sum_k \lambda_k (a_{kj}) - \sum_z \lambda_{zj} \leq 0 \qquad \forall j \qquad \textbf{(3.12a)}$$

$$\frac{\partial L_{II}}{\partial x_i^v} = -W_i^v + \lambda_i \leq 0 \qquad \forall i \qquad \textbf{(3.12b)}$$

$$\frac{\partial L_{II}}{\partial x_z} = -W_z^v + \sum_j \lambda_{zj} (d_{zj}) \leq 0 \qquad \forall z \qquad \textbf{(3.12c)}$$

$$\frac{\partial L_{II}}{\partial \lambda_i} = \sum_j a_{ij} y_j - x_i^v \geq 0 \qquad \forall i \qquad \textbf{(3.12d)}$$

$$\frac{\partial L_{II}}{\partial \lambda_k} = \sum_k a_{kj} y_j - b_i^f \geq 0 \qquad \forall k \qquad \textbf{(3.12e)}$$

$$\frac{\partial L_{II}}{\partial \lambda_{zj}} = y_j - d_{zj} x_z^v \geq 0 \qquad \forall j, \forall z \qquad \textbf{(3.12f)}$$

$$y_j,\ x_i^v,\ x_z^v,\ \geq 0 \qquad \forall j,\ \forall i,\ \forall z \tag{3.12g}$$

From equations 3.12a - c, the two required conditions of the theory of the firm can be obtained. First, to obtain a maximum objective value, equations 3.12a - g are set equal to zero (assuming non-zero values for all activities and Lagrangian multipliers) and re-arranged. The first three equations (3.12a - c) thus become:

$$P_j = \sum_i \lambda_i(a_{ij}) + \sum_k \lambda_k(a_{kj}) + \sum_z \lambda_{zj} \qquad \forall j \tag{3.13a}$$

$$W_i^v = \lambda_i \qquad \forall i \tag{3.13b}$$

$$W_z^v = \sum_j \lambda_{zj}(d_{zj}) \qquad \forall z \tag{3.13c}$$

As noted earlier, λ represents the amount of profit from an additional unit of a resource made available for use in the production, or simply the marginal value of the resource. Therefore, equation 3.13b shows that the cost of the i^{th} allocable variable input equals the marginal value of the input. Recall that the second condition of the theory of the firm states $VMP_{ij} = r_i$, for all i and j.

Similarly, the optimality condition concerning non-allocable inputs (i.e., $\sum_j^n VMP_{zj} = W_z$) is shown in equation 3.13c. The right-hand side of the equation represents the multiplication of the amount of the j^{th} output that can be produced by a unit of the z^{th} non-allocable input use and the implicit marginal value for the z^{th} non-allocable input in producing the j^{th} output, summed over all outputs. In other words, this is the sum of values of marginal physical productivity from all j outputs due to the z input use.

Thus, the equation is identical to the second condition of the theory of the firm in regard to the non-allocable factors.

Equation 3.13a is consistent with the output condition for the theoretical model. The left-hand side (P_j) may be interpreted as the marginal revenue associated with production of another unit of output j. The first right-hand side term ($\sum_i \lambda_i (a_{ij})$) represents the implicit value (or explicit cost, given 3.13b) for allocable input i multiplied by the amount of inputs i required to produce one unit of product j, summed over all allocable inputs. This may be interpreted as the marginal cost for allocable inputs required to produce an additional unit of product j. The second and third right-hand side terms ($\sum_k \lambda_k(a_{kj})$) and ($\sum_z \lambda_{zj}$) have similar interpretations for fixed resources and non-allocable inputs, respectively. Overall, the right-hand side of 3.13a is equal to the total marginal cost of producing another unit of product j.

Therefore, solutions of linear programming models, in satisfying the Kuhn-Tucker conditions, also satisfy the first order conditions from the theoretical firm model. Nevertheless, it should be noted that the Kuhn-Tucker conditions only characterize the optimal solution. The conditions do not provide an analytical algorithm for obtaining a solution. Many algorithms have been developed to derive solutions for mathematical programming problems. One of the most common algorithms in computer programming package is the "Simplex Method" (Lee, Moore and Taylor 1985). Most commercial software designed to solve mathematical programs use algorithms that are similar to the simplex method.

3.3.4 Assumptions of Linear Programming

There are seven basic assumptions associated with linear programming; fixedness, finiteness, determinism, continuity, homogeneity, additivity and proportionality. These are discussed by Lee, Moore and Taylor (1985). For this analysis, the most crucial, and potentially most limiting, of these assumptions are continuity, additivity and proportional.

Continuity of decision variables implies that the solution activities are not restricted to integer values. The activities can take on any real values. This assumption is not always true in real farm situations. Some activities cannot be fractional. For example, milking cow numbers cannot take on a non-integer value. Therefore, in the case where restrictive integer values are required, an alternative mathematical programming technique, called integer programming, may be used (Lee, Moore and Taylor 1985).

The assumption of additivity of activities is interpreted to mean that if units of an activity are added together, their total product is the sum of their individual products. This assumption implies that each activity is independent. No interaction effects between activities are allowed.

Proportionality of activities and resources implies that regardless of the level of use for a resource, the return-to-scale is constant. The contribution of each variable in the constraint (i.e., $a_{ij}y_j$) is directly proportional to the level of the y_j variable, regardless of the values of any other decision variables in the problem. Similarly, a constant gross margin per unit of activity is assumed. This represents a "perfectly elastic demand curve for the product and perfectly elastic supplies of any variable inputs that may be used" (Hazell and Norton 1986, p.13).

Additivity and proportionality are important because together they define the linearity of the activities in the model. Linearity means that if all resource supplies are doubled, then all of the activity levels in the optimal solution will be doubled as well as the optimal value of the objective function. In other words, there are no economies or dis-economies of scale in production.

3.4 Summary

This chapter has provided a summary discussion of the theory relevant to the economic problem addressed in this study. In particular, the issue of BST adoption is addressed through the use of production economic theory, assuming a multi-product multi-input production framework, along with the overall objective of maximizing short-run profits within a purely competitive market. An adjustment that must be made to the standard model is the incorporation of milk quota considerations.

Given this theoretical framework, the conceptual framework that is used to apply the model is linear programming. This technique is consistent with the economic theory, and provides the optimal solution, given that the structure of the model accurately represents the constraints and objectives for the farm operator. Therefore, it is an appropriate methodology for the purposes of this study.

CHAPTER FOUR REPRESENTATIVE FARMS AND THE EMPIRICAL MODEL

4.1 Introduction

This chapter is devoted to a discussion of empirical model development. The discussion includes the development of defining characteristics for the representative dairy farms, and other data requirements. This is followed by a presentation and discussion of the empirical model. Empirical procedures relating to how the representative dairy farms are used in the analysis of BST adoption are also discussed.

4.2 Definitions of Representative Farms

Representative farms may be defined as homogeneous classes of the producer population (Fox and Driver 1980). These farms are used as proxies to represent a population of similar farms. However, the criteria used to define similarity depend on the factors that classify the representative farms into these homogeneous groups. For example, if representative farms are based on the level of milk production, then similar farms simply imply that the farms produce the same level (approximately) of milk. Other factors that can be used as potential defining characteristics for representative dairy farms include dairy or crop technology, herd size, financial situation, etc.

4.2.1 Representative Farm Development

There are various methods for developing representative dairy farms for use in linear programming analysis (Fox and Driver 1980). Surveys of dairy farms may be conducted to collect information from individual producers. The collected information is then analyzed using statistical techniques such as cluster analysis or analysis of variance to classify sub-groups of farms. Representative farms are then selected from these sub-groups. The advantage of this method is that a classification of farms is obtained from primary data. However, the monetary costs associated with this method are significant. Furthermore, this method may not be feasible in terms of the time and sample size required for a region as large as western Canada.

An alternative method is to develop representative farms using data collected by other organizations. This can reduce the survey handling problem for large geographic regions or large numbers of farms. The expense associated with this method is less than for surveying. Nevertheless, since the sampling process may vary by organization, uniformity of data may be a concern. In using this method, an assumption is required that the surveying institutions randomly and independently choose their farms sample. If the survey sample is not chosen by random selection, the resulting data may be biased. Therefore, randomness and independent distribution of farm selection assumptions must be valid for all data sources.

This study utilizes the second method in developing representative western Canadian dairy farms; that is, the use of secondary survey data. Given the advantages and disadvantages of each method, the costs associated with conducting a survey of dairy farmers outweigh any costs (i.e., potential biases) associated with the use of previous survey data. Also, many of the surveys conducted to obtain these data are designed to be random and representative (e.g., Agricultural Census). Thus, the bias in these data sources are likely to be minimal.

4.2.2 Characteristics of Representative Farms

The primary factor used to classify representative western Canadian dairy farms is herd size. A herd size distribution of dairy farms in western Canada is obtained from 1986 Agricultural Census data (unpublished data obtained from Statistics Canada upon request). Three representative dairy herd sizes are identified from the overall distribution; 35 cows, 60 cows and 95 cows. These are actually the average herd sizes for three representative herd size intervals from the overall distribution; 26 to 40 cows, 51 to 70 cows and 86 to 105 cows, respectively. The three representative herd sizes are referred to in this study as small (35 cows), medium (60 cows) and large (95 cows) herds. Details for the herd size distribution are provided in Appendix C (Table C.1).

The secondary factor used in the classification process is milk production. A frequency distribution of milk production level for each herd size group (i.e., herd size interval) is obtained from individual provincial dairy herd improvement associations (Alberta Dairy Herd Improvement Corporation; British Columbia Dairy Herd Improvement Services; Quebec Dairy Herd Analysis Services)[12]. The milk distributions suggest that the modal levels of milk production in each of the prairie provinces are similar. Detailed distributions are shown in Appendix C, Figures C.1 to C.3).

The small and medium herds are further classified by milk production level (low and high). The low and high levels for the herds are 6500 and 8000 kilograms (kg.) of

[12] Milk production data for both Alberta and Manitoba are provided by Alberta Dairy Improvement Corporation. Saskatchewan milk production data are provided by Macdonald College, Quebec Dairy Herd Analysis Services.

milk production per cow in each lactational year, respectively[13]. Two production levels are used in the analysis instead of a single modal level for each herd size, due to the substantial variation in average milk production levels among farms (shown in Appendix C, Figures C.1 to C.2). A significant number of farms produces at levels higher than the modal level, while others are below the mode. Thus, the two levels are representative of farms with low and high production levels[14].

For the large herd (95 cows), the modal level (7250 kg per cow) is chosen as the representative production level for use in the analysis. This is due to the uniqueness of the milk production frequency distribution for the large herd. Unlike the other two herds, variability around the mode of milk production distribution for the large herd is small (shown in Appendix C, Figure C.3). The average milk production level for most of the large farms is close to the modal level. Therefore, the mode is used as the representative milk production level.

The characteristics for the representative dairy farms are summarized in Table 4.1, which includes both the primary and secondary classification factors. However, the representative farms defined in Table 4.1 do not include dairy farms in British Columbia. This is because milk production distributions in B.C. are significantly different from those for the prairie provinces. For example, the modal level of milk production for each herd size is 1000 kg higher than for the corresponding herd size in the prairie provinces

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[13] The average calving interval for each herd is assumed to be 12 months.

[14] It should be noted that, although the representative production levels used in the analysis are identical for the small and medium herds, the modal value for the medium herds is actually 750 kg per cow greater than the corresponding value for the small herds.

(Figures C.2 to C.4 in Appendix C). Furthermore, the physical size (i.e., acres or hectares of land) of British Columbia dairy farms is significantly smaller than for dairy farms in the prairie region[15]. Owing to these unique characteristics of the British Columbia dairy sector, this study does not include British Columbia dairy farms. Only data for prairie dairy farms (i.e., Manitoba, Saskatchewan and Alberta) are used in the analysis.

Table 4.1 Characteristics of Representative Dairy Farms

Items/Herd Classification	Small	Medium	Large
Herd Size Range (cows)	26-40	51-70	86-105
Average Herd Size (cows)	35	60	95
Annual Milk Production (kg/cow)			
Low	6500	6500	N/R[a]
High	8000	8000	N/R[a]
Mode	6750	7500	7250
Daily Milk Production (kg/cow)			
Low	25	25	27
High	30	30	27

[a] N/R represents not required.

4.3 Data Requirements
4.3.1 Dairy Enterprise Data

The dairy enterprise includes milk cattle, classified as cows, cull cows and heifers, herd replacement heifers and calves, and bull calves to be sold for veal.[16] If required, the

[15] This is based on personal communication with B.C. Agriculture Personnel.

[16] Calves are cattle that are less than one year of age. Heifers are female cattle that are between one and two years of age.

farmer may purchase additional milk cattle. The cows are assumed to be milked for 305 days, with the other 60 days each year being a dry period to rest the cow in preparation for calving and a new lactation cycle. Bull calves and heifer calves are born in equal proportions. Heifer calves are kept for herd replacement, and it is assumed that dairy farmers sell bull calves when several weeks old. Thirty percent of the milking herd is culled each year. Culled cows are replaced with replacement heifers or purchased cows. Any heifers not required as replacements are sold at two years of age. Mature milk cattle are assumed to weigh 650 kg., heifer calves weigh 150 kg. and heifers weigh 450 kg.

The costs of raising and maintaining cattle are divided into three parts: ration costs, non-feed operating costs, and labour costs. Rations and ration costs are determined endogenously by the model. Nutrient requirements for all cattle are based on National Research Council (1988) guidelines. Nutrients considered in the ration formulation include: net energy or digestible energy; crude protein; calcium; phosphorus and acid detergent fibre. Maximum dry matter intake is also considered. Potential purchased feeds include canola meal and soybean meal[17]. These may be used in combination with alfalfa hay, feed barley, feed oats and utility wheat, which all may be grown or purchased. The nutrient composition of the potential feeds is obtained from National Research Council (1988) guidelines, on an "as-fed" basis. The nutrient requirements and composition of

[17] Commercially pre-mixed dairy ration is sometimes used by farmers. For the purposes of this analysis, commercial ration is not included, for two reasons. Farmers are assumed to have the equipment required to mix feed for the rations. Also, commercial ration is a higher cost feed.

feed are shown in Appendix C (Table C.2). Separate rations are formulated for lactating cows, dry cows, replacement heifers and heifer calves.

Non-feed operating costs for the dairy enterprise include expenses for veterinary services and medicine, dairy supplies, breeding, utilities, building and machinery repairs associated with the dairy enterprise, insurance and other miscellaneous costs. Labour is excluded from this cost, and is dealt with later. Estimates of these operating costs are obtained from several sources, including Alberta Agriculture, Economics Branch, Production Economics Service Division (1990b), Saskatchewan Milk Control Board (1990), Petkau (1991), Meyers, Norris, Penny and Co. (1990), Olson and Tvedt (1990) and Manitoba Agriculture, Animal Industry Branch (1986). An average of these values is used as the cost estimate in this analysis.

The actual values used in this analysis are presented in Table 4.2[18]. It should be noted that a single cost for milk cows is used for all herd sizes and production levels. This assumption is legitimate, for three reasons. Where cost estimates for prairie dairy farms are available for different herd sizes, the non-feed operating costs are not significantly different. Also, much of the cost advantage for larger herd sizes is attributable to more efficient labour use, while much of the cost advantage for higher producing cows is attributable to improved feed efficiency. Both of these costs are excluded from this estimate. Finally, by maintaining a constant cost per cow, the cost per kg. of milk will be lower for high producing herds.

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[18] The death rate for calves and replacement heifers is five percent. The monetary losses for these cattle are incorporated into the costs for other cattle in the herd.

Labour requirements for the dairy enterprise are largely determined by milking technology. In western Canada, most dairy farms utilize tie-stall technology (University of Saskatchewan, Division of Extension and Community Relation 1987). However, larger herds tend to use free-stall barns and milking parlour technology, because of labour efficiencies (e.g., automated feeding and reduced labour for milking). In this study, the following assumptions are made: small herds have tie-stall barns while medium and large herds use free stall barns and milking parlours. The types of equipment assumed to be used for milking and other tasks are based on engineering results obtained from a computer program designed to estimate labour needs (Fuller 1980). A detailed list of machinery for each farm is provided in Appendix C (Table C.3).

Table 4.2 Operating Costs of Production for Dairy Cattle ($/head)

Cattle Category	Production Cost $/Cow
Milk Cows	$ 503.67
Heifers	$ 106.93
Calves	$ 120.50

Once the dairy herd technologies are determined, labour requirements for cattle are estimated. The estimates are based on engineering estimates for each task that are compiled in the computer program FACILITY (Fuller 1980). Monthly labour requirements per cow are obtained and are assumed to be constant throughout the year.

As a result, total annual labour hours required are obtained by multiplying monthly labour hours by twelve. These estimates are provided in Table 4.3[19].

Table 4.3 Annual Labour Hours Requirement for Raising Cattle (hours./head)

Herd Size	Small	Medium	Large
Milking Cows			
High Milk Production	59.22	43.13	33.15[a]
Low Milk Production	53.99	39.12	
Heifers	11.76	4.20	3.58
Calves	14.38	5.16	4.38

[a] For the large herd, the estimate applies to the modal milk production level.

4.3.2 Cropping Enterprise Data

All of the representative dairy farms are assumed to grow crops for sale and for use in dairy enterprise rations. Crop production and use is determined endogenously by the model. The crop enterprises are included in the model are selected based on the major crops grown on western Canadian dairy farms (unpublished 1986 Agricultural Census data from Statistics Canada). The crops included are: hard red spring wheat, oats, barley, alfalfa hay and canola. Table 4.4 provides the types of crops that may be grown for the different herd sizes.

[19] The annual labour requirements are actually divided into seasonal requirements for the analysis. The seasons consist of two two-month periods (May - June and July - August, respectively) and the remaining eight months. This is done for reasons relating to crop labour requirements, discussed below.

Table 4.4 Potential Crops for the Representative Farms

	Herd Size		
	Small	Medium	Large
Crop Grown For Feed and For Sales	Alfalfa Hay, Wheat, Oats, Barley	Alfalfa Hay, Wheat, Oats, Barley	Alfalfa Hay, Wheat, Oats, Barley
Crop Grown For Sales Only		Canola	Canola

In western Canada, crop rotation patterns vary significantly from province to province and also between regions within a province. For example, farmers may alternate summerfallow and cereal grains. Another potential rotation pattern may be cereal grains for two years, followed by two to four years of forage crops. The crop rotation modelled in this study represents only one potential pattern, and is based on agronomic considerations. Cereal grains (i.e., wheat, oats and barley) may be grown in each year, with the selection of cereal grains made endogenously by the model. If alfalfa is grown, the length of stand is five years. Wheat, barley and/or oats may be used as covering crops in the establishment of alfalfa. Canola is limited to a maximum of 25 percent of total cultivated area, because of disease control considerations[20].

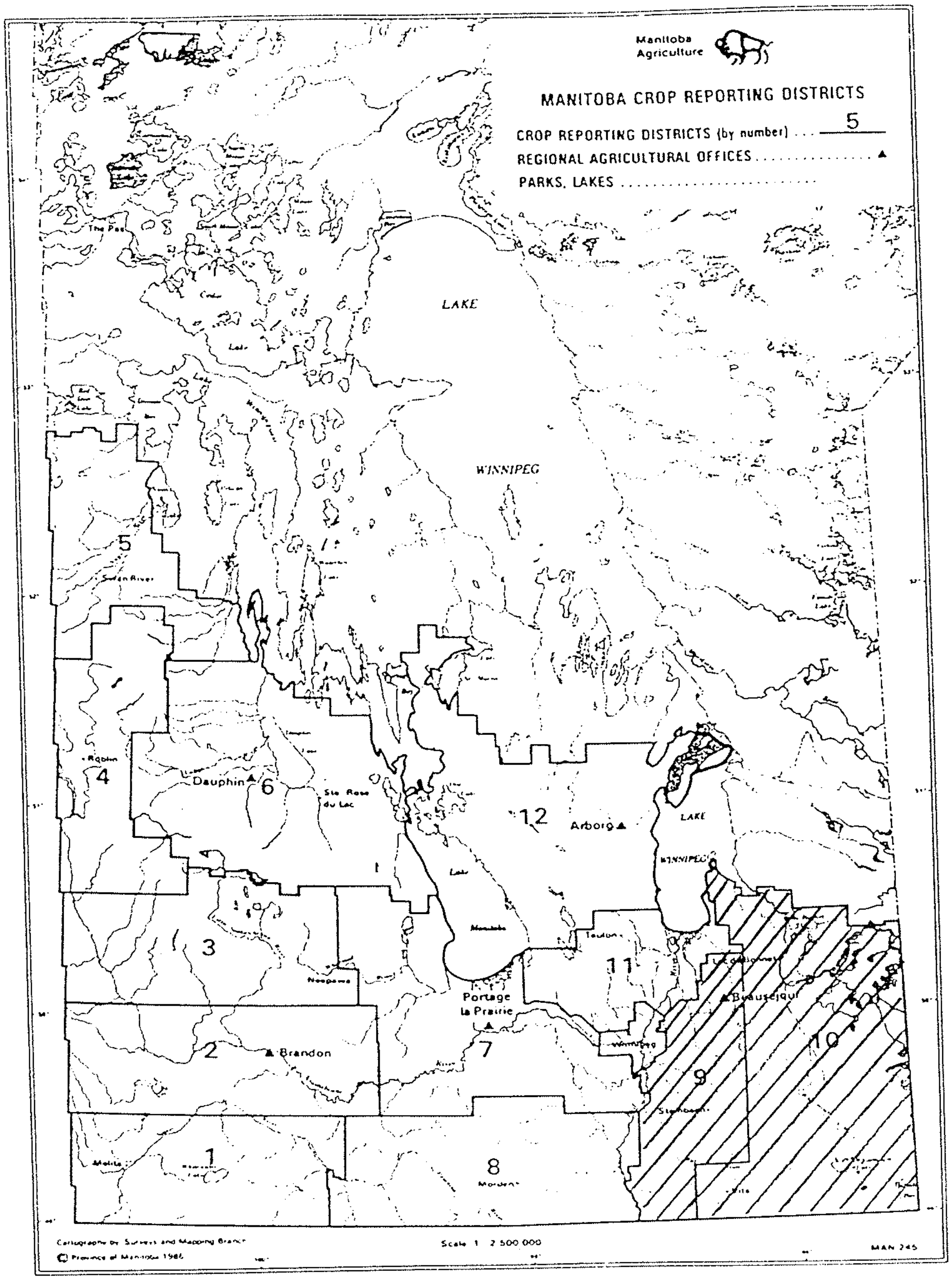
Crop yields are obtained from several sources, including Alberta Agriculture, Statistics Branch (1980 to 1989), Manitoba Agriculture, Statistic Branch (1981 to 1987a; and 1988 to 1990b), and Saskatchewan Agriculture and Foods, Economic Branch, Statistics Section (1981 to 1989a). Historical average crop yields are obtained for regions

[20] This information is obtained through personal communication with Dr. D.F. Kraft.

with the greatest concentration of dairy herds in the three provinces, and are themselves averaged to provide yield estimates for the model. Figures 4.1, 4.2 and 4.3 illustrates the selected regions in each province. Table 4.5 provides the resulting yield estimates.

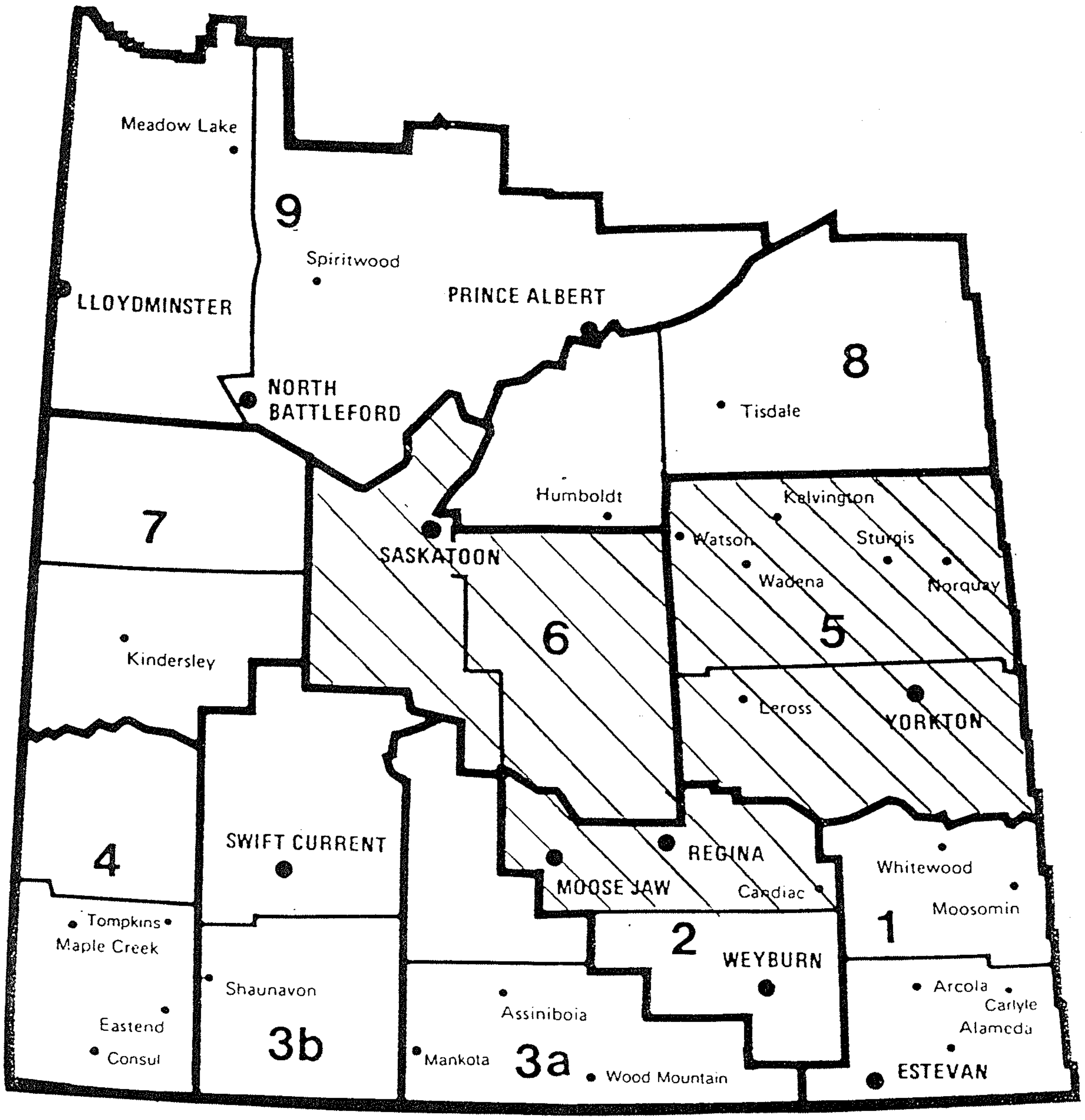
Production costs for the various crops include expenses for seed, fertilizer, chemicals, crop insurance premium, machinery and building repairs associated with crop enterprises, and utilities. As is the case with dairy enterprise costs, labour expenses are specifically excluded. The costs of production for crops are obtained from information published by provincial agriculture departments, including Manitoba Agriculture, Farm Management Branch (1986 and 1990a; and 1991e); Saskatchewan Agriculture and Food, Economics Branch, Farm Management Section (1987); and Alberta Agriculture, Economics Branch, Production Economic Service Division (1987 to 1990a). Information over the time period from 1987 to 1990 is used for selected regions in each province (shown in Figures 4.1 to 4.3). These regions, representing the greatest concentration of dairy herds as noted earlier, are used in order to obtain a more accurate estimate of crop production costs. Table 4.5 provides the total operating costs (excluding labour cost) for the various crops. These estimates are based on averages for the cost figures from the sources listed above. Economies of size for crop production are assumed to occur primarily in labour requirements rather than in the non-labour operating cost. As a result, the cost for each type of crop is constant across all representative farms.

Figure 4.1 **Selected Dairy Regions in Manitoba for Estimating Crop Yield and Production Costs**



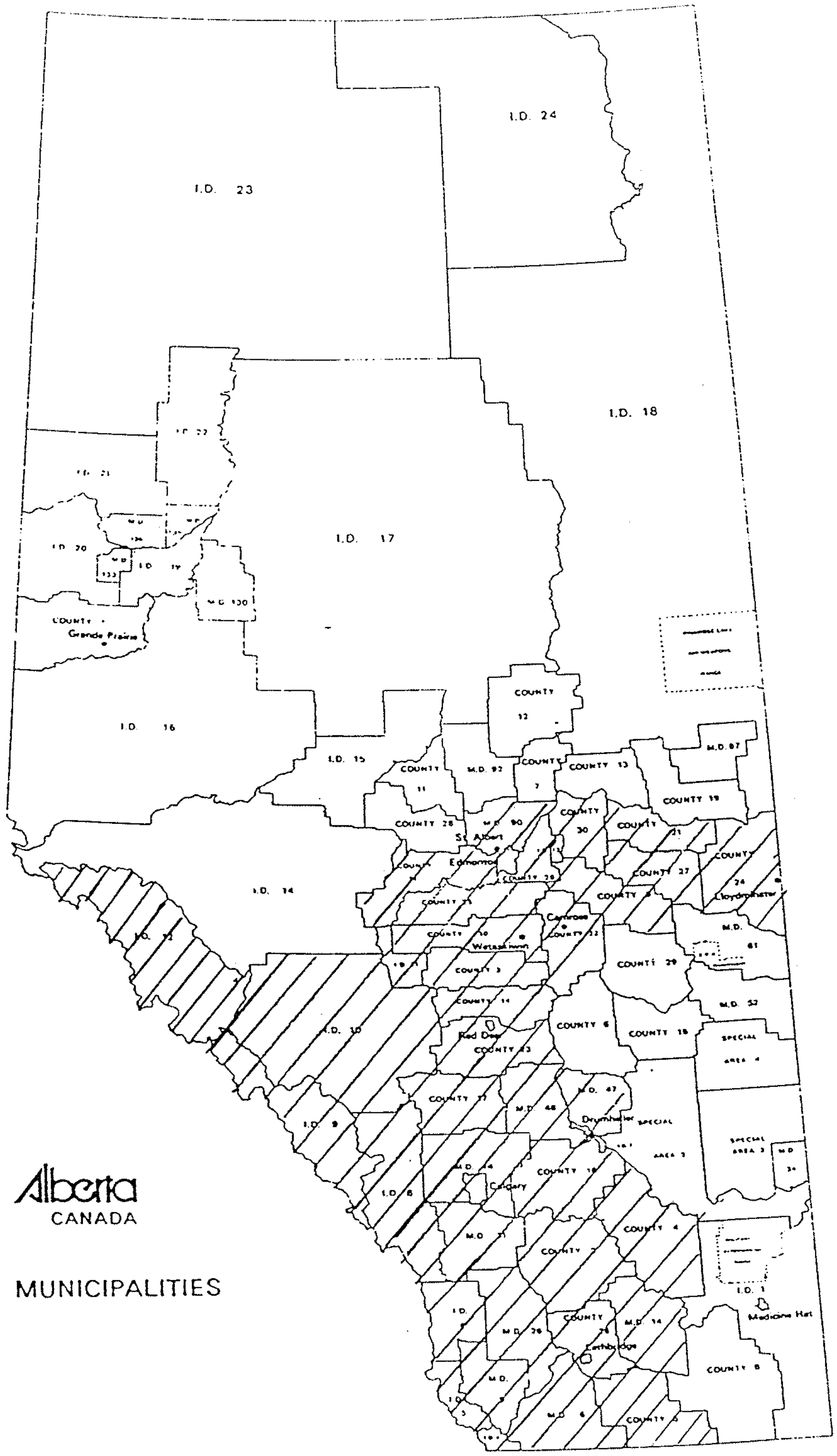
Source: Manitoba Agriculture, Statistics Branch 1981 to 1987a.

Figure 4.2 **Selected Dairy Regions in Saskatchewan for Estimating Crop Yield and Production Costs**



Source: Saskatchewan Agriculture and Food, Economics Branch, Statistics Section 1989 and 1990b.

Figure 4.3 Selected Dairy Regions in Alberta for Estimating Crop Yield and Production Costs



Source: Alberta Agriculture, Statistics Branch 1990b.

Table 4.5 Estimated Yields and Production Costs (excluding labour) for Various Crops

Crop	Yield (tonnes/hectare)	Variable Production Costs ($/ha.)
Spring Wheat	1.96084	$ 148.54
Barley	2.68835	$ 145.21
Oats	2.28724	$ 137.58
Alfalfa Hay	3.97005	$ 104.39
Canola	1.28770	$ 139.48

Labour requirements for crops enterprises are determined by required field tasks, as well as the size of equipment available to complete the tasks. Crop equipment assumed to be on the farms is based on the types of crops to be grown and the total cultivated area available for the representative farms. A complete list of the crop equipment with handling capacity is provided in appendix C (Table C.4). The field capacities for the machinery are based on estimates from Fuller, Lazarus and Norquist (1989).

Estimates of required labour hours for the various crops (shown in Table 4.6) are based on survey results from Pokrant et al (1983). Labour requirements for dairy farms of similar size in the different provinces are assumed to be the same. Differences in labour requirements among the three representative farms are made based on relative differences in the size and field capacity for the crop equipment list obtained from Fuller, Lazarus and Nordquist (1989). In addition, some operator supervisory labour is required for hired labour. An assumption is made that five percent of the operator's available hours are required for supervisory duties.

Labour requirements are divided into three different periods. Spring, consisting of May and June, is the seeding period. During this period, cultivation and seeding tasks are carried out. The second period is summer, assumed to be July and August only. The tasks in this period include crop maintenance and harvesting. The third period includes all other months in the year. During this eight month period (September to April inclusive), only the dairy enterprise requires labour. Crop enterprises require very little time (before winter) to carry out tasks such as tilling the soil and spreading fertilizer to prepare for seeding in the following year. These hours, therefore, are not considered.

Table 4.6 Labour Hours Requirement for Growing Crops (hours/hectare)

Items\Herd Size	Small	Medium	Large
Cereal Grains[a]	3.85	3.05	2.85
Canola	3.17	2.51	2.34
Alfalfa Hay	5.55	2.34	5.06

[a] Cereal grains include wheat, oats and barley.

4.3.3 Whole Farm Data

Labour availability is important factor to consider, given the labour requirements for crop and dairy enterprises. Many farm operators[21] today have off-farm employment. Agricultural Census data indicate, however, that in percentage terms, this percentage is low (unpublished 1986 Agricultural Census data obtained from Statistics Canada). In other words, the primary use of operator labour is still devoted to farm enterprises. Since

[21] To avoid confusion between employed operators and the legal owner of a farm, owners here are referred to as operators.

the percentage differences in off-farm work among the three herd sizes are minimal[22], the available operator labour hours for the different herds in this study are assumed to be identical. Total labour available for on-farm tasks is 4050 hours per year. Of this total, 2700 hours are from the operator (full-time), 1350 hours from the operator's spouse (part-time). The total free family labour is equivalent to approximately 11.1 hours of labour per day for 365 days. There is no limit on labour hiring.

With respect to land availability, total area includes both owned and rented land. The average owned cropland areas are 143, 301 and 581 hectares for the small, medium and large herds, respectively. Farmers also typically rent some land for growing crops. Since equipment capacity for the farms imposes limitations on the maximum acreage that can be efficiently managed, this limits the area that can be rented. The maximum rented area for the three herds is assumed to be approximately 35 percent of owned acreage. Data for total owned and rented land acreage used to establish farm size and maximum rented area are obtained from the 1986 Agricultural Census (unpublished data from Statistics Canada). Since Statistics Canada does not require respondents to report owned and rented cropland acreage separately, the owned cropland available for each representative herd is calculated based on the percentage of total owned cropland to the total operated acreage in the individual group of herd sizes. Area and respective percentages are provided in Appendix C (Table C.6).

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[22] The difference between the highest and lowest off-farm work percentage is approximately 5 percent, while the difference for hired labour is 11 percent (Statistics Canada, Agricultural Census, 1986a). The off-farm employment figures are provided in Appendix C, Table C.5.

4.3.4 Exogenous Data

Exogenous data requirements are those data that are determined independently of the representative farm operations. These include output and input prices (milk, cattle, feed, crop, etc.), interest rates and milk quota values. Estimation procedures for these data requirements are discussed below.

Milk prices are obtained from provincial milk marketing or milk control boards. Each province has different classifications for milk. For example, the Alberta Dairy Control Board classifies milk into four types. The first three types are related to fluid milk, while the fourth type is for industrial milk. On the other hand, the Manitoba Milk Producers' Marketing Board classifies milk into seven groups. The first three groups are for fluid milk. The remainder are for industrial milk.

With respect to the price of milk used in this study, a blended price of milk expressed as a farm-gate value[23] is used. Table 4.7 provides historical farm-gate prices (adjusted to a 1989 dollar base) for the three provinces.[24] The blended milk price for each province is calculated based on the percentage shares of fluid and industrial milk quota. In Alberta, the relative percentage is 75:25. In Saskatchewan, the percentage is

[23] Farm-gate return represents the price paid by provincial dairy boards less expenses such as marketing, quota levies, administration fees to the marketing board and transportation costs freight to the closest plant.

[24] All prices are adjusted to 1989 dollar base by using Farm Product Price Index. The index is provided in appendix C, Table C.7.

about 71:29, while the percentage in Manitoba is 45:55.[25] The resulting average of farm-gate milk prices in the prairie provinces is $ 50.55 per hectolitre.

Table 4.7 Farm-Level Milk Blended Prices (1989 $/hl)

Year	Manitoba	Saskatchewan	Alberta
1987	$ 53.19	$ 58.76	$ 51.39
1988	$ 48.83	$ 48.84	$ 48.96
1989	$ 48.54	$ 47.26	$ 49.19
Three-Year Average	$ 50.19	$ 51.61	$ 49.85

Source: Alberta Agriculture, Economics Branch, Production Economics Service Division 1989b; Saskatchewan Milk Control Board; and unpublished information from the Manitoba Milk Producers' Marketing Board.

Similar to milk pricing, the milk quota system is not uniform across all of the prairie provinces. The dairy quota system in Alberta is of a traditional type, where fluid and industrial milk quota are transacted separately in different markets. This kind of system is also utilized in Ontario. There is, however, no milk quota exchange market in Saskatchewan. All milk quotas are transferred together with milking cows or dairy herds, when sold. In other words, there is no explicit market value for the milk quota. An alternative to these two systems is the "Integrated Pool"[26] milk quota system adopted in Manitoba. This system works as an integrated system for both types of milk quota. For

[25] The sources for these ratios are Alberta Agriculture, Economics Branch, Production Service Division (1989b), Saskatchewan Milk Control Board (1990), and unpublished information from the Manitoba Milk Producers' Marketing Board (1990).

[26] The information is obtained from personal communication with personnel of Manitoba Milk Producers' Marketing Board

example, 100 litres of milk quota implicitly consists of 45 litres of fluid milk quota and 55 litres of industrial milk quota. With this system, there is no need to have individual markets for industrial and fluid milk quota. Nevertheless, one characteristic which is common to all the provinces is that the regulatory boards do not control the price of milk quota. Prices are freely determined by market forces.

Historical quota values are provided in Table 4.8. The market quota value used in the analysis is $ 240 per kilogram, which is the average of adjusted Manitoba quota prices and adjusted Alberta blended quota prices.[27] However, the validity of using a current (i.e., pre-BST) quota price in the post-BST adoption period is of concern. The market price for quota may change after BST is adopted in the sector. Given the short-run nature of the modelling scenario, quota prices are not expected to have change substantially due to BST adoption. Moreover, the BST adoption rate is assumed to be modest in the short-run, as will be discussed later in this chapter. Therefore, the effect of BST adoption on milk quota prices is assumed to be modest. Post-optimality analysis is also conducted to test the sensitivity of the solutions to changes in milk quota prices.

Since milk quota purchases typically involve a substantial expenditure, payment is usually made using debt financing. The repayment period may extend to five years or more. In this study, the financing of milk quota is assumed to occur over a five-year period, during which time the original amount borrowed is paid back, along with interest.

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[27] Quota prices are adjusted to a 1989 dollar basis using a farm input price index for western Canada, These price indices are provided in Appendix C, Table C.8.

The payment schedule for quota purchases is provided in Table 4.9. The interest rate used in calculating these payments is discussed below, and provided in Table 4.12.

Table 4.8 Milk Quota Price (1989 $/kg for 365 Days of Delivery)

Year	Manitoba[a]	Alberta Fluid Milk	Alberta Unused Industrial Milk
1987	N/A	279.91	15.04
1988	N/A	260.91	19.07
1989	225.46	N/A[b]	13.20
Average Value of the Three Years	225.46	270.41	15.77
Average Quota Price In the Province	225.46	254.61[c]	
Average Milk Quota Price Assumed in this Study	240.00		

[a] Manitoba data for 1987 and 1988 are not available, as a different quota system was used in those years.

[b] 1989 fluid milk quota price is not available because data processing has not been finished by Alberta Agriculture.

[c] A blended quota price for Alberta is calculated as follows: [$ 15.77 per kg. of butterfat × 365 days / 27.78 litres per kg. of butterfat] × 25% share of industrial milk + $ 270.41 × 75% share of fluid milk.

Cattle prices are collected from the "Livestock Market Review" (Agriculture Canada, Agriculture Development Branch, Livestock Development Division 1985 to 1990). Five years of cattle prices (1985-89) are adjusted to a 1989 dollar base using the Farm Product Price Index for western Canada, and are then used to establish average prices for the analysis. The resulting prices are provided in Table 4.10. Historical price data are provided in Appendix C, Table C.9. The average figure for western Canada is expressed in dollars per hundred weight. A 650 kg. (i.e., 1430 pound) culled milk cow is, thus, worth $ 845.85 (i.e., 650 kg.x2.2 lb./kg.x[$ 59.15/100lb.]). Bull calves are assumed to weigh 45.45 kg. (i.e., 100 pounds), on average, when sold.

Table 4.9 Payment Schedule for Debt Financing of Milk Quota Purchases

Year	Principal	Interest	Total Payment
1	$ 48.00	$ 31.20	$ 79.20
2	$ 48.00	$ 24.96	$ 72.96
3	$ 48.00	$ 18.72	$ 66.72
4	$ 48.00	$ 12.48	$ 60.48
5	$ 48.00	$ 6.24	$ 54.24

Table 4.10 Livestock Prices (1989 $/100 lbs)

Livestock Category	Livestock Price ($/100 lbs)
Feeder Cows (Cull Cows)	$ 59.15
Feeder Heifers (Cull Heifers)	$ 87.29
Veal (Bull Calves)	$ 96.10

While prices for cull cows, heifers and calves are available from published sources, prices for purchased milk cow are not formally recorded. According to provincial dairy cost of production studies, the price range for purchased cows is $ 1100 to $ 1500, depending on the production level and weight of the cow. For modelling reasons, the price is assumed to be $ 1350 per cow (Manitoba Agriculture, Farm Business Management 1989d; Alberta Agriculture, Economics Branch, Production Economics Service Division 1989b; and Saskatchewan Milk Control Board 1990). Debt financing for purchased milk cows is assumed to be completely paid back with interest over a one year period. The total payment, thus, becomes $ 1525.5 (assuming a 13 percent interest rate as stated in Table 4.12).

Crop prices are collected from statistical handbooks and yearbooks published by the Canadian Grain Council (1981 to 1990), provincial Departments of Agriculture in Alberta, Saskatchewan and Manitoba, as well as some unpublished sources.[28] Cereal grain prices are calculated as the average of net board grain prices and non-board feed prices. The net board grain price is calculated from the final payment set by the Canadian Grain Commission less the expenses for primary elevator and transportation.[29] Since grain prices fluctuate substantially, nine year average prices (1981 to 1989) are required in the calculation of an annual average price. Alfalfa hay is not commonly transacted in the market in western Canada as are cereal or oilseed grains. As a result, for this analysis farmers are assumed to grow hay for use in rations. No commercial (i.e., buying or selling) activity is associated with the forage. Table 4.11 provides the resulting nine-year average crop prices[30].

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[28] These unpublished sources include Agricultural Feed Price Listing obtained from Dr. J.R. Ingalls and Dr. D.F. Kraft.

[29] Transportation expense for cereal grains includes the cost paid by farmers to ship board grains to Vancouver or Thunder Bay.

[30] The original sources for the prices used in estimating these averages are Canadian Grain Council (1981 to 1989); Manitoba Agriculture, Statistics Branch (1981 to 1987a, 1988 to 1990b); Saskatchewan Agriculture and Food, Economics Branch, Statistics Section (1981 to 1989a). Prices are adjusted to a 1989 dollar basis using the Saskatchewan Farm Product Price Index. The Saskatchewan index is used because the transportation costs assume that the grain is shipped to exporting ports from Saskatchewan.

Table 4.11 Farm-Level Crop Prices (1989 $/tonne)

Items	Spring Wheat	Oats	Barley	Canola
Nine-Year Average	$ 159.15	$ 104.82	$ 100.74	$ 275.08
Fifteen-Year Average (1975-89)	$ 152.47	$ 84.47	$ 99.77	$ 283.77

In Table 4.11, the nine-year average oats price is higher than the barley price. This is not a common occurrence and is probably due to price fluctuations during 1987-1989. The historical price ratio (from 1981 to 1986) between oats and barley is about 0.9:1. For reference, fifteen-year average prices for the crops are also provided in Table 4.11. The fifteen-year average prices indicate even a lower ratio between oats and barley, approximately 0.85:1. In order to estimate a more reasonable price for oats, the oats price is assumed to be 95 percent of the nine-year average barley price. This percentage is between the historical price ratio of 0.9:1 and the price ratio for the nine-year average prices as shown in Table 4.11. The resulting oats price becomes $ 95.70 per tonne.

Purchased feed prices are collected from agricultural feed price listings and the fifteen-year average price listing presented in Table 4.11.[31] Canola meal and soybean meal prices are taken from this price listing. An average of prices for 1981, 1985 and 1989[32] are calculated and used as the price coefficients for these two purchased feeds. The purchase prices for feed barley and oats are assumed to be different from the farm

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[31] The agricultural feed price listings are unpublished, and obtained in personal communication with Dr. J.R. Ingalls and Dr. D.F. Kraft, of the University of Manitoba.

[32] Only these years are available from the agricultural feed price listings.

selling price by a margin that incorporates the costs of transportation from the elevator to the farm (i.e., $ 0.01528/kg). As a result, the purchase price for feed barley is $116.02 per tonne and for oats is $ 110.98 per tonne. Purchased feed wheat is assumed to be utility wheat. The purchase price is $ 125.66 per tonne, calculated from the fifteen-year average price listing.

Cropland rental rates may vary significantly depending on factors such as location, and the type and quality of soil. For these reasons, rental rates for a large region like the prairie provinces are difficult to obtain. For this study, an assumption is made that the rental rate will be equal to approximately 30 percent of total crop returns from the rented land.[33] This figure includes rental, fence investment, municipal taxes and all other related expenses. The rental rate is calculated from the average return per hectare for the four specified farm crops. The resulting rental rate is $ 81.15 per hectare.

Hired labour wage rates for agriculture are seldom published in government statistical publications. Therefore, estimation of wage rate for this study is based on cost of milk production studies. In 1989, the hourly non-board wage rate for the dairy sector was $ 9.12 in Alberta (Alberta Milk Control Board, Economics Branch, Production Economics Service Division 1989b) and $ 10.59 in Manitoba (Meyers, Norris and Penny Co. 1990). Since labour wage rate is one of the least fluctuating costs in production, data from a single year are sufficient for estimating wage coefficient. The average wage rate for the prairie provinces, therefore, is estimated as $ 9.86 per hour, not including board.

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[33] The figure is obtained from personal communication with Dr. D.F. Kraft, Department of Agricultural Economics and Farm Management, University of Manitoba.

Debt financing is a common practice for farmers, and the financing rate (i.e., interest rate) is crucial to the farm operation. From the financial structural characteristics of dairy farms, using information provided by the Farm Credit Corporation (unpublished data)[34], farmers obtain most of their short and intermediate-term debt financing from chartered banks (summarized in Table C.12 in Appendix C). Table 4.12 provides the average monthly prime lending rate set by chartered banks during the period 1985 to 1990 (Bank of Canada, Editorial Board 1985 to 1990). The interest rate for agricultural loans is usually 1 to 1.5 percentage points higher than the prime rate.[35] The farm loan rate used in the analysis is, therefore, 12.5 percent as shown in Table 4.12. In addition to the short-term rate, a five year intermediate capital financing rate is also provided in Table 4.12. This five year rate is used for debt financing of milk quota purchases.

Table 4.12 Interest Rates for Short and Intermediate-Term Financing

Item	Prime Rate (%)	Five Year Financing Rate (%)
Five Year Average	11.00	11.65
Rate Used in the Analysis	12.50	13.00

[34] The data on which this is based are for all supply managed industries, which include dairy, turkey, broiler chicken, and egg production. All of these industries are similar in terms of the nature of the capital investment, being intensive in fixed input investment (e.g., machinery and building) relative to other inputs. Although the absolute investment levels for fixed inputs differ between the industries, it is assumed that the financial structure, as measured by the leverage ratio, is similar. Using the data for this study, therefore, will not result in misrepresentation of the financial characteristics for dairy farms.

[35] This information was obtained in personal communication with an official of the Canadian Imperial Bank of Commerce.

In addition, farmers usually use short-term debt financing for only a portion of total operating expenses. The farm operations in this study are assumed to finance only 25 percent of the total operating cash expenses each year. These expenses are financed with an operating loan which is held for four months. As a result, the actual interest payment for the operating loan is the total operating cash expenses multiplied by 1.04 percent.[36]

Due to the dynamic nature of this analysis, the discount rate is also important. A dollar received or paid today is valued differently from a dollar received or paid in two years time, because of changes in the purchasing power and time preferences. Therefore, income received in later periods should be discounted. The discount rate used here is the net real rate; that is, the rate of return on an investment less the inflation rate. The rate of return on an investment is calculated from intermediate-term bond yields paid by private corporations from 1985 to 1990, and the inflation rate is approximately by the percentage change in the consumer price index (CPI) (Bank of Canada, Editorial Board 1985 to 1990). The reason for using intermediate-term bond yields instead of one-year bond yields is that the former rate is close to the planning horizon for this study. The average values and resulting real discount rate are provided in Table 4.13, while the historical data are shown in appendix C, Table C.14.

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[36] The effective interest rate is equal to $0.125 \times 0.25 \times 1/3 = 0.0104$ or 1.04 percent.

Table 4.13 Calculation of the Discount Rate Used for Analysis

Item	Corporate Bond Yield (%)	Change in CPI (%)
Average of Six Years	10.46	3.72
Net Discount Rate		6.74

4.4 BST Data

Along with the data requirements discussed earlier, additional model parameters are required for the BST adoption scenario. Milk production response to BST use is required. Also, the effects of BST on production costs and labour requirements are also necessary.

As noted earlier, the increase in milk production resulting from use of BST is assumed to be 10 percent annually. The daily production increase for the assumed 210 days of treatment is therefore 14.5 percent (average). In absolute terms, the average daily increase is over 3 kg. during the treatment period. These values are based on estimates from the Council for Agricultural Science and Technology (1989) and the University of Massachusetts, Cooperative Extension (1989).

The cost of purchasing BST is assumed to be $ 0.36 for 35 mg. of BST[37] (Schieldt 1989; Legates 1989; Oxley 1988). BST use is assumed to be initiated after 95 days postpartum. The duration of injection is approximately 210 days for every lactation, as noted above. Thus, the annual BST cost is $ 75.60 per cow. The method of treatment is assumed to be bi-weekly injections. This method appears to be the most likely, in

[37] This represents the amount of BST required daily per cow.

terms of feasibility. It is further assumed that BST has no adverse effects on the health, longevity and reproductive ability of the cow. Average fat and protein percentages, lactose and mineral contents are assumed to be unchanged. Milk from BST treated cows is also assumed to have no harmful effects for human consumption.

Besides the cost of purchasing BST, treated cows require extra services (e.g., health care). An allowance in the operating costs is made for BST use. As an estimation of this extra expense, a 10 percent increase in the cost of purchasing BST is assumed. As a result, the total BST cost becomes $ 83.16 per cow per year.

BST use results in increased feed requirements. Rations are endogenously re-formulated based on additional nutrient requirements resulting from increased milk production. These requirements are provided in Appendix C (Table C.2). Some researchers claim that BST treated cows require higher quality of feed (e.g., McNaughton 1988). To simplify the modelling requirements, the quality of feed is assumed to remain constant. Thus, increased feed quantity compensates for the requirement of better quality feed. Maximum dry matter intake increases in response to the increased milk production. Accordingly, BST use may result in changes in crop purchases and sales for the farm. All of these changes are endogenously determined by the model.

Labour hours required for dairy production after BST is adopted will also change. Therefore, 3, 3.5 and 4 percent[38] increases in required labour hours after BST use are assumed for the small, medium and large herds, respectively. These increases reflect the

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[38] These figures are suggested by Dr. J.R. Ingalls, Department of Animal Science, University of Manitoba.

additional time required for injection, milking and general care of the cow. All changes in dairy production requirements due to BST use, except nutritional requirements, are summarized in Table 4.14.

Table 4.14 Effects of BST Adoption on Farm-level Data

Farms/Production Level	Change in Annual Milk Production (kg./cow)	Change in Daily Milk Production[a] (kg./cow)	Change in Annual Labour Requirement (hour/cow)	BST Cost ($/cow)
Small				
Low Production	+650	+3.1	+ 2.2	+83.16
High Production	+800	+3.8	+ 2.4	+83.16
Medium				
Low Production	+650	+3.1	+ 1.5	+83.16
High Production	+800	+3.8	+ 1.4	+83.16
Large	+725	+3.5	+ 1.0	+83.16

[a] This represents the average daily increase per cow over the 210 treatment period.

4.5 Analytical Procedures
4.5.1 The Empirical Model

As discussed in the previous chapter, the production decisions for the representative dairy farms are modelled using a linear programming framework. In particular, a multi-period (i.e., dynamic) linear programming model is developed and used to model the impacts of BST adoption. The structure of the model represents the basic dairy farming practices in western Canada.

The empirical dynamic linear programming model consists of an objective function and a set of constraints. The estimation procedures for the various model coefficients have been discussed previously. The structure of the base (i.e., non-BST) model is provided below.

Subscripts are used to indicate time periods, types of cattle and crops, and to identify different nutrient considerations for ration formulation.

f	≡	type of purchased feed
	=	barley, oats, wheat, canola meal and soybean meal
g	≡	type of cattle for sale
	=	cull cows, cull heifers and bull calves
h	≡	type of homegrown feed
	=	barley, oats, wheat, and alfalfa
j	≡	type of cattle in herd
	=	milk cows, replacement heifers and heifer calves
l	≡	type of crop grown
	=	barley, oats, wheat, canola and alfalfa
n	≡	nutrient consideration for ration formulation
	=	energy (net or digestible), crude protein, calcium, phosphorus and acid detergent fibre
s	≡	season for labour requirements
	=	spring, summer and other
t	≡	time period (year)
	=	1, 2 and 3
v	≡	type of crop for sale
	=	barley, oats, wheat and canola

The fixed coefficients used in the model reflect prices and costs, labour requirements and availability, and dairy and crop enterprise parameters.

R ≡ discount rate

Prices and Cost Coefficients

P_v^c ≡ price received per hectare of production for crop v

P_g^{cat} ≡ price received per animal for cattle type g

P^m ≡ price received per kilogram for milk

W_l^c ≡ annual production cost per hectare for crop l

W_j^{cat} ≡ annual production cost (excluding feed and labour) per animal for cattle type j

W_j^{repl} ≡ cost per animal to purchase replacement milk cows

W_f ≡ price paid per kilogram for purchased feed f

W_s^{lab} ≡ price paid per hour of hired labour in season s

W_t^{land} ≡ price paid per hectare for rented land

Land and Crop Rotation Coefficients

CANMAX ≡ maximum percentage of the cultivated land base that can be devoted to canola production

LAND ≡ total cultivated area owned by the farm operator

RENTMAX ≡ Maximum hectares of land that may be rented each year

ALFMAX ≡ maximum percentage of alfalfa harvested that was grown in the previous year

Labour Coefficients

$LABOUR^s$ ≡ total hours of operator/family labour available in seasons

$LCAT_j^s$ ≡ hours of labour required per animal for cattle type j in season s

$LCRP_l^s$ ≡ hours of labour required per hectare for crop l in season s

Dairy Enterprise Coefficients

BULLPCT ≡ percentage of calves born each year that are bull calves

CULLPCT ≡ percentage of milk cows that are culled each year

$DEATH^{calves}$ ≡ percentage of heifer calves that die each year

$DEATH^{heifers}$ ≡ percentage of replacement heifers that die each year

HEIFPCT ≡ percentage of calves born each year that are heifer calves

MILK ≡ kilograms of milk produced per cow

QUOTA ≡ milk production quota for the farm operation

a_h^n ≡ kilograms of nutrient n provided per hectare of production from homegrown feed h

a_f^n ≡ kilograms of nutrient n provided per kilogram of purchased feed f

$MAXDM_j$ ≡ maximum kilograms of dry matter intake per animal for cattle type j

$NUTREQ_j^n$ ≡ requirement of nutrient n per animal for cattle type j

Operating Interest Coefficients

CSTPCT ≡ percentage of eligible costs that are financed with an operating loan

INTE ≡ annual interest rate (percentage) paid for the operating loan

YRPCT ≡ percentage of a full year for which the operating loan is held

The model activities are defined as follows:

HL_t^s ≡ hours of labour hired in season s of year t

$OPINT_t$ ≡ operating loan interest paid in year t

$RENT_t$ ≡ hectares of land rented in year t

Crop Enterprise Activities

$CROP_t^l$ ≡ hectares of crop l grown in year t

$CRPFD_t^{hj}$ ≡ hectares of homegrown feed crop h fed to cattle type j in year t

$CRPSAL_t^v$ ≡ hectares of crop v sold in year t

$CRPTRANS_{t,t+1}^l$ ≡ hectares of crop l stored from year t to year t+1

Dairy Enterprise Activities

M_t	$\equiv$	total kilograms of milk produced and sold in year t
$CATTLE_t^j$	$\equiv$	number of animals for cattle type j in year t
$CATSAL_t^g$	$\equiv$	number of animals for cattle type g sold in year t
$FEED_t^{fj}$	$\equiv$	kilograms of purchased feed f fed to animal type j in year t
$REPLHEIF_t$	$\equiv$	number of replacement heifers moved into the milking herd in year t
$REPLPUR_t$	$\equiv$	number of replacement milk cows purchased in year t

The linear programming model, consistent with the above notation, is defined in such a way to maximize discounted gross margins, where gross margin is defined as revenue minus production costs and operating interest. The model is formally stated as follows:

Maximize:

$$\sum_t \frac{1}{(1+R)^t} [(P^m \times M_t) + \sum_v (P_v^c \times CRPSAL_t^v) + \sum_g (P_g^{cat} \times CATSAL_t^g)$$

$$- \sum_l (W_l^c \times CROP_t^l) - \sum_j (W_j^{cat} \times CATTLE_t^j) - \sum_f (W_f \times \sum_j FEED_t^{fj})$$

$$- W^{repl} \times REPLPUR_t - \sum_s (W_s^{lab} \times HL_t^s) - W_t^{land} \times RENT_t - OPINT_t] \qquad \textbf{(4.1)}$$

subject to :

$$M_t \leq QUOTA \qquad \forall t \qquad \textbf{(4.2)}$$

$$M_t \leq MILK \times CATTLE_t^{cows} \qquad \forall t \tag{4.3}$$

$$CATSAL_t^{cull} = CULLPCT \times CATTLE_t^{cows} \qquad \forall t \tag{4.4}$$

$$CATSAL_t^{bull} \leq BULLPCT \times CATTLE_t^{cows} \qquad \forall t \tag{4.5}$$

$$CATTLE_t^{calves} \leq HEIFPCT \times CATTLE_t^{cows} \qquad \forall t \tag{4.6}$$

$$CATTLE_t^{heifers} \leq (1 - DEATH^{calves}) \times CATTLE_{t-1}^{calves} \qquad \forall t \tag{4.7}$$

$$REPLHEIF_t + CATSAL_t^{heifers} \leq (1 - DEATH^{heifers}) \times CATTLE_{t-1}^{heifers} \qquad \forall t \tag{4.8}$$

$$CATTLE_t^{cows} \leq CATTLE_{t-1}^{cows} - CATSAL_{t-1}^{cull} + REPLHEIF_t + REPLPUR_t \qquad \forall t \tag{4.9}$$

$$\sum_h (a_h^n \times CRPFD_t^{hj}) + \sum_f (a_f^n \times FEED_t^{fj}) \geq NUTREQ_j^n \times CATTLE_t^j) \qquad \forall n,\ \forall t,\ \forall j \tag{4.10}$$

$$\sum_h CRPFD_t^{hj} + \sum_f FEED_t^{fj} \leq MAXDM_j \times CATTLE_t^j \qquad \forall t,\ \forall j \tag{4.11}$$

$$\sum_l (LCRP_l^s \times CROP_t^l) + \sum_j (LCAT_j^s \times CATTLE_t^j) - HL_t^s \leq LABOUR^s \qquad \forall t,\ \forall s \tag{4.12}$$

$$\sum_l CROP_t^l - RENT_t \leq LAND \qquad \forall t \tag{4.13}$$

$$RENT_t \leq RENTMAX \qquad \forall t \tag{4.14}$$

$$CROP_t^{canola} \leq CANMAX \times (LAND + RENT_t) \qquad \forall t \tag{4.15}$$

$$CROP_t^{alfalfa} \leq \sum_l CROP_{t-1}^l + ALFMAX \times CROP_{t-1}^{alfalfa} \quad \forall t, \forall l \text{ except alfalfa, canola} \tag{4.16}$$

$$CRPSAL_t^l + \sum_j CRPFD_t^{lj} + CRPTRANS_{t,t+1}^l - CRPTRANS_{t-1,t}^l - CROP_t^l \leq 0 \quad \forall t, \forall l \text{ except alfalfa, canola} \tag{4.17a}$$

$$CRPSAL_t^{canola} + CRPTRANS_{t,t+1}^{canola} - CRPTRANS_{t-1,t}^{canola} - CROP_t^{canola} \leq 0 \qquad \forall t \tag{4.17b}$$

$$\sum_j CRPFD_t^{alfalfa,j} + CRPTRANS_{t,t+1}^{alfalfa} - CRPTRANS_{t-1,t}^{alfalfa} - CROP_t^{alfalfa} \leq 0 \qquad \forall t \tag{4.17c}$$

$$INTE \times YRPCT \times CSTPCT \times (\text{operating expenses of individual years}) - OPINT_t \leq 0 \quad \forall t \tag{4.18}$$

Non-negativity of all the activities (4.19)

Equation 4.1 represents the objective function. Constraints are presented in equations 4.2 to 4.19. Equation 4.2 limits milk sales to be no greater than the milk quota available. Equation 4.3 requires that total milk production be limited by the herd size and the milk production per cow. Equations 4.4, 4.5 and 4.6 define cull cow numbers, bull calf numbers and heifer calf numbers, respectively, based on specified model parameters (percentages), and the number of milk cows. Equations 4.7 and 4.8 limit the numbers of replacement heifers and heifers sold or moved into the milk herd, respectively, based on inventories from the previous year (and associated death loss). Equation 4.9 limits the current milk cow herd size to be no greater than the previous year's herd size, less cull sales, plus replacement heifers moved into the herd and any purchased replacements.

Equations 4.10 and 4.11 deal with ration formulation. Equation 4.10 ensures that the various nutrient requirements are met through the use of homegrown and/or purchased feed for each type of cattle on the farm. Equation 4.11 ensures that the limit on dry matter intake is not exceeded for any class of cattle.

Equation 4.12 deals with labour requirements in each of the three seasons (i.e., spring, summer and other). In particular, labour requirements for dairy and crop enterprises are met, in each season, through a combination of operator labour and hired labour.

The next seven equations deal with crop activities. Equation 4.13 limits total crop production to be no greater than the area available from owned and rented land. Equation 4.14 limits the area that can be rented in each year. Equations 4.15 and 4.16 define the agronomic or rotational limitations for production of canola and alfalfa, respectively.

Equations 4.17a to 4.17c are transfer constraints which link crop production and utilization. For all crops except alfalfa and canola (i.e., barley, oats and wheat), crop production plus any previous production in storage may be sold, fed to dairy cattle or stored for future use (4.17a). Canola produced and stored from previous years may be sold or stored for future use (4.17b). Alfalfa production plus previously stored production may be fed or stored (4.17c).

Equation 4.18 defines operating interest in terms of eligible costs, the annual interest rate, the proportion of eligible costs to be financed, and the percentage of the year over which the loan is held. Finally, Equation 4.19 restricts all activities to have non-negative values.

This base model is adjusted slightly to incorporate adoption of BST. Some model coefficients (e.g., nutrient requirements for rations, milk production per cow, costs of production) are changed to reflect adoption. An additional activity, representing quota purchase is also added. This affects several of the equations, including the limit on milk sales, and the objective function. Finally, additional equations are required to reflect and incorporate the debt financing required for the quota purchase.

4.5.2 Modelling of BST Adoption

BST adoption is incorporated into the empirical linear programming models, adjusting the parameters discussed previously (Section 4.4). If BST is adopted, all farms are assumed to administer the hormone to 100 percent of the herd. Within this framework, the annual response rate of 10 percent, in terms of milk production, is applied to the representative farms. Comparisons of solutions for the milk response rate resulting from BST adoption to the base solution will be carried out. In order to determine whether BST is a viable technology for the dairy farms, the discounted gross margin (i.e., the gross revenue net of variable costs) for the farm operations is used as the criterion.

4.5.3 BST Adoption with Different Quota Scenarios

The BST administration will be examined under two scenarios: with and without quota purchases. The effects of BST use for each herd will first be examined under a no quota purchase scenario. The models will then be solved again allowing for quota purchases. For simplicity, all individual herds are assumed to be able to purchase the amount of milk quota required to maintain the original herd size. In practice, there may be limitations due to milk handling, the supply of milk quota and financing ability, etc., that restrict the operator from doing this. However, for analytical purposes, this assumption is made in order to examine the potential effects of BST under a quota purchase scenario. Solutions of BST response rate under the two scenarios will be compared.

4.5.4 BST Adoption with Changing Milk Price - A Second Round Effect

Milk prices in the prairie provinces are determined by milk boards (for fluid milk) and by the Canadian Dairy Commission (for industrial milk) based on a milk price formula. This milk price formula includes the costs of producing milk, livestock revenue from the dairy enterprise and a certain percentage of returns on farm assets. The milk price formula is given as follows:

$$P_t = A \times P_{t-1} + (1 - A) \times (COST_{t-1} - LVSTK_{t-1} + 0.15 \times ASSET_{t-1}) \quad \textbf{(4.20)}$$

where P is milk price, COST is variable cost of producing a litre of milk, LVSTK is revenue from dairy livestock sales per litre of milk, and ASSET is total market value of investment in farm assets, such as machinery, building, all cattle on the herd and milk quota, expressed as per litre of milk. The subscript t represents time periods. A is a coefficient ($0 \leq A \leq 1$) that identifies the relative weight placed on the two terms in the monetary value expression.

As BST is expected to reduce the average cost of producing one litre of milk, milk prices will decrease accordingly. This decrease may affect operators' decisions in the next production period. This effect should be incorporated into the modelling procedure. However, this is difficult to do within a farm-level model as the effects are occurring on an aggregate level.

When significant numbers of dairy herds adopt BST, production cost changes on the adopting farms in the industry will be reflected in the milk price formula. Milk price change in the intermediate-term is important, because the effects of BST on milk prices would likely take place over several years. During these years, farmers will likely not change fixed inputs. As a result, the study of BST impacts on farm profitability is complete with the consideration of milk price changes. At the end of the third year, the adoption rate is assumed to be 20 percent[39] (Zepeda 1990; McCarthy, Shapiro and Perreault 1986).

4.5.5 Long-Term Effects of BST Adoption to the Western Canadian Dairy Industry

The long-term effects of BST use on the western Canadian dairy industry and related agricultural sectors will be discussed based on the implications of the short-run

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[39] In the Product Life-cycle theory (McCarthy, Shapiro and Perreault 1986), a product's life can be divided into four periods: introductory; growing; mature and ending. In each period, there would be a certain percentage of adoption by customers, depending on the type of products, customers' responses and the length of each period, etc. However, for the introductory period, the adoption rate is expected to be as low as twenty percent.

solutions. Long-run effects may include structural changes in the dairy industry such as herd size adjustments, industry size adjustments (e.g., numbers of firms), sector performance and quota prices. Related agricultural sectors include the feed sector, veal and beef markets, artificial insemination and breeding markets, etc.

4.6 Summary

In this chapter, representative dairy farms are defined as farms having given herd sizes and production levels. The average herd sizes for small, medium and large herds are 35, 60 and 95 cows, respectively. Annual low and high production levels per cow are defined as 6500 kg. and 8000 kg., respectively. These two levels apply to the small and medium herds only. The large herd has only one production level (i.e., 7250 kg. per cow per year).

Data for the model are discussed, in terms of the sources, coefficient estimation and applications in the model. Various types of data are discussed, including data for the dairy and cropping enterprises; farm-level data; and exogenous data.

After BST is adopted, some coefficients are adjusted, including dairy operating costs, feed requirements and required labour hours for treated cows. The BST response rate on milk production is assumed to be 10 percent annually, or by 14.52 percent during the 210 days of treatment period.

With respect to the empirical model, the objective value is the sum of real three-year discounted gross margins. The model consists of the objective function and six sets of constraints. The objective function is expressed as the gross margin for the dairy, livestock and cropping enterprises. The model constraints define and limit activities such as feed requirements, maximum milk production, available milk quota, livestock raised and sold, crop production and disposition, and land and labour requirements, etc.

The empirical model is run under three scenarios: base run (no BST); BST use with no quota purchase; and BST use with quota purchase allowed to maintain the original herd size. The effects of BST on milk prices in the intermediate-term are also considered. In the three year period, the maximum BST adoption rate is assumed to be 20 percent. This rate is used in the milk price formula adopted by provincial milk board to calculate the new milk price. Finally, the long-run BST effects on the dairy and related agricultural sectors are discussed, based on the short-run solutions. The potential structural changes in the dairy industry include herd size, farm numbers and milk quota prices.

CHAPTER FIVE LINEAR PROGRAMMING MODEL RESULTS

5.1 Introduction

This chapter consists of eight sections. The first section discusses the validation of the linear programming model in the analysis. The second, third and fourth sections provide a summary of the modelling results for the base scenario and short-run BST administration under the assumed quota scenarios, respectively. The fifth section presents results of the post-optimality analysis. The sixth section in this chapter provides the results of BST adoption on milk prices. Then, the last two sections discuss the implication of short-term results and likely long-term implications of BST use, respectively.

5.2 Model Validation

Validation is an important consideration in any economic modelling analysis. A model is considered to be valid if it accurately replicates (approximately) the system that is being simulated (McCarl 1984). There are several alternative methods that can be used to determine the validity for empirical models, including comparisons of model results to actual data, rigorous statistical testing of model results, etc. The choice of validation method depends upon the degree of rigour desired, along with the availability of information required to implement the particular procedure.

In this study, model validation is concerned with the ability of the linear programming models to accurately replicate financial and physical performance of the representative dairy farms. Rigorous validations methods, such as those noted above, are not feasible for use, however. Implementation of these methods requires detailed farm-level information for western Canadian dairy farms. This information, particularly for financial performance, is not easily obtained. Also, the model results do not represent true profit, but gross margins for the farms. This information is generally not available in published or unpublished sources.

Two methods are used to validate the linear programming models in this study. These are: i) validation by assumption; and ii) validation through expert opinion. Both are legitimate validation methods in the absence of more rigorous tests. These are briefly discussed below.

Validation by assumption involves examination of the activities and relationships incorporated into the model. If these activities and relationships are sound, then the model is considered to be valid for use.[40] In the case of the linear programming models in this study, the model relationships are developed using advice from experts concerning standard practices for western Canadian dairy farms. This includes the considerations for crop rotations, dairy ration formulation, etc. Given this, the empirical models used in this study "pass the test" of validation by assumption.

Validation by expert opinion involves examination of the model solutions by experts in order to determine if the results seem reasonably accurate. If the solutions pass this test, then the model is considered to be valid for use in the analysis. For this study, the base model solutions are reviewed by experts who are familiar with the structure and

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[40] As McCarl (1984) points out, too many models are validated strictly through assumption. It is agreed that more rigorous validation procedures would be preferable, but as noted earlier, are not feasible in this case.

performance of western Canadian dairy farms.[41] Using this procedure, any unusual results are identified and one of two actions are taken; the results are either adequately explained or the models are adjusted accordingly. Given the results of these two validation procedures, the linear programming models are considered to be valid for use in analyzing the short-term impacts of BST on representative western Canadian dairy farms.

5.3 Optimal Solutions for the Representative Farms[42]

The representative farm linear programming models are solved using the General Algebraic Modelling System (GAMS) program (Brooke, Kendrick and Meeraus 1988). This computer program has several alternative algorithms for solving different types of mathematical models, such as linear, non-linear and mixed integer programming. Theoretically, the mathematical models for the representative dairy farm operations should be solved using mixed integer programming. The reason for this is that some activities (i.e., livestock numbers) take on integer values. Rounding off figures in a solution from a linear programming model does not always accurately represent the true mixed integer solution. However, linear programming is the most appropriate empirical technique among the various mathematical programming options.[43] Therefore, linear programming

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[41] The experts utilized for this purpose are Dr. J.R. Ingalls of the Department of Animal Science, University of Manitoba, and Dr. D.F. Kraft of the Department of Agricultural Economics and Farm Management, University of Manitoba.

[42] In presenting the results for the base solutions, the values represent the results for years two and three of the model. These represent the "normal" years of operation; that is, after any adjustments that occur in the first year.

[43] There are also some technical problems with the mixed integer programming solver in GAMS (version 2.05) that preclude its use in this analysis.

analysis is utilized, and results, where appropriate, are rounded to the nearest integer value. To justify the linear programming solutions, two assumptions are required. They are: a) solutions from the linear programming are feasible; and b) the solutions approximate the true global optimal solutions. The assumptions are important and necessary because the solutions may become technically infeasible after rounding the linear programming results to integer values.

5.3.1 Gross Margins for the Representative Farms

Gross margins and objective function values (i.e., the sum of discounted gross margins) for the base models are presented in Table 5.1. As discussed previously, the gross margin represents the difference between gross revenue and variable costs, and is not true profit. Depreciation and debt servicing on intermediate and long-term loans, as well as accrual adjustments, are not included. If these were considered, the profit would likely be less than the gross margins presented here.

The range of gross margins for individual years is \$ 101200 to \$ 341780. The level of gross margin is positively related to the herd size and production level. Higher gross margins for larger herds are due to many reasons, such as economies of size for both dairy and cropping enterprises, and larger land area being available for growing feed crop, (i.e., reduced purchased feed). However, economies of size and more cropping area for bigger farms are usually associated with having larger or more powerful machinery. This results in a greater investment in assets, and greater depreciation costs.

In Table 5.1, the gross margin per milk cow for the farms is also presented. These values range from \$ 2890 to \$ 3770. Overall, the relative values for the gross margins among the various representative farms are the same, whether expressed on a whole herd basis or on a per cow basis.

Table 5.1 **Gross Margins for the Representative Farms ($), on a Whole Herd Basis**

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Objective Value	284957.71	350314.88	525350.18	637837.34	962227.61
Gross Margin[a]	101200	124420	186600	226570	341780
Gross Margin Per Milk Cow	2891.43	3554.86	3110.00	3776.17	3597.68

5.3.2 Livestock Numbers and Financial Performance of the Dairy Enterprise

Milk cattle numbers represent the average herd size from the same size range used in defining the representative dairy farms. Other cattle numbers such as cull cows, replacement heifers, calves and veal, are based on the assumed herd percentages discussed in the previous chapter. Since cull heifers are female calves that remained in the herd as replacements, the number is equal to calf numbers raised in the previous year less the number of replacement heifers. Moreover, low and high production herds have identical numbers of livestock. The difference between the two production cases is in terms of the milk production level instead of livestock numbers. Livestock numbers for all representative farms are shown in Table 5.2.

Table 5.2 Livestock Numbers for the Representative Dairy Farms

Type of Cattle	Small	Medium	Large
Milk Cows	35	60	95
Replacement Heifers	11	19	30
Female Calves	17	29	47
Cull Cows	11	18	29
Cull Heifers	6	10	16
Bull Calves	17	29	47

Revenue from livestock sales is \$ 16123.07 for the small herd. Of this amount, \$ 9304.35 is from sales of cull cows and \$ 5185.02 is from sales of cull heifers. The remainder is from veal sales. Total revenue from livestock sales for the medium and large herds is \$ 26653.90 and \$ 42008.9, respectively (shown in Table 5.3).

Dairy non-feed production costs for the whole herd are also presented in Table 5.3. Feed costs for the representative farms are discussed separately in the next sub-section. In calculating the production cost, all labour hours, whether operator, family or hired, are given a value of \$ 9.86 per hour. In other words, the actual cash expenses are less than the figures presented in Table 5.3.

Similar to the gross margins, the non-feed production costs vary depending on production level and herd size. Production level and costs are positively related, as more labour is required for high producing cows. Costs also increase with herd size, as more cattle are being raised and maintained. However, the cost per milk cow decreases as herd size increases. This is due to the presence of economies of size in terms of labour requirements.

Table 5.3 **Livestock Sales and Non-feed Production Costs[a] for Representative Farm Dairy Enterprises ($)**

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Livestock Sales	16123.07	16123.07	26653.90	26653.90	42008.90
Total Non-feed Production Cost	44957.48	46882.35	63286.69	65681.34	91513.30

[a] Figures include the costs for all dairy and replacement cattle, including interest.

5.3.3 Dairy Rations and Feed Costs for the Representative Farms

Both dairy cow and replacement cattle rations are comprised of farm grown hay and barley, and purchased canola meal (shown in Table 5.4). Forage (i.e., alfalfa hay) acreage comprises between 25 and 38 percent of total cultivated land for the representative farms (as shown in Table D.1 of Appendix D), but the percentage decreases as herd size increases. Forage production per milk cow is identical across the three herd sizes, however (i.e. 1.49 hectares per cow). Solutions also indicate that a fixed amount of forage is used to provide energy for the milk cattle. In other words, the level of forage used for milk cow rations is more greatly influenced by energy requirements, than by fibre or dry matter requirements.

Homegrown barley and canola meal are used as concentrate feeds for milk cattle (i.e., energy and protein sources). Barley use (hectares of production) increases significantly for the high production herds compared to the low production herds. This is because high producing cows require higher levels of energy, and barley has greater energy content than alfalfa or canola. Canola meal is also high in energy (but lower than barley), crude protein and phosphorus, and helps to meet all required nutrition at the cheapest cost in combination with hay and barley.

Table 5.4 Feed Types and Ration Costs[a] for Milk Cows and Replacement Cattle[b] for the Representative Farms, on a Whole Herd Basis.

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Feed Types For Milk Cows					
Farm Hay (ha.)	52.4	52.4	89.9	89.9	141.8
Farm Barley (ha.)	8.6	15.6	14.8	26.7	31.5
Canola (kg.)	27080.0	30617.8	46422.9	52487.6	77241.2
Feed Cost For Milk Cows ($)	16500.42	18643.13	27751.79	31311.59	46117.01
Feed Cost per Milk Cow ($)	471.44	532.66	462.53	521.86	485.44
Feed Cost For Replacements ($)	4163.66	4163.66	6902.39	6902.39	10926.81

a Figures include interest expenses (i.e. 1.0104 x feed cost).
b Replacement cattle refer to heifers and calves reared in normal operating years (i.e., years two and three). Feed costs for replacements in the first year are not significantly different.

Comparisons between the small and medium herds indicate that identical amounts of barley and canola meal are fed on a per cow basis[44] (i.e., 0.25 hectare of barley and 773.7 kg. of canola meal for low production, and 0.45 hectare of barley and 874.8 kg. of canola meal for high production). Barley and canola meal utilization per cow in the large

[44] The feed use on a per milk cow basis is calculated by dividing individual feed used for the herd by milk cow numbers. The results are presented in Table 5.11, where comparisons are made between pre- and post-BST scenarios.

herd is between the average values for the low and high production cases of the small and medium herds.

Feed costs for milk cows and replacements on a whole herd basis are provided in Table 5.4. Feed cost per milk cow is positively related to production levels, but is inversely correlated to herd size. Feed cost per cow for a given production level decreases as herd size increases from small to medium, thus confirming the presence of economies of size. The feed cost is multiplied by a larger number of cattle in the large herd, resulting in a greater total feed cost. On the other hand, higher producing cows have greater feed costs[45] than lower producing cows due to greater use of barley and canola meal. There is no difference in feed costs for replacements in the high and low production cases, as the replacement numbers are identical.

5.3.4 Implicit Milk Quota Values for the Representative Farms

As noted in previous chapter, the marginal value of milk quota for the representative farms is provided by the shadow price for the quota constraint. However, the LP model incorporates returns from the quota only for the first three years. The shadow price, therefore, represents the maximum amount (discounted to a present value) that the objective value would increase over the three-year period by purchasing an additional unit of quota. It should not be directly interpreted as the price that farmers

[45] If milk production per cow increases, some other higher cost nutrient considerations (e.g., fat) in the diet should be considered. Then, the resulting feed cost for a cow would be higher than the costs obtained here. However, owing to the complexity of the empirical model, these additional nutrition requirements are not included in the analysis.

would pay for a unit of quota. This is because farmers expect the quota to generate returns over a longer time period. This difference may be reconciled by converting the shadow price value into an annuity using the same discount rate used in the objective function. Then, interpretations can be made either in the short or long-run. Since a litre of milk quota would give a uniform series of returns every year, the present value of an annuity formula[46] is appropriate for the conversion of the shadow price value. The resulting annuities for the farms are shown in Table 5.5.

The annuities of the modelling results are based on a three-year discounting period. The annuity for the market value presented in Table 5.5 is based on a 15-year time horizon. According to the theory of the firm, the value of marginal physical productivity for an input (i.e., VMP) should be equal to the factor cost in equilibrium. Therefore, these values should represent the maximum amount that farmers are willing to pay annually for acquiring additional units of quota.

The market value of milk quota on an annuity basis is \$ 25.90, which is close in value to the estimated marginal value for the medium herd, low production case.

Several factors determine the marginal values for milk quota. These factors include the discount rate, the time horizon used for discounting, and additional capital assets required in conjunction with the acquisition of additional milk quota. The discount rate is a subjective rate, which may differ between farmers. Some farmers may place a higher value on time than the value used in this study. However, some others may have

[46] The formula is given as $V_o = A \{[1 - (1+i)^{-N}] / i\}$, where V_o denotes the present value of an annuity. A denotes the annuity, i represents the discount rate and N represents the time horizon (Barry, Hopkin and Baker 1983).

a lower discount rate for the farm business. Changes in the discount rate would result in different implied values for the quota.

Table 5.5 Implicit Quota Values for the Representative Farms, on an Annuity Basis[a]

Herd Size\Production Case	Marginal Value ($)
Small\Low	23.92
Small\High	37.09
Medium\Low	26.19
Medium\High	39.06
Large	31.64
Quota Market Value[b]	25.90

a The shadow values for quota are converted to an annuity based on a three-year time horizon, and the market value for quota is converted using a 15-year time horizon.

b This annuity is based on a market value of $ 240, which is the assumed purchase price for the analysis.

Shorter time horizons for quota decisions will also result in higher annuity values. Changes in the relevant time horizon may be due to lack of confidence by the farmers in the continuation of the dairy supply management system. In order to ensure an adequate return to the capital invested in purchasing milk quota, the annuity has to be higher. Finally, the quota shadow values assume that additional investment in capital assets such as machinery, land, etc. is not required. However, if additional investment in these assets is required for expansion, the total investment for quota and fixed assets would be higher. Thus, profits from additional milk sales would be lower, and consequently, farmers will place a lower value on quota.

The resulting annuity value for the milk quota may vary due to any of the above factors. As a result, the marginal values estimated from the modelling analysis provide a reasonable range of quota values that different farmers may have for milk quota.

Comparisons of the annuities between the low and high production cases (Table 5.5) indicate that high production herds are willing to pay more for acquiring additional units of milk quota. This is because a litre of milk production is more profitable in the high production herds than in the low production herds. On the other hand, the annuities for the medium herd are higher than for the small herd. This is due to lower costs per litre of milk production for the medium herds than for the small herds, resulting in higher gross margins. The annuity value for the large herd lies among the values for the other four farm cases as a result of herd size and production level considerations.

5.3.5 Commercial Crop Production and Profitability of the Cropping Enterprises

The maximum area available for crop production is utilized by each of the representative farms. All owned cropland is used for crop production, and each farm rents the maximum allowable acreage; that is, 50 hectares of rented land for a total of 193 hectares of cultivated land for the small herd, 100 and 200 hectares of rented land for a total of 401 and 781 hectares of cultivated land for the medium and large herds, respectively.

Besides the area allocated for production of hay and barley (for use in rations), the rest of cultivated land is devoted to wheat and canola. For each of the farms, the maximum allowable area is allocated to canola (i.e., 25 percent).[47] Wheat acreage is directly affected by feed crop acreage.

Table 5.6 presents wheat and canola acreage for the representative farms. Low production herds have greater wheat acreage than corresponding high production herds, as higher producing cows require more barley to meet increased energy demands. As a result, less area is left for production of wheat. Also, the percentage of total cropland allocated to wheat is greater for the small herds than for the medium herds (over 50 percent versus less than 40 percent, as shown in Table D.1 in Appendix D). This is at least partially due to the canola production for the medium herds, which accounts for 25 percent of the cropland. Wheat constitutes approximately 45 percent of total cropland for the large herd. However, total cash crop acreage (wheat and canola) is approximately 70 percent of total cultivated land for the large herd, which is a greater percentage than for either of the other two herd sizes.

The percentage of gross margins arising from cash crop sales for the representative farms indicates that the major source of farm income is from dairy sales. Between 7 and 20 percent of the farm gross margin is from cash crop sales (shown in Table D.2 of appendix D, depending on the particular representative farm). For the small herds, gross margin from cash crop sales represents less than 10 percent of total gross margin.

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[47] The exception to this is the small herd size. Canola activities are not included for these farms.

Table 5.6 **Commercial Crop Acreage and Their Contribution to Gross Margins**

	Small		Medium		Large
	Low	High	Low	High	
Wheat Acreage (ha.)	108.0	101.1	155.4	143.5	348.0
Net Profit From Wheat Sales[a] ($)	9252.39	8399.35	12251.25	10685.21	30090.53
Canola Acreage (ha.)	----	----	100.2	100.2	195.2
Net Profit From Canola Sales ($)	----	----	18866.39	18866.39	37083.71
Total Annual Gross Margin from Crop Production ($)	9252.39	8399.35	31117.64	29551.60	67174.24

a Cropland rental costs are included in the calculation of total cost for wheat production.

5.3.6 Hired Labour for the Representative Farms

Table 5.7 provides a summary of labour hiring activities for the farms. Labour hiring in spring months occurs only for the large herd. Operator/family labour is sufficient in all other cases. In addition, there is no labour hired outside of spring and summer by any of the herds. Labour hiring activity occurs primarily in the summer season.

The model results indicate that herd size and land area play important roles in determining the amount of hired labour. Larger herd sizes and farm acreage are associated with more hired labour. This is to be expected due to increased labour requirements, and constant operator/family labour availability. Hired labour activities also increase with production levels, due to the higher labour requirements for each milk cow.

Table 5.7 Hours of Hired Labour for the Representative Farms

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Spring (hours)	0	0	0	0	252.2
Summer (hours)	476.2	509.9	1043.7	1085.7	2259.8
Total Annual Wages ($)	4695.33	5027.61	10290.88	10705.00	24768.32

5.4 BST Adoption - No Quota Purchase Scenario

The first BST adoption scenario assumes no additional milk quota is purchased. As a result, it is expected that additional cows will be culled in order to maintain total milk production at the pre-BST level. The solutions for these models are compared to the non-BST base solutions.

The results presented in Table 5.8 demonstrate that the general effects of BST on farm gross margins are consistent across all farms, but the percentage change varies. The gross margin for all of the representative farm cases increases significantly in the first year relative to the base scenario, due to revenue from additional cull cow sales. Cull cow sales increase in the first period because fewer cows are required to maintain the same level of milk production. This is a windfall gain from using BST. After the first period, cull cattle numbers return to normal (i.e., pre-BST percentage).

Table 5.8 Impact of BST on Farm Profitability ($ of Gross Margin) - No Quota Purchase Scenario

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Objective Value ($)	287457.01	352861.72	529257.83	641813.03	967963.00
(% change from the base solution)	(+0.9)	(+0.7)	(+0.8)	(+0.6)	(+0.6)
Gross Margins ($)					
Year 1	104370	127600	191860	231850	349980
(% change from the base solution)	(+3.0)	(+2.5)	(+2.7)	(+2.3)	(+2.3)
Years 2 & 3	100900	124140	185940	225930	340570
(% change from the base solution)	(-0.3)	(-0.2)	(-0.4)	(-0.3)	(-0.4)

BST seems to be relatively beneficial to the farms only in the first year of adoption. With the windfall gain from extra culled cattle, gross margins increase by 2.3 to 3.0 percent, depending on the herd size and production level. The change in farm gross margin in normal operating years (i.e., years 2 and 3) due to BST adoption are negative. The percentage decreases are approximately 0.2 to 0.4 percent. The gross margin decreases because of the relative effects of BST on dairy production costs and livestock revenue. For this scenario, BST is beneficial in terms of cost savings only. There is no increase in milk sales. However, the reduction in livestock sales after the first period reduces farm income. The cost savings due to BST adoption are more than offset by the decline in livestock sales revenue.

The percentage decreases in the gross margin for the high production herds in normal operating years are lower than for the low production cases. Generally speaking, the total cost of producing a litre of milk is less for high producing cows. Moreover, the average BST cost, on a per litre basis, becomes less as the production level increases. Hired labour costs for the high production herds are reduced to a greater extent than for the low production herds. In addition, revenue from wheat sales increase to a greater extent in the high production herds. This is due to reduced requirements for feed grains for use in dairy rations.

5.4.1 Livestock Numbers and Financial Performance of the Dairy Enterprise - No Quota Purchase Scenario

As expected, BST adoption without quota purchase results in reduced milking cow numbers. This is shown in Table 5.9. The small herd requires approximately 3 milk cows and one additional heifer[48] to be culled from the herd, a reduction in cattle numbers of approximately 9.1 percent. The same percentage changes applies to the medium and large herds, but the actual numbers, of course, are different. The resulting cattle numbers for the low and high production cases are the same, given that the initial herd sizes are identical. The most significant difference between the high and low production cases is in terms of the cost savings for the herds.

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[48] Milk cows culled due to BST adoption are sold at the beginning of the first year, while all other cull cattle are assumed to be sold at the end of each year.

Table 5.9 Impact of BST on Livestock Numbers - No Quota Purchase Scenario[a]

Herd Size	Small	Medium	Large
Milk Cows	32	55	87
BST Culls	3	5	9
Replacement Heifers	10	17	27
(Change)[b]	(-1)	(-2)	(-3)
Heifer Calves	16	27	42
(Change)[b]	(-1)	(-2)	(-5)
Cull Cows	10	16	26
(Change)[b]	(-1)	(-2)	(-3)
Cull Heifers	5[c]	9	14
(Change)[b]	(-1)	(-1)	(-2)
Bull Calves	16	27	42
(Change)[b]	(-1)	(-2)	(-5)

[a] With the exception of BST cull, these livestock numbers are for "normal" years of the analysis; that is, years 2 and 3.

[b] This is the change relative to the base scenario.

[c] Because of calves carried forward, the small herd has 7 cull heifers, and the medium and large herds have 12 and 19 cull heifers, respectively, in first period.

Livestock revenue changes for all of the herds are positive in the first year, (i.e., by 15 to 16 percent). This is shown in Table 5.10. This is due to additional milk cows and heifers that are culled due to BST use, as explained earlier. Livestock sales revenue increases by approximately $ 2500, $ 4000 and $ 7000 for the small, medium and large herds, respectively. After the first year, however, culled cattle numbers are lower than for the base scenario. This results in livestock sales revenue being reduced by approximately 11 percent.

Table 5.10 **Financial Performance for the Dairy Enterprise - No Quota Purchase Scenario**[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Change in Revenue from Livestock Sales					
Year 1 ($)	+2450.77	+2450.77	+4073.69	+4073.69	+7187.11
(% Change)	(+15.3)	(+15.3)	(+15.3)	(+15.3)	(+16.8)
Years 2 & 3 ($)	-1806.12	-1806.12	-2748.07	-2748.07	-4746.39
(% Change)	(-11.2)	(-11.2)	(-10.3)	(-10.3)	(-11.1)
Dairy Non-Feed Production Cost Savings[b]					
Period 1 ($)	30.39	122.30	-532.62	-411.99	-3219.49
(% Change)	(0.1)	(0.3)	(-0.8)	(-0.6)	(-3.5)
Periods 2 & 3 ($)	480.85	570.76	-82.97	37.667	-2500.94
(% Change)	(1.1)	(1.2)	(-0.1)	(0.1)	(-2.7)

[a] All figures represent changes relative to the solution for the base scenario.
[b] Positive figures represent cost savings, while negative figures represent increased costs.

Conversely, the representative farms have increased milk production costs on a per cow basis. The non-feed production cost per milk cow increases because of the cost of BST. Nevertheless, the fact that there are fewer dairy cattle under this BST scenario has an offsetting effect on total cost. The effects of BST on total non-feed cost for the herd may be positive or negative, depending on the relative changes in the cost per milk cow and cattle numbers in the herd.

Estimated savings for total dairy enterprise non-feed costs are also shown in Table 5.10. Overall, the percentage changes in costs are small. Cost savings for the small herd with low and high production levels are 0.1 and 0.3 percent (or $ 30 to $ 120), respectively, in the first year. These savings increase to slightly more than one percent in the following years. The increased cost savings are due to fewer cattle being raised in the second and third years. The high production case of the small herd exhibits a greater degree of cost savings, because of the lower percentage increase in non-feed costs per cow for high producing cows, as discussed earlier. It is also because of the greater cost savings for hired labours, compared to the low production case.

The overall effect on costs for the medium and large herds is negative; that is, costs increase. The only exception is the high production medium herd, which exhibits a 0.1 percent decrease in years 2 and 3. Cost increases are relatively insignificant for the medium herd (less than one percent), while they are somewhat larger (2.7 to 3.5 percent) for the large herd. These changes are a result of the increased cost per cow outweighing the effect of reduced livestock numbers.

5.4.2 Dairy Rations and Feed Costs - No Quota Purchase Scenario

Not surprisingly, feed use and ration costs change after BST is adopted. The effect of BST on individual feed use per milk cow, and changes in feed use and costs for the herds are summarized in Tables 5.11 and 5.12, respectively. Basically, the types of feed used in dairy and replacement rations do not change if BST is adopted. Nevertheless, the relative share of each feed in the ration does change.

Table 5.11 **Annual Milk Cow Rations on a Per Cow Basis - No Quota Purchase Scenario**

Feed Types\Scenario	Base	BST
Low Production Case, Small and Medium Herds		
Alfalfa (ha.)	1.49	1.51
Barley (ha.)	0.246	0.327
Canola Meal (kg.)	773.71	827.74
High Production Case, Small and Medium Herds		
Alfalfa (ha.)	1.49	1.46
Barley (ha.)	0.444	0.606
Canola Meal (kg.)	874.79	927.26
Large Herd		
Alfalfa (ha.)	1.49	1.49
Barley (ha.)	0.246	0.445
Canola Meal (kg.)	773.71	874.79

The effects of BST on individual cow rations vary by production level. After BST is administrated, the use of alfalfa, barley and canola meal all increase for low production cow rations. With the increase in production due to BST, nutrient requirements increase, along with dry matter intake. For these low producing cows, the additional requirements can be met by increasing intake of all three feeds. The increase in barley use, however, is relatively greater than for either alfalfa or canola meal, on a per cow basis. This is due to the importance of energy levels in maintaining higher milk production.

Table 5.12 **Dairy Rations and Feed Costs on a Whole Herd Basis - No Quota Purchase Scenario**[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Changes For Milk Cows					
Farm Alfalfa (ha.)	-4.3	-5.9	-7.3	-10.3	-12.5
Farm Barley (ha.)	+1.8	+3.7	+3.1	+6.4	+6.9
Canola (kg.)	-743.0	-1114.1	-1273.8	-1909.8	-1690.8
Feed Cost Changes Per Milk Cow ($)	+30.8	+36.09	+29.86	+35.15	+35.28
Feed Cost Changes For the Whole Herd ($)	-520.00	-546.60	-893.97	-929.49	-1145.16
(% Change)	(-3.2)	(-2.9)	(-3.2)	(-2.9)	(-2.5)
Feed Cost Changes For Replacement Cattle					
Year 1 ($)	-145.78	-145.78	-193.25	-193.25	-333.33
(% Change)	(-3.5)	(-3.5)	(-2.8)	(-2.8)	(-3.0)
Years 2 and 3 ($)	-403.01	-403.01	-629.72	-629.72	-1003.63
(% Change)	(-9.7)	(-9.7)	(-9.1)	(-9.1)	(-9.2)

[a] All changes are relative to the base scenario results. Positive numbers represent increases and negative numbers represent decreases.

For higher producing cows, the ration changes attributable to BST adoption are slightly different. Barley and canola meal use increases, while the forage (e.g., alfalfa) content of the ration decreases. Although dry matter intake increases, it is not sufficient to allow the additional nutrient requirements to be met by increasing all feeds. Therefore, a substitution of concentrates (i.e., barley and canola meal) for forage occurs in the ration. The ration changes for the large herd fall in between the others. Alfalfa use remains constant, while the use of barley and canola meal increases.

Table 5.12 provides a summary of the aggregate effects for these ration changes. The decrease in milk cow numbers offsets, at partially, any increases in feed use per cow. The net effect is that only barley use increases for the farms. Alfalfa and canola meal use in aggregate cow rations decreases. It should be noted that nutrient requirements for replacement heifers and heifer calves are not affected by the adoption of BST. However, total feed use decreases, due to decreased livestock numbers.

While feed costs per cow increase due to BST use (Table 5.12), total dairy feed cost for the herds decreases by between 2.5 and 3.2 percent, depending on the farm cases. There are no differences between herd sizes (for the same production level), in terms of percentage savings. However, feed cost savings are greater for the low production herds than for the high production herds. The difference is due to the substitution of concentrate for forage required in the high production herds, which causes barley use to increase and forage use to decrease. Barley is a more expensive feed than alfalfa, in terms of production costs. Total feed costs for heifers and calves decrease by 9 to 10 percent in "normal" operating years, due to reduced livestock numbers.

5.4.3 Marginal Values for Milk Quota - No Quota Purchase Scenario

The marginal values for milk quota increase after BST use, as previously hypothesized (Chapter One). This result occurs because BST improves the overall profitability of milk production for each cow. The milk quota annuities and relative changes from the base results are shown in Table 5.13. The increments for the annuities range from \$ 1.15 to \$ 1.52 (or approximately 3 to 6 percent), depending on the farm.

Comparisons of the results for the different farms suggest that quota values increase to a greater degree for low production herds. This is associated with the relative changes in the objective values shown in Table 5.8. BST use results in the low production herds having slightly greater gross margin increases than for the high production herds (i.e., 0.8 to 0.9 percent versus 0.6 to 0.7 percent, respectively). Similarly, the percentage changes in the gross margins for the small herds are greater than for the medium herds. This is also reflected in the milk quota value annuities, as shown in Table 5.13.

Table 5.13 Impact of BST on Implicit Quota Values, on an Annuity Basis - No Quota Purchase Scenario

Herd Size/Production Level	BST (\$)	Δ from Base (\$)
Small/Low	25.44	+1.52
Small/High	38.35	+1.26
Medium/Low	27.58	+1.39
Medium/High	40.21	+1.15
Large	32.79	+1.15

5.4.4 Cropping Enterprises - No Quota Purchase Scenario

Adoption of BST also has effects on crop production, through the changes in feed requirements for milk cows. As noted in Table 5.12, barley used for rations increases for all farms, while alfalfa use is decreased. The net effect in all cases is to reduce the amount of land required to produce feed crops for the milking herd. The amount of land required to grow feed crops for replacements also decreases, as livestock numbers are reduced with this adoption scenario.

Some aspects of crop production do not change. Under this BST adoption scenario, all farms continue to use the maximum amount of land for crop production; that is, they continue to rent the maximum area allowed by the model. Farms also continue to produce the maximum amount of canola allowed (i.e., 25 percent of total cropland). Therefore, the land that is no longer needed for feed production, after BST is adopted, is used to grow wheat.

As shown in Table 5.14, wheat production increases for all farms. This wheat is sold as a cash crop by the farms (i.e., it is not used in dairy rations). Since BST does not affect costs or returns for wheat on a per hectare basis, this results in increased revenue and net returns from cash crop production (also shown in Table 5.14).

Given the greater area for crop production associated with larger herd size, it is not surprising that the increase in wheat production is positively related to herd size. The degree of increase is also slightly greater for low production herds than for high production herds, reflecting the greater requirement of feed barley for the higher producing cows. The net effect of BST adoption without quota purchase is to increase

Table 5.14 Impact of BST on Wheat Production and Returns - No Quota Purchase Scenario[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Changes in Wheat Production (ha.)					
Year 1	+3.1	+2.9	+5.3	+4.9	+7.2
Years 2 & 3	+4.6	+4.4	+7.9	+7.6	+11.5
Changes in Net Returns from Wheat					
Year 1	+383.27	+358.52	+697.48	+644.85	+961.85
(% Change)	(+4.2)	(+4.3)	(+5.7)	(+6.1)	(+3.2)
Years 2 & 3	+568.70	+543.97	+1039.64	+1000.16	+1536.29
(% Change)	(+6.1)	(+6.5)	(+8.5)	(+9.4)	(+5.1)

[a] These changes are relative to the base scenario results.

(slightly) the importance of cash crop production in terms of overall farm financial performance.

5.4.5 Hired Labour Activities - No Quota Purchase Scenario

There is a trade-off, in terms of labour requirements, if BST is adopted under this scenario. Labour per cow increases, but there are fewer cows in the herds. Also, there are fewer replacements and calves. The net effect is to reduce total labour requirements for all herds, and therefore to reduce the amount of hired labour. This is shown in Table 5.15.

Annual hours of hired labour decrease for all farms, by 35 to 123 hours, depending on the farm and year of the analysis. Annual hired labour costs are reduced by as much as 9.6 percent (the small herd, high production). The degree of decrease in hired labour hours is directly related to herd size and production level. Herd size affects the degree of change because more cows are culled in larger herds, resulting in greater savings. Milk production level is significant because higher producing cows require more labour. Therefore, the labour savings from culling a given number of cows are greater if milk production per cow is greater.

Table 5.15 Impact of BST on Hired Labour Activities - No Quota Purchase Scenario[a]

Herd Size		Small		Medium		Large
Production Level		Low	High	Low	High	
Change in Hired Labour (hours)						
Year	Season					
1	Spring	--	--	--	--	-31.0
2 and 3	Spring	--	--	--	--	-31.3
1	Summer	-35.0	-41.7	-48.9	-59.7	-77.2
2 and 3	Summer	-42.6	-49.1	-58.4	-69.2	-92.0
Annual Change in Hired Labour Cost (%)						
Year 1		(-7.3)	(-8.2)	(-4.7)	(-5.5)	(-4.3)
Years 2 and 3		(-8.9)	(-9.6)	(-5.6)	(-6.4)	(-4.9)

[a] These changes are relative to the base scenario results. Negative numbers represent reduced hours or wages.

5.5 BST Adoption - Quota Purchase Scenario

Results of the BST on the dairy herds are significantly different if milk quota may be purchased. The resulting effects on the gross margins for the representative farms are presented in Table 5.16. If the farmer is allowed to purchase sufficient milk quota to maintain the original herd size after BST is adopted, milk sale revenues increase. The farmer must pay for the additional quota, but the net effect is higher gross margins. Moreover, there is a slightly greater increase in the gross margin each year (relative to the base scenario) due to declining interest payments for the quota purchases.

As shown in Table 5.16, gross margins in all periods increase relative to the base scenario results. The increases range from 1.9 to 3.3 percent. These increases are also greater than those for the no quota purchase BST scenario. In the quota purchase scenario, BST has cost savings on a per litre of milk production. However, total production costs (including feed and non-feed costs) for the whole herd increase, as the cost per cow increases.

The results indicate that herds with higher producing cows seem to benefit more from using BST in this scenario. This is because the production cost per litre of milk is lower for the high production herds. In addition, the additional BST expense for high producing cows is also lower relative to the total operating cost, as discussed previously. Finally, the gross margins from wheat sales increases to a greater extent in the high production herds, contributing to the higher farm gross margins.

Table 5.16 BST Impact on Farm Gross Margins - Quota Purchase Scenario

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Objective Value ($)	291639.73	360619.27	537030.03	655480.73	984282.23
(% Change from Base Solution)	(+2.3)	(+2.9)	(+2.2)	(+2.8)	(+2.3)
(% Change in No Quota Scenario)[a]	(+0.9)	(+0.7)	(+0.7)	(+0.8)	(+0.6)
Gross Margins ($)					
Year 1	103320	127750	190260	232200	348760
(% Change from Base Solution)	(+1.9)	(+2.6)	(+1.9)	(+2.4)	(+1.9)
(% Change in No Quota Scenario)[a]	(+3.0)	(+2.5)	(-2.7)	(+2.3)	(+2.3)
Year 2	103590	128100	190780	232870	349670
(% Change from Base Solution)	(+2.4)	(+2.9)	(+2.2)	(+2.8)	(+2.3)
(% Change in No Quota Scenario)[a]	(-0.3)	(-0.2)	(-0.4)	(-0.3)	(-0.4)
Year 3	103980	128580	191450	233690	350840
(% Change from Base Solution)	(+2.7)	(+3.3)	(+2.6)	(+3.1)	(+2.7)
(% Change in No Quota Scenario)[a]	(-0.3)	(-0.2)	(-0.4)	(-0.3)	(-0.4)

[a] These are the changes for the no quota purchase scenario, relative to the base scenario results.

5.5.1 Financial Performance of the Dairy Enterprise - Quota Purchase Scenario

As is the case for gross margins, BST effects on dairy revenue and non-feed production costs under the quota purchase scenario are significantly different from the results for the no quota purchase scenario. Revenue changes significantly in this scenario, due to increases in milk sales, and changes in cash crop sales. Also, if the herd size is maintained at the same size as before BST is adopted, the costs associated with the dairy enterprise increase. Changes in milk sale revenues and non-feed production costs (excluding quota purchase expenses) for each farm case are provided in Table 5.17. Although not noted in Table 5.17, all farms purchase the maximum quota allowed, in order to maintain the initial herd size.

Debt servicing required in order to purchase additional milk quota is an important consideration for farmers. Since interest payments for quota purchases represent an expense to the farms, these payments must be included in the decision to purchase quota. The results suggest that, even if farmers have to spend extra money (i.e., interest) to purchase milk quota, it is still profitable to expand production. Table D.3 in Appendix D provides the interest payments for five-year financing of milk quota purchases.

As noted earlier, all farms purchase sufficient quota to maintain initial herd sizes. Therefore, milk sale revenues increase by 10 percent for all farms, as the response rate to BST is 10 percent. However, the absolute amounts of milk production and revenue increases are related to the original levels of milk production for the various farms (Table 5.17).

Table 5.17 Impact of BST on the Dairy Enterprise Performance, on a Whole Herd Basis - Quota Purchase Scenario[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Change in Revenue					
Years 1, 2 and 3 ($)	+11500.13	+14154.00	+19174.50	+24264.00	+34813.79
Change in Non-feed Production Costs					
Years 1, 2 and 3 ($)	+3690.58	+3770.51	+5860.52	+5946.61	+11510.88
(% Change)	(+8.2)	(+8.0)	(+9.3)	(+9.1)	(+12.6)
(% Change in No Quota Scenario, Year 1)[a]	(-0.1)	(-0.3)	(+0.9)	(+0.6)	(+3.5)
(% Change in No Quota Scenario, Years 2 and 3)[a]	(-1.1)	(-1.2)	(+0.1)	(-0.1)	(+2.7)

[a] These changes are relative to the base scenario results.

[b] These are the percentage changes for the no quota purchase scenario, relative to the base scenario results.

Non-feed production costs increase with BST use, as the cost per cow increases and the livestock numbers remain unchanged from the base scenario. Comparisons between the results of the small and medium herds suggest that cost increases for the herds are inversely related to production level, in percentage terms. This is because the percentage increase in cost per milk cow for the high production herds is smaller, as noted earlier.

Also, the results in Table 5.17 indicate that the production cost increases, in percentage terms, are greater for the medium herds than for the small herds. Similarly, the percentage increase is greater for the large herd than for the medium herds. Since there is no cost change for raising heifers and calves, these cost increases are solely caused by BST treatment for milk cattle. Calculations of cost increases per milk cow indicate that the small herd has higher cost increases, ($ 106 versus $ 98 for the small and medium herds, respectively), as consistent with the hypothesis of size economies in labour requirements for bigger herds. It is only changes of both numerator and denominator of a fraction in the mathematical calculation that results in higher percentage increases for the medium herd. A similar argument may be made for the relationship of costs for the medium and large herds.

5.5.2 Dairy Rations and Feed Costs - Quota Purchase Scenario

The effects of the BST quota purchase scenario on dairy rations are similar to the effects for the no quota purchase scenario. Table 5.18 presents the annual rations per cow for the various scenarios. The rations for the two BST scenarios are identical. This is not surprising, given that the production increase per cow is the same in both cases.

Table 5.18 **Annual Milk Cow Rations on a Per Cow Basis - Quota Purchase Scenario**

Feed Types\Scenario	Base Scenario	BST, No Quota Purchase	BST, Quota Scenario
Low Production Case, Small and Medium Herds			
Alfalfa (ha.)	1.49	1.51	1.51
Barley (ha.)	0.246	0.327	0.327
Canola Meal (kg)	773.71	827.74	827.74
High Production Case, Small and Medium Herds			
Alfalfa (ha.)	1.49	1.46	1.46
Barley (ha.)	0.444	0.606	0.606
Canola Meal (kg)	874.79	927.26	927.26
The Large Herd			
Alfalfa (ha.)	1.49	1.49	1.49
Barley (ha.)	0.246	0.445	0.445
Canola Meal (kg)	773.71	874.79	874.79

Alfalfa, barley and canola meal all increase for low production herds. For high production herds, barley and canola meal increase while alfalfa use decreases (i.e., substitute concentrate for forage).

Table 5.19 provides a summary of BST effects for rations and feed costs, on a whole herd basis. Only information concerning rations and costs for milk cows are presented, as the numbers of replacements and calves are unchanged from the base scenario (i.e., constant herd size). The aggregate changes in feed use for each herd are

Table 5.19 Impact of BST on Dairy Rations and Feed Costs on a Whole Herd Basis, all years - Quota Purchase Scenario[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Feed Changes For Milk Cows					
Farm Alfalfa (ha.)	+0.5	-1.3	+0.9	-2.3	+0.5
Farm Barley (ha.)	+2.9	+5.6	+4.8	+9.7	+10.7
Canola (kg.)	+1890.7	+1836.4	+3241.2	+3147.9	+5864.2
Change in Feed Costs for Milk Cows					
Per Cow ($)	+30.57	+36.21	+29.44	+35.22	+35.33
For the Herd ($)	+1069.86	+1267.15	+1766.54	+2113.18	+3355.92
(% Change)	(+6.5)	(+6.8)	(+6.4)	(+6.7)	(+7.3)
(% Change in No Quota Scenario, in year 1)	(-3.2)	(-2.9)	(-3.2)	(-2.9)	(-2.5)
(% Change in No Quota Scenario, in years 2 and 3)	(-9.4)	(-7.8)	(-7.2)	(-8.9)	(-8.0)

[a] All changes (absolute and percentage) are relative to the base scenario results

consistent with the changes per cow, as milk cow numbers are constant. Alfalfa and barley production, along with canola meal purchases, increase for the low production herds (and the large herd). Barley production and canola meal purchases increase, while alfalfa production decreases, for high production herds. The net effect in all cases is to increase the amount of land required to produce dairy feeds, and to increase feed purchases.

These changes also have the effect of increasing feed costs for the dairy herds. On a per cow basis, annual feed costs increase by $ 29.44 to $ 36.21, depending on the farm. Annual herd-level feed costs increase by $ 1069.86 (the small herd, low production) to $ 3355.93 (the large herd). In percentage terms, costs increase by approximately 6 to 7 percent. The percentage changes for high production herds are slightly greater, due to the substitution of concentrates for forages in the dairy cow rations.

5.5.3 Marginal Values for Milk Quota - Quota Purchase Scenario

Given the effects of this BST scenario on gross margins, it would be expected that the shadow price for milk quota for all farms would increase relative to the base scenario. This is true, with one exception. Table 5.20 provides the implicit quota values (annuity basis) for this scenario. With the exception of the medium-sized, high production herd, they are all greater than for the base scenario.

It would also be expected that these implicit quota values would be lower than the values for the no quota purchase scenario. As the quota constraint is relaxed, the value of an additional unit of quota should be reduced. However, this is not the case, except for the medium-sized, high production herd. All other herds have identical quota values for both BST scenarios. This result is due to the step-wise nature of factor demand functions assumed in linear programming. Rather than a continuously-downward sloping demand, the implied demand function for quota in the mathematical model is a series of steps. For those farms with identical quota values for both the quota purchase and non-quota purchase option, the relaxation of the quota constraint is not sufficient to move to a different step.

Table 5.20 **Impact of BST on Implicit Quota Values, on an Annuity Basis - Quota Purchase Scenario**

Herd Size	Quota Purchase		No Quota Purchase
Herd Size/Production Level	Annuity ($)	Δ Relative to the Base Solution ($)	Δ Relative to the Base Solution ($)
Small/Low	25.44	+1.52	+1.52
Small/High	38.35	+1.26	+1.26
Medium/Low	27.58	+1.39	+1.39
Medium/High	37.05	-2.01	+1.15
Large	31.85	+1.15	+1.15

The medium-sized, high production herd exhibits the expected relationship for implicit quota values for the two BST scenarios. The value drops when the quota constraint is relaxed. However, the value for the quota purchase scenario is below the original base solution quota value. This is not to say that milk production is less profitable for this farm with BST use. This result is due to other factors (i.e, nutrient requirements for greater milk production) becoming more constraining. This reduces the value of an additional unit of quota.

5.5.4 Cropping Enterprises - Quota Purchase Scenario

As discussed earlier, cash crop sales increased under the no quota purchase BST scenario. Contrary to these results, BST has a negative effect on cash crop acreage and sales under the quota purchase scenario. Canola production remains constant for all farms, while wheat production decreases. The decreases, summarized in Table 5.21, are due to increased feed requirements for dairy rations. Wheat acreage is reduced by 3.4 to 11.1 hectares. The reductions are positively related to production level and herd size. This is not surprising, given the relationship between total additional nutrient requirements, and the numbers of cows being fed and/or the level of milk production (discussed earlier).

The changes in wheat production have corresponding effects on the gross margins generated by cash crops, also summarized in Table 5.21. Annual gross margins from wheat decrease by 4.5 to 9.1 percent. The degree of decrease is directly related to herd size and production level, again because of the relative impacts of this BST scenario on feed crop requirements for the different herds. The net effect of the quota purchase scenario is to decrease the importance of cash crop production to the farm's overall financial performance, which is exactly the opposite of the non-quota purchases scenario.

Table 5.21 **Impact of BST on Wheat Production, all Years - Quota Purchase Scenario**[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Changes in Wheat Acreage (ha.)	-3.4	-4.3	-5.8	-7.4	-11.1
Net Change in Gross Margin from Wheat Sales[b] ($)	-420.34	-531.61	-763.28	-973.84	-1482.85
(% Change)	(-4.5)	(-6.3)	(-6.2)	(-9.1)	(-4.9)
(% Change for No Quota Scenario, in year 1)	(+4.2)	(+4.3)	(+5.7)	(+6.1)	(+3.2)
(% Change for No Quota scenario, in years 2 and 3)	(+6.1)	(+6.5)	(+8.5)	(+9.4)	(+5.1)

a All changes are relative to the base scenario results.
b Cropland rental cost is included in total cost of wheat production.

5.5.5 Hired Labour Activities - Quota Purchase Scenario

As in the previous BST scenario, required labour hours per cow increase with BST treatment. However, total labour hours required for the herds also increase since no milking cows are sold. Increases in hired labour hours are also due to changes in crop production patterns. Table 5.22 provides a summary of the changes in labour hours hired by the farms and wage expenses after BST is adopted.

In terms of labour hiring activities, most of the herds still require no hired labour in spring. However, for this scenario, the medium-sized high production herd does hire a small amount of labour in spring. Spring hired labour for the large herd also increases.

Summer hired labour also increases for all representative farms. Consistent with the base scenario results, none of the farms require hired labour in any other seasons.

The pattern of change in hired labour differs slightly between the farms. The degree of increase is greater for low production herds because of the difference in crop production pattern; low milk production farms increase alfalfa production, while high milk production farms decrease alfalfa production.

Similar reasoning may be used to explain the difference between changes for the medium-sized, high production herd and changes for the large herd. Spring hired labour increases to a greater extent for the medium herd size because of increased barley production, which requires a certain amount of spring labour, and decreased alfalfa production, which requires more summer labour. The opposite pattern occurs for the large herd because both alfalfa and barley production increase.

Table 5.22 Impact of BST on Hired Labour Activities, all Years - Quota Purchase Scenario[a]

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Changes in Hired Labour (Hours)					
Spring	----	----	----	+9.9	+16.2
Summer	+14.7	+10.9	+17.2	+9.5	+17.8
Changes in Annual Hired Labour Expenses (%)	(+3.1)	(+2.1)	(+1.6)	(+1.8)	(+1.4)
Percentage Change for No Quota Purchase Scenario					
Year 1	-7.3	-8.2	-4.7	-5.5	-4.3
Years 2 and 3	-8.9	-9.6	-5.6	-6.4	-4.9

[a] Changes are relative to the base solution results.

Hired labour hours and wage expenses increase to a lesser extent for larger herds because of size economies in dairy and cropping labour requirements. As discussed in Chapter Four, required labour hours per milk cow after BST adoption are assumed to increase by a smaller percentage for larger herds (i.e., 4 and 3.5 percent for the small and medium herds, respectively).

Comparisons of the results for the quota purchase and no quota purchase scenarios indicate two very different patterns for hired labour inputs. For the no quota purchase scenario, the solutions indicate cost savings for labour hiring. Conversely, labour hiring in the quota purchase scenario increases as a result of maintaining the herd sizes.

5.6 Sensitivity Analysis

While rigorous methods are used in this study to estimate relevant model coefficients, the true values for many of these coefficients are subjective or uncertain. In some cases, estimation errors leading to incorrect parameter estimates may have significant effects on the model results. This section provides a summary of sensitivity analyses for the model results. These analyses are undertaken to test the stability of model solutions to changes in relevant parameter estimates. The coefficients tested in the sensitivity analyses are the discount factor; milk price; dairy purchased feed prices; BST cost; milk quota prices and dairy non-feed production costs. In most cases, a twenty percent increase and decrease, respectively, in the parameter estimates are used for the analyses. If the model solutions are not stable for twenty percent changes, smaller changes are modelled to estimate the relevant critical point.

5.6.1 Discount Rate

The first coefficient to be tested is the discount rate. The discount rate represents a subjective time preference rate for the farm operator. Since the rate is subjective, different farmers may have very different time preferences for income. This may affect the optimal choice of output and/or input levels. Therefore, it is useful to test the stability of the modelling results with respect to changes in this rate.

Using twenty percent changes, the resulting discount rates become 8.08 and 5.39 percent, for a decrease and increase, respectively. All of the base models for the representative farms are solved, using these new discount factors.

Model results indicate that only the objective function value changes as a result of changes to the discount rate. None of the model activities change for any of the farm cases. Milk quota shadow prices change slightly. Overall, the original base solutions are quite stable with respect to either an increase or decrease of the discount factor. As the base solutions do not change, the discount factor is not expected to have any effect on the BST solutions. Furthermore, the relative differences between the base scenario solutions and the BST solutions for the two quota scenarios are also expected to be constant.

5.6.2 Milk Price

Milk price is another parameter that may change (likely decrease) due to a number of factors. For example, milk marketing boards may reduce milk prices if dairy production costs decrease (for reasons other than BST). Milk prices may also be affected by future dairy policy changes. Therefore, the second coefficient to be tested is the milk price (i.e., the average price used in this study). The price for milk is reduced by twenty percent (i.e., by $ 0.4044 a litre). This is done not only to test whether farm activities in the model solutions are stable in response to milk price decreases, but also to see how the price decreases may affect the results for adoption of BST. The analysis is done for price decreases only. This is because milk price increases would not likely affect the activity levels, but only increase the gross margins for the dairy enterprise. Therefore, the solutions are expected to be stable with respect to price increases.

A 20 percent decrease in milk price does not change the activity levels for the base scenario or the no quota purchase BST scenario. The gross margin in each year and the objective function decrease for these scenarios. The shadow prices for milk quota also decrease significantly, if compared to the original results. This is not surprising, however, because a litre of milk is now less profitable than before. All other activities remain unchanged from the original solutions.

Conversely, modelling results for the quota purchase BST scenario change significantly even for a 15 percent decrease in milk price. For all farm cases, no milk quota is purchased, due to low profitability for milk production. However, since BST is used and milk production per cow increases, some cows are sold, resulting in solutions similar to the no quota purchase scenario. The solutions for the quota purchase scenario are stable, however, for price decreases that are 10 percent or less (in absolute terms).

5.6.3 Purchased Feed Prices

Sensitivity analyses are also conducted for purchased feed prices, as feed prices may fluctuate from year by year, depending on crop conditions and other factors. Changes in these prices may affect farmers' decisions concerning the use of homegrown feed or purchased feed. It is therefore important to test the sensitivity of the modelling results with respect to feed price changes.

Rather than look at individual feed prices, the feeds are grouped into cereals (wheat, barley and oats) and oilseeds (canola meal and soybean meals). The sensitivity of model results to changes in prices for these groups is then examined. The grouping is considered to be appropriate because prices for crops within each group tend to be positively correlated with each other.

Since no purchased cereals are used in the original solutions, increased cereal prices are not expected to affect the solutions. Therefore, only price decreases are considered. Test results indicate that the modelling solutions are sensitive to decreases in cereal feed prices. Any decrease in the prices causes the solutions under all modelling scenarios (BST and non-BST) to change. When the prices for commercial cereal feed decrease, the opportunity cost of using homegrown feed becomes higher. As a result, farmers do not grow barley, and reduce the use of alfalfa and canola meal in rations. Oats are substituted for these feeds (to a certain extent). There is also a corresponding increase in wheat production, which is sold.

The effects of both increased and decreased oilseed meal prices are examined in the sensitivity analysis. Similar to the decrease in cereal prices, if canola and soybean meal prices increase by even 3 percent, farmers substitute more homegrown barley and use less canola meal. Both hay and wheat acreage decrease as well. Conversely, oilseed meal feed prices may decrease as much as 20 percent (i.e., $ 0.1896 per kg. of canola meal and $ 0.2662 per kg. of soybean meal), without changing the activity levels for the solutions. This is because farmers cannot easily substitute more canola meal (or soybean meal) into the rations without decreasing energy or fibre levels.

In summary, the modelling solutions are not stable with respect to feed prices changes. Particularly for cereal prices, slight changes cause farmers to change the formulation of dairy rations. Nevertheless, even when the results are not stable with respect to feed prices, these price changes do not affect the general impacts of BST adoption. Changes in the objective function value, gross margins, feed costs and gross margins from cash crop sales for the farm cases may occur when feed prices change. However, none of the new solutions change the general results for BST adoption.

5.6.4 Cost of BST

Sensitivity analyses are also done for the BST cost coefficient. The actual cost for BST is quite uncertain since it is not yet commercially available. If BST cost is lower than the amount assumed in this study, the resulting dairy production costs would be lower than modelling in the study. Accordingly, the gross margins would improve. However, it is unlikely that this change would affect activity levels. Conversely, BST purchasing cost may be higher than assumed in this study. Profitability of milk production after adoption, therefore, is likely to be significantly affected by the cost of BST. A 20 percent increase in BST cost is, therefore, assumed for sensitivity analysis. The new BST cost becomes $ 100 per cow for each lactation.

If BST cost increases for the no quota purchase scenario, the gross margins for the representative farms decrease further, because of increases in the production costs. Certainly, this is likely to further discourage farmers from adopting the technology.

However, despite the decreased gross margins, there are no changes for any activities. Only the marginal value for milk quota declines slightly, compared to the original solutions.

In the quota purchase scenario, BST is still profitable for farmers to adopt, even at the higher price. Gross margins in all years decrease relative to the original solutions, of course. However, as is the case for the no quota purchase scenario, there are no changes to any other activities, relative to the original BST solutions.

5.6.5 Milk Quota Price

The solutions are also tested for stability with respect to quota prices changes. Quota prices are another uncertain coefficients in the model. Quota prices may change in response to introduction of BST (as discussed earlier), or for other reasons such as uncertainty concerning the future of supply management. In the BST adoption scenario with quota purchases allowed, changes in quota price may affect the solutions. Again, only a 20 percent increase in quota price is assumed for sensitivity tests. Since all farms purchase the maximum quota allowed in the original solutions, it is unlikely that a decrease in quota prices would affect the solutions. Tests are only done for the quota purchase scenario because no quota purchase is allowed in either the base scenario or no quota purchase scenario.

Sensitivity analysis results indicate that if quota prices increase by 20 percent, there is no effect on the activity levels for the quota purchase scenario. The objective value and gross margins decrease, as the quota expense increases. The marginal value of milk quota also decreases, due to reduction in gross margins for milk sales. Overall, the solutions are stable with respect to the increase in quota prices.

5.6.6 Dairy Production Costs

Finally, sensitivity analyses are conducted for non-feed dairy production costs. Typically, the effects of changing production costs should be similar to the effects of changes to the milk price, through the impact on gross margins. However, the main purpose of changing the production costs is to determine the difference (if any) in the effects of BST on the gross margins. Recall that results in the no quota purchase scenario indicate slight decreases in gross margin for the second and third years of the analysis. A 20 percent increase and decrease in the non-feed production costs are assumed, resulting in costs of $ 604.40 and $ 402.94 per cow, respectively. No other costs are changed in this analysis.

For the no quota purchase scenario, all farm cases that previously had negative changes in the gross margin after BST use now, have improved performance if production costs increase. In years two and three, the percentage changes in the gross margin relative to the base scenario become more positive (although the increases are relatively insignificant). The reason for this is that BST has a bigger impact (relatively speaking) on cost reductions; that is, culling cows because of BST saves the farm more money. Only the large herd still has negative results, with gross margins decreasing by approximately 0.06 percent. This general improvement is because the savings for dairy non-feed production costs now exceed the negative effects of reduced livestock revenue.

From this result, it can be inferred that BST would also have positive effects on the gross margins of the farms, if livestock prices were to decrease.

Conversely, the effects of BST become more negative if dairy production costs decrease. Under these circumstances, the total cost savings on fewer cattle are reduced, and are unable to offset the production cost increase per milk cow and the reduction in the livestock revenue. Besides the gross margins and the marginal values for milk quota, no other changes occur in the activity levels for the solutions.

In the quota purchase scenario, solutions are stable with respect to the production cost increase and decrease. Since the dairy cost changes affect both the base run and the BST models in a similar fashion, the relative differences in the gross margins between the base scenario and BST scenario with quota purchase remain constant.

5.7 Second Round Effect of BST Adoption on Milk Prices

Under the supply management system, farm-level milk prices are affected by the level of production costs, including operating, feed, labour and BST costs. If these decline on a per litre of milk basis, as is the case for the BST scenario, the price per litre of milk will decrease. This milk price decrease would not occur immediately after BST is used, due to the expected low adoption rate for the technology. Nevertheless, as more farmers adopt BST over time, the effects of BST will be more prevalent throughout the sector. Therefore, there would be a time lag between BST adoption and any decrease in milk prices. This lag may be three to five years after BST is introduced to the industry, depending on the adoption rate. BST effects in terms of the production cost savings would be reflected back to milk marketing boards through the sample of farms used to estimate provincial costs of production.

The maximum cumulative adoption rate in this study is assumed to be 20 percent over the three-year planning period, as mentioned perviously. The likely cost changes and milk prices resulting from this rate of adoption are presented in Table 5.23. The milk price formula used by milk marketing board, as presented in Chapter Four, is utilized to calculate the new milk price.

As indicated in Table 5.23, milk production costs per litre of milk decrease by the same amount for both BST scenarios, (approximately 2.3 percent). For the no quota purchase scenario, the milk price would decrease by 0.3 percent. Production costs per litre of milk production decrease, but revenue from livestock sales also decreases, which partially offsets the cost savings.

No change in milk price is expected for the quota purchase scenario. Production costs per litre of milk in this BST scenario decrease, but the livestock revenue (converted to a per litre of milk basis) decreases as well. As a result, the cost savings are offset by livestock revenue reductions, and there is no change in the milk price resulting from BST adoption.

These price changes are very minor. Even if a 100 percent adoption rate is assumed, the milk price would be reduced by 1.5 percent at most. To this end, BST is likely to have very little impact on milk prices, even at high adoption rates. This may be seen by reviewing the sensitivity analysis results for milk prices, presented earlier.

Table 5.23 **Changes in Dairy Production Costs and Milk Prices from BST Adoption ($/litre)**

		No Quota Purchase Scenario		Quota Purchase Scenario	
Herd Size, Production Level	Base ($)	Δ ($)	Δ (%)	Δ ($)	Δ (%)
Small, Low	0.2884	-0.0072	-2.5	-0.0072	-2.5
Small. High	0.2488	-0.0062	-2.5	-0.0062	-2.5
Medium, Low	0.2512	-0.0050	-1.9	-0.0050	-1.9
Medium, High	0.2165	-0.0044	-2.0	-0.0044	-2.0
Large	0.2192	-0.0037	-1.7	-0.0037	-1.7
Weighted Average[a]	0.2512	-0.0057	-2.3	-0.0057	-2.3
Changes in Milk Price[b] 20% Adoption Rate			-0.3[c]		0
100% Adoption Rate			-1.5		0

[a] The weighted average is calculated based on the relative shares for the three types of herds in the prairie region (shown in appendix C, Table C.1). For small and medium herds, the average figure for the low and high production cases is used in the calculation of the weighted average.

[b] This is calculated assuming that the total farm asset value is $ 262500 for the small herd (unpublished data obtained from Farm Credit Corporation upon request). The calculation is based on the small herd because of its bigger share in the sector relative to the other herd sizes.

[c] The calculation for the quota purchase option is done using average livestock sales revenue from the solutions. Otherwise, the average revenue for the farms would be smaller due to a greater decrease in livestock sales. The milk price would increase in this case.

5.8 Implications of the Short-Term BST Results

Given the results of the analysis that have been discussed in this chapter, several implications can be drawn, in terms of the short-term impacts of BST on western Canadian dairy farms. Perhaps the most obvious of these is the optimal means of adoption; that is, adoption without quota purchase versus adoption with quota purchase. For the no quota purchase scenario, the discounted sum of gross margins increases by less than one percent for all farms. Conversely, the objective function increases by two to three percent for the quota purchase scenario. Neither scenario represents a significant increase in potential returns, but the differences between the two scenarios are significant.

From the results presented earlier, it is likely that producers who adopt BST will prefer, over a short-term planning horizon, to purchase quota in order to maintain their current herd sizes. Dairy producers are unlikely to adopt a technology if no additional returns are generated, and gross margins actually decrease in the years following adoption.[49] Also, the response to BST assumed in this study is 10 percent. The actual response will vary between farms and between cows. Lower response to BST results in reduced cost savings, making the no quota purchase option even less attractive.

Implications may also be drawn with respect to how BST effects will differ between western Canadian dairy farms (i.e., by herd size and/or production level). The results for both BST scenarios (no quota purchase and quota purchase) suggest that there are no significant differences in the effects that can be attributed to herd size. The absolute changes in gross margins, of course, are different. However, the percentage changes in net returns are very similar. This contrasts with the effects of milk production

[49] It cannot be said with certainty that profitability for the dairy farms would not increase under the no quota purchase scenario. The economic model in this study does not explicitly account for changes in the opportunity costs of operator labour and management, and asset investment. These opportunity costs, after BST adoption with no quota purchase, will decrease due to the reduced herd size and labour requirements. If the decrease in opportunity costs is more than sufficient to offset the decrease in gross margins, then profitability will increase.

per cow. In both absolute and relative (i.e., percentage) terms, BST effects are more pronounced for higher producing cows. In other words, herds with more productive cows are likely to benefit more from adopting BST.

The use of BST also has implications for other aspects of the farm operation (i.e., crop management and labour management), in the short-run. The actual effects depend upon the nature of BST adoption; that is, whether quota is purchased or not. Assuming that most early adopters will attempt to purchase enough quota to maintain current herd sizes (as suggested above), the effect on crop management will be to decrease the size and importance of any cash crop enterprises on the dairy farms. More area will be required to produce feed for dairy rations, leaving less time and land available for cash crop production. Evidence of this is provided in the study results through decreased wheat production for the representative farms for the quota purchase scenario.

Also assuming that quota purchases accompany BST adoption, there will be increased dependence on hired labour. More labour will be required per cow, resulting in increased total requirements. For farms where hired labour is utilized before adoption of BST, more labour will be hired. For farms not previously using hired labour, more pressure will be placed on operator and/or family labour availability. Alternatively, these farms may initiate the use of hired labour, depending upon the circumstances.

In the short-run, BST adoption will also have impacts at the sector level (e.g., quota values, farm and cow numbers). For example, the results of the analysis suggest that most adopting farmers would be willing to pay more for milk quota after BST is introduced. Implicit quota values, both before and after BST use, are directly related to milk production levels and herd size. However, the degree of increase in perceived quota values resulting from adoption of BST is greater for smaller, less productive herds.

While demand for quota may increase for some farmers, the actual supply of milk quota is relatively constant. Therefore, adopting farmers may have difficulty in obtaining as much quota as that scenario would suggest is optimal. Quota may become available from less efficient producers who decide to reduce the size of their dairy enterprises, or exit from dairy farming altogether, as a result of increased returns for selling milk quota. However, in the short-run, dairy farm numbers in each province would be relatively constant.

The effects of BST on dairy farm and cow numbers will be minimal, in the short-run. As noted above, farm numbers are not likely to be greatly affected. The impact on dairy cow numbers will depend upon the adoption rate. Assuming that a significant number of farms adopt BST, cow numbers will decrease. If farms adopt and do not increase milk quota levels, cows will have to be culled in order to maintain production levels. If most farms adopt and purchase additional quota, cows will have to be culled from the farms that are selling milk quota. Again, however, the impacts in the short-run will likely be small.

BST may also have some short-term impacts on related agricultural sectors. These include beef and cropping sectors, along with markets for inputs such as farm labour, bull semen, etc. As with the other impacts, the direction and degree of any effects attributable to BST adoption will depend upon the adoption rate and the nature of BST adoption. Given the size of the dairy sector in western Canada, relative to the beef and cropping sectors, the effects of any increased culling rates, increased or decreased crop production, etc. will likely be small.[50] Any impacts on input markets will also be small, for a short-term adoption scenario.

5.9 Long-Term Implications of BST Use

This study is not intended to provide a rigorous analysis of long-term impacts for BST use. However, some implications of possible long-term consequences can be drawn, based on the short-term results. Perhaps the most important of these concerns possible structural adjustments by dairy farms in western Canada. As discussed earlier, the optimal short-term adoption strategy for the representative farms is to purchase milk quota and maintain initial herd sizes, once BST is adopted. However, farmers may also consider to expand their herd sizes. This is because BST effects on gross margins will be greater if the herd is allowed to expand (Jeffrey and Eidman 1992). This expansion would require additional investment in fixed assets, however. Additional milk quota, land, buildings and/or machinery would be required in conjunction with the expanded herd size. The exact nature of the optimal size and structure cannot be determined from the analysis in this study. The major reason for this is that the empirical model in this study assumes a fixed level of investment in capital assets, and cannot incorporate the implications of change (costs and benefits) in this level.

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[50] One exception to this may be the market for bull calves intended for veal production. Dairy farms represent an important source for these animals.

Availability and adoption of BST will have long-run impacts on non-adopting farms. As discussed earlier, adoption of BST by some farms will have effects on milk prices and milk quota values. As more farms adopt BST, these effects may become more pronounced. More efficient non-adopting farms may not be significantly affected, except that financial performance may suffer somewhat.[51] Less efficient non-adopting farms may be more significantly affected. These farms may leave the industry, because of weakened financial performance due to lower milk prices, and because of the prospect of realizing contingent gains in milk quota values.

Some long-term sectoral implications can also be drawn from the analysis. Given the possibility of structural adjustments by adopting farms, the resulting western Canadian dairy sector may consist of fewer and larger dairy farms. This trend is already present in the sector, as discussed earlier (Chapter One) and thus BST may have the effect of reinforcing this trend.

Adoption of BST will also have long-term implications for milk quota values. As discussed in the previous section, quota values would likely increase in the short-run, given a reasonable number of farms adopt the biotechnology. Over a longer time period, quota values are likely to remain somewhat higher than the pre-BST levels, given the improved profitability of milk production. However, it is uncertain whether the long-term post-BST values will be greater or lower than the quota values determined in the short-

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[51] Previous studies have suggested that the decision to adopt BST may be related to factors that would suggest more efficient management of the dairy enterprise (e.g., Kalter et al 1985, Zepeda 1990). Thus, in a long-term adoption scenario, the number of farms that are efficient and do not adopt BST may be small.

run analysis. As more farms adopt BST, there will be greater demand for quota, suggesting even higher values. As more inefficient non-adopting farms leave the industry, however, more quota will become available for adopting farms to purchase. This may offset the increased demand to a certain extent. The long-term net effects on quota values are, therefore, uncertain.

As discussed for the short-term implications, BST use may have some effects on other related agricultural sectors. Given the size and importance of the sector relative to other agricultural sectors in western Canada, the long-term effects on beef and crop prices, as well as input markets, is still likely to be minimal. The magnitude of any effects on these sectors will, of course, depend upon the nature of the impacts of BST on the dairy sector (e.g., adoption rate, response rate, resulting structural adjustments, farm numbers).

CHAPTER SIX SUMMARY AND CONCLUSION

6.1 Summary of the Study

6.1.1 Economic Problem, Objectives and Hypotheses

From experiments, BST has been shown to increase milk production by 10 to 25 percent under normal dairy herd conditions and appropriate herd management. This bio-technological development may be attractive for dairy farmers to adopt. However, there are some economic questions yet to be answered regarding BST adoption on dairy farms. The main objective of this study is to examine the effects of BST on representative western Canadian dairy farm operations.

Within this general study objective, there are several specific research objectives. The first of these is to examine whether BST is profitable to adopt, given the environment within which western Canadian dairy farms must operate. The second objective is to model the short-run effects of BST adoption on dairy farms with respect to optimal output levels, herd size, input combinations (e.g., feed and labour use) for the dairy enterprise, and necessary adjustments in other enterprises of the farm. Third, the analysis is designed to assess the impact of BST use on milk quota values. A fourth objective is to assess any impacts that BST may have on milk prices through reductions in production costs. Fifth, given the model results, the likely long-run impacts of BST adoption in terms of structural change in the dairy and related agricultural sectors in western Canada are assessed.

In order to achieve these objectives, farms representative of dairy farms in western Canada are defined for use in the study, using important physical and financial characteristics as the basis for definition. Modelling is conducted through the use of a mathematical model, which is specifically developed for assessing the impacts of BST adoption on the representative dairy farms.

Prior to the modelling, some research hypotheses are made. First of all, it is hypothesized that adoption of BST will increase gross margins for the farm business, which are defined as the main criterion for determining whether or not BST is profitable. It is assumed that BST adopting farms will either produce the same amount of milk with fewer of milk cows, or increase milk production and maintain the initial herd size by purchasing additional milk quota. Regardless of the adoption scenario, it is assumed that farmers will change input combinations for the dairy and cropping enterprises in response to BST use, in order to obtain the maximum level of gross margins. Furthermore, the value of milk quota is hypothesized to increase in either option. Also, BST is hypothesized to have some impacts on milk prices through its effects on dairy production costs. Finally, the structure of the western Canadian dairy sector (i.e., to the number and size of dairy farms, etc.), and related agricultural sectors such as feed markets, livestock markets and labour markets, are hypothesized to be affected by BST availability and adoption in the long-run.

6.1.2 Representative Farm Development and Data Requirements

Two characteristics are used to define the representative dairy farms: herd size and milk production per cow. Three different herd sizes are defined: small (35 milk cows), medium (60 milk cows), and large (95 milk cows). The small and medium herds are further characterized into low and high production cases (i.e., 6500 and 8000 kg. of milk production per cow per year on average, respectively). Average annual milk production per cow for the large herd is assumed to be 7250 kg. In addition, owing to the unique structure of the dairy and other agricultural sectors in B.C., this study does not include B.C. farms in the analysis. The representative farms therefore represent dairy herds in the prairie provinces (i.e., Manitoba, Saskatchewan and Alberta).

The representative farms are unique in terms of labour requirements for dairy and cropping enterprises, types of crops grown, availability of cropland and maximum allowable milk quota allotment. Other farm-level data required for the analysis include operate costs, nutrient requirements and content (for feed), availability of purchased feeds, costs of production for crops, operator and hired labour hours availability, etc. Dairy rations and associated ration costs are endogenously determined within the empirical model. Other data are exogenous to the farms, and include prices of commercial feed, milk prices, milk quota price, livestock prices, selling prices for cash crops, land rental rates, interest rates for debt financing and the discount rate. However, feed rations and costs are endogenously determined in the model.

If BST is used, milk production per cow is assumed to increase by 10 percent annually, or equivalently 14.52 percent daily during the 210 days of treatment. Moreover, adopting farmers are assumed to use BST on all milk cattle in the herd. Annual BST cost is an exogenous variable, and is assumed to be $ 83.16, including the purchasing cost and other related expenses. Changes of feed requirements due to BST use are based on dairy nutrition guidelines, and rations and ration costs are, again, endogenously determined by the model. Labour requirements are increased by between 3 and 4 percent for BST adoption by the representative farms. Since BST adoption does not require changes in capital asset investment for the dairy or cropping enterprises, this investment is assumed to be constant.

6.1.3 The Empirical Model and Analytical Procedures

The empirical model used in the analysis is linear programming. The objective function, which is maximized, is defined as the sum of three-year discounted gross margins, where gross margin is defined as revenue from milk, livestock and cash crops sales less the associated variable production costs for the enterprises. The model constraints define and limit the various activities and relationships for the representative farms, and include ration considerations, crop rotations, labour and land availability and use, crop production use, milk production and sales, etc.

The empirical models are solved for three different scenarios: the base run without BST adoption; BST use assuming no milk quota purchase; and BST use, allowing milk quota to be purchased (only to the extent that the original herd size may be maintained). Effects of BST use on dairy production costs and milk prices in the intermediate-term are also examined. The milk price formula used by milk marketing boards is utilized to calculate the potential milk price changes after BST adoption. In addition, the long-run implications of BST adoption on the western Canadian dairy sector are drawn, based on the short-run results.

6.1.4 Modelling Results

The modelling results for each BST scenario are compared to the base solutions. For the no quota purchase scenario, results indicate that discounted gross margins over the three-year planning horizon increase by an insignificant amount. Gross margins increase in the first year, as farmers would have windfall gains from extra livestock sales. Afterward, numbers of milk cows and the replacements kept in the herd are fewer. Revenue from livestock sales therefore decrease. The gross margin of the farm business after the first year decreases slightly if BST is adopted with no quota purchase. The small herds and the high production herds have slightly better results in terms of gross margins after BST is adopted. Given the increase in the objective function, it is not surprising that implicit quota values increase with BST adoption.

In regard to the dairy rations, the types of feed used in the ration after BST adoption remain unchanged; farm grown alfalfa and barley, and purchased canola meal. However, the relative concentrations of each feed used in dairy rations change in response to adjustments in nutrient requirements. Feed costs for dairy cattle increase on a per cow basis, but decrease in normal operating years after BST is used if considered for the whole herd.

For the no quota purchase scenario, BST use positively affects on cash crop acreage. The reduced herd size results in less land being required for feed production. The net effect is to increase the gross margins from crop sales on the farms. BST adoption also reduces hired labour hours requirements for the farms, again because of reduced livestock numbers.

The results for the quota purchase scenario are significantly different from the no quota purchase scenario. The percentage increases in discounted gross margins are higher than for the no quota purchase scenario. Similar to the results for no quota purchase scenario, however, the small herd and the high production herd display greater percentage increases in gross margins over the three-year planning horizon. Gross margins increase in all years for all farms, relative to the base scenario. Again, quota values increase for most of the farms.

All farms purchase sufficient quota to maintain the initial herd size. Therefore, there are no changes in livestock revenue, relative to the base solutions. However, since the cows are more productive after BST treatment, the production costs for each cow and the whole herd increase. The types of feed used in dairy rations remain unchanged, but the relative shares of each feed in the rations do change.

Given the increased feed requirements and no change in livestock numbers, more of the cropland is required to produce feed crops. This has the effect of reducing the cash crop acreage, more specifically the wheat acreage. Thus, the gross margins from cash crop sales decrease. Finally, labour hiring activities increase for all representative farm cases after BST adoption.

Milk prices are estimated to change by an insignificant amount in the three to five years immediately after BST is introduced to the sector. Given a 20 percent adoption rate, the weighted-average per litre milk production cost for the farm cases would reduce marginally, under either BST scenario. Accordingly, the effects of BST on milk price would be insignificant.

The stability of the solutions with respect to changes in important parameters is tested using sensitivity analysis. The BST solutions are most sensitive to changes in milk prices and purchased feed prices. For the quota purchase scenario, a decrease in milk prices of more than 10 percent would result in the same solutions as for the no quota purchase option; that is a reduction in herd size. Changes in purchased feed prices would affect ration composition.

6.1.5 Short-Term and Long-Term Implications of BST Adoption for Dairy Farms

Although this study is not designed to draw conclusions with respect to sectoral implications or long-term consequences of BST adoption, some conclusions may be made. In the short-run, adopting farms are more likely to maintain current herd sizes and purchase additional milk quota as a result of BST use. However, given the relatively fixed supply of quota, the ability of the farms to do this may be limited. As a result, it is likely that milk quota prices will increase in the short-run. Adoption of BST by a significant number of dairy farms will also have some effects on farm and cow numbers in the dairy sector, although these effects will likely be small.

The long-term implications of BST use may be more significant. Adopting farms may have incentives to expand the herd size in response to improved profitability. The degree to which this may take place cannot be determined from this analysis, however. The likely impact on the dairy sector will be to reduce the number of farms. The average herd size in the sector will be larger than it is at present. Quota values will remain higher than pre-BST levels, but the change relative to the short-term values is uncertain. The impacts on related sectors (e.g., beef, cropping, input markets) are likely to be minor.

6.1.6 Conclusion

BST increases gross margins for dairy farms in the milk quota expansion scenario. Nevertheless, the technology is still profitable to be adopted on dairy farms even without additional quota purchase, in terms of reductions in investment (i.e., opportunity costs). Results indicate that both BST scenarios have unique advantages. Whether farmers decide to adopt the technology may depend on the type of adoption strategy under consideration. Nevertheless, BST impacts on dairy farms and the dairy sector are not significant. Input use is slightly changed, and adjustments in cropping enterprises are small as well.

6.2 Limitations of this Study and Recommendations for Further Study

6.2.1 Limitations of this Study

The first limitation of this study relates to the proportionality assumption for linear programming in modelling milk production. The assumption implies that returns-to-scale are constant throughout the production process. However, milk production from a cow is a not constant returns-to-scale process. A dairy cow has a maximum level of milk production. After this production level is reached, additional use of inputs (e.g., feed and labour) would yield no additional milk production. In this study, the constant returns-to-scale assumption applies to a cow only up to the annual production level.

A second limitation concerns the modelling of dairy ration requirements for the dairy farms. In modelling nutrition requirements, a minimum required level of nutrients and maximum dry matter intake are calculated. Moreover, nutrient composition for available feeds is also obtained from dairy nutrition guidelines. However, dairy farmers seldom follow these nutrition requirements rigorously in practice. They base ration composition on factors such as previous experience. On the other hand, nutrient composition in the feed used for rations on dairy farms is not constant, as assumed, unless farmers are using commercial pre-mixed feed. Feed quality varies significantly, particularly farm grown feed crops, due to the factors such as weather. Feed quality is also highly affected by storage facilities.

Another potentially significant limitation is the assumption of constant prices for milk and milk quota. As discussed earlier, BST adoption may have effects on both these prices. Attempts are made to incorporate these impacts into the analysis. However, the ability to accurately model these effects within this modelling framework is limited.

A final limitation is the short-term nature of the empirical model used in this study. A limiting assumption in this study is that the level of investment in land, buildings and machinery is fixed. Model results suggest that it is optimal for producers to expand their herd sizes beyond the initial levels. However, without considering the additional requirements of capital assets required in conjunction with the herd expansion, it cannot be determined whether this expansion is truly optimal.

6.2.2 Recommendations for Further Study

The first recommendation is a thorough study of the long-run BST impacts to western Canadian dairy sector. This study is designed to assess the short-term effects of BST for dairy farms. The long-run implications of the technology are made from the short-run modelling results. However, whether the adopting farmers decide to reduce the herd size or expand milk sales, there may be adjustments in fixed asset investment associated with the decision. Therefore, further study on the long-term BST impacts is necessary. To examine the impacts thoroughly, a modelling procedure is required that includes fixed asset investments modelling are recommended.

Second, the theory of the firm (multi-output, multi-input) is utilized as the theoretical framework for this study. The theory includes allocable and non-allocable inputs in production. However, risk analysis is not considered in this study. Dairy farming in Canada involves less risk regarding output prices or yields than other agricultural businesses such as crop production, or production of beef or hogs. Output prices of dairy farms are supported by federal and provincial milk agencies through the supply management system. Nevertheless, the dairy enterprise is still exposed some levels of risk. For example, crop yields and livestock prices are uncertain. BST response rate and cost are also uncertain at the present time. Even the future existence of the supply management quota system is uncertain, due to the current trade liberalization in GATT negotiations (Gilson, 1989). Therefore, a study on BST issue including the risk analysis would improve the relevance of the results.

Finally, this study only answers some of the questions concerning BST adoption for dairy farms. There are still some other important questions that need to be considered before BST licence is granted. These include questions such as the attitude of consumers towards BST milk; importing restrictions from other countries on milk from BST-injected cows; and thorough long-term impacts of BST adoption to the structure of the dairy sector.

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Appendix A Setting and Performance of the Western Canadian Dairy Industry

A.1 Canadian Dairy Industry Marketing Institutions[52]

The Canadian dairy industry operates under a system of supply management. In Canada, there are basically two markets for milk production: the fluid milk market (table milk and fresh cream) and the industrial milk market (dairy products such as butter, cheese, yogurt and ice-cream). Each province is responsible for production and regulatory managmement of fluid milk. The federal government has jurisdiction over the industrial milk market.

The milk supply management system is operated through a federal-provincial agreement known as the National Milk Marketing Plan. This plan is regulated by the Canadian Milk Supply Management Committee (CMSMC), which is chaired by the Canadian Dairy Commission. Each year the Committee determines the national milk production target and Market Sharing Quota (MSQ) for both butterfat and industrial milk supplies. The national production target is based on the projected market demand for dairy products in Canada, together with the consideration of dairy product imports (milk equivalent) and estimated volume of butterfat removed from fluid milk. The CMSMC then estimates the provincial shares of the national quota. Each province allocates its respective share of the national quota to individual producers according to its own provincial quota policies.

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[52] The information presented in this discussion is obtained from The Canadian Dairy Commission.

In 1989, the total national market sharing quota was 170.7 million kilograms of butterfat and 47.4 million hectolitres of industrial milk. As a region, western Canada had approximately 17 percent of the national MSQ (Tables A.1 and A.2). Among the four western provinces, Alberta had the highest share of MSQ, 6.6 percent. The other three provinces had between 2.6 and 3.9 percent. However, the MSQ share for the western Canadian dairy sector is relatively small compared to Ontario and Quebec, which have about 31.1 and 47.5 percent, respectively.

A.2 Dairy Institutions in Western Canada

As mentioned before, each province is responsible for regulating production of fluid milk and distribution of the provincial share of the national MSQ. Each province has created an institution to fulfill these functions. In Manitoba, it is the Manitoba Milk Producers' Marketing Board. Saskatchewan has the Milk Control Board, while Alberta has the Milk Control Board. The Milk Control Board in B.C. is in the process of changing to the Milk Marketing Board. Although the names of the institutions are different, their jobs and functions are the same; that is pricing and marketing dairy production, and distributing milk quota among dairy farmers. They also plan promotion and advertising strategies, provide information to local dairy farmers and represent the province in negotiations with the federal Dairy Commission and other provincial milk marketing boards.

A.3 Review of Performance for the Western Canadian Dairy Industry

The volume of milk sold from dairy farms increased during the period of 1978-1988. Table A.3 shows the historical volume for both kinds of milk sold from these farms. Volume of fluid milk sold by dairy farms fluctuated, but industrial milk sales has increased tremendously during these years. For example, Alberta dairy farmers sold 113547 more kilolitres of industrial milk in 1988 than they did in 1978, while Saskatchewan's volume increased by 67918 kilolitre over the same period. The other two western provinces also had impressive increases as well. As the numbers of farms shipping industrial milk decreased in all provinces, this increase in industrial milk supply was caused by fluid milk shipping farms increasingly shipping industrial milk. This fluid increased production was the result of larger herd sizes and/or increases in productivity for cows.

Another important consideration for the western Canadian dairy industry is the net cash receipts for farmers. Table A.4 shows the total net cash receipts and receipts per dairy farm in real terms (1989 dollar). Figures show that dairy farmers in all provinces had higher earnings in the late 1980's than a decade earlier. Net receipts per farm had increased at least $ 24000 within the ten-year period. This increase may be at least partly due to increased productivity per cow.

On the demand side for milk, demand for fluid milk in Western Canada increased slightly between 1975 and 1988. Figures show that total milk consumption in each province fluctuated over these years (Table A.5). Milk consumption per person was also variable (Table A.6).

Table A.1 **Provincial Shares of the National Quota for Butterfat (millions of Kilograms) and milk (millions of hectolitres), 1978-89 by Province**

Year[a]	Item	Eastern Canada	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Total
1978	Butterfat (millions kg.)	7.27	78.92	51.55	6.42	4.28	11.04	5.10	164.58
	Milk (millions kg.)	2.02	21.92	14.32	1.78	1.19	3.07	1.42	45.72
1979	Butterfat (millions kg.)	7.65	82.79	54.07	6.73	4.49	11.58	5.35	172.66
	Milk (millions kg.)	2.12	23.00	15.02	1.87	1.25	3.22	1.49	47.96
1980	Butterfat (millions kg.)	7.81	84.37	55.11	6.66	4.44	11.45	5.45	175.29
	Milk (millions kg.)	2.11	23.44	15.31	1.85	1.23	3.18	1.51	48.69
1981	Butterfat (millions kg.)	7.81	84.37	55.11	6.66	4.44	11.45	5.45	175.29
	Milk (millions kg.)	2.17	23.44	15.31	1.85	1.23	3.18	1.51	48.69
1982	Butterfat (millions kg.)	7.88	84.37	55.11	6.86	4.58	11.81	5.45	176.06
	Milk (millions kg.)	2.19	23.44	15.31	1.91	1.27	3.28	1.51	48.91
1983	Butterfat (millions kg.)	7.56	80.75	52.45	6.66	4.37	11.28	5.20	168.18
	Milk (millions kg.)	2.10	22.43	14.57	1.82	1.21	3.13	1.45	46.72
1984	Butterfat (millions kg.)	7.67	82.23	53.53	6.69	4.46	11.49	5.30	171.38
	Milk (millions kg.)	2.13	22.84	14.87	1.86	1.24	3.19	1.47	47.61
1985	Butterfat (millions kg.)	7.59	81.38	52.97	6.62	4.41	11.37	6.22	170.57
	Milk (millions kg.)	2.11	22.61	14.72	1.84	1.23	3.16	1.73	47.38

Source: Canadian Dairy Commission 1975 to 1990.

Table A.1 - Continued

Year[a]	Item	Eastern Canada	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Total
1986	Butterfat (millions kg.)	7.47	80.05	52.16	6.52	4.34	11.19	6.18	167.91
	Milk (millions kg.)	2.08	22.24	14.49	1.81	1.21	3.11	1.72	46.64
1987	Butterfat (millions kg.)	7.47	79.96	52.24	6.52	4.34	11.19	6.18	167.90
	Milk (millions kg.)	2.08	22.21	14.51	1.81	1.21	3.11	1.72	46.64
1988	Butterfat (millions kg.)	7.40	81.10	53.03	6.61	4.40	11.35	6.25	170.33
	Milk (millions kg.)	2.11	22.53	14.73	1.84	1.22	3.15	1.74	47.32
1989	Butterfat (millions kg.)	7.69	81.07	53.05	6.61	4.40	11.35	6.57	170.75
	Milk (millions kg.)	2.14	22.52	14.74	1.84	1.22	3.15	1.83	47.43

[a] The Canadian Dairy Commission Committee changed its calender year from April 1-March 31 to August 1-July 31 commencing 1979.

Source: Canadian Dairy Commission 1975 to 1990.

Table A.2 Percentage Share of National Market Sharing Quota (MSQ), 1978-89 by province

Year[a]	Eastern Canada	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia
1978	4.4 %	47.9 %	31.3 %	3.9 %	2.6 %	6.7 %	3.1 %
1979	4.4 %	47.9 %	31.3 %	3.8 %	2.6 %	6.7 %	3.1 %
1980	4.5 %	48.1 %	31.4 %	3.8 %	2.5 %	6.7 %	3.1 %
1981	4.5 %	48.1 %	31.4 %	3.8 %	2.5 %	6.7 %	3.1 %
1982	4.5 %	47.9 %	31.3 %	3.9 %	2.6 %	6.7 %	3.1 %
1983	4.5 %	48.0 %	31.2 %	3.9 %	2.6 %	6.7 %	3.1 %
1984	4.5 %	47.9 %	31.2 %	3.9 %	2.6 %	6.7 %	3.1 %
1985	4.5 %	47.7 %	31.1 %	3.9 %	2.6 %	6.7 %	3.7 %
1986	4.6 %	47.6 %	31.1 %	3.9 %	2.6 %	6.7 %	3.7 %
1987	4.5 %	47.6 %	31.1 %	3.9 %	2.6 %	6.7 %	3.7 %
1988	4.5 %	47.6 %	31.1 %	3.9 %	2.6 %	6.7 %	3.7 %
1989	4.5 %	47.5 %	31.1 %	3.9 %	2.6 %	6.6 %	3.8 %

[a] The Canadian Dairy Commission Committee changed its calender year from April 1-March 31 to August 1-July 31 commencing 1979.

Source: Canadian Dairy Commission 1975 to 1990.

Table A.3 **Volume of Milk Sold by western Canadian Dairy Farms (kilolitres), 1978-88 by Province**

	Manitoba		Saskatchewan		Alberta		British Columbia	
Year	Fluid	Industrial	Fluid	Industrial	Fluid	Industrial	Fluid	Industrial
1978	110189	128195	101475	54207	220010	203036	281305	141180
1979	110534	132072	108634	46434	238943	203212	294836	130768
1980	110180	143864	98524	66766	253539	217741	305378	153388
1981	108415	148987	99835	81622	264459	246593	314103	159515
1982	108392	153706	101891	91229	266342	280307	310410	174842
1983	108168	150659	102774	98322	258552	274038	303938	163573
1984	109197	156778	104170	107891	254049	303279	302919	176394
1985	110811	147466	98082	95378	255677	286525	304312	178588
1986	114028	147843	97484	110503	257950	309522	311680	176182
1987	116509	157318	98836	112888	258652	311487	312415	178779
1988	117298	161945	98251	122125	260207	316586	317225	183098

Source: Statistics Canada 1976 to 1990b.

Table A.4 **Total Real (1989) Net Cash Receipts (including Supplementary Payments), less Cream Sales, 1975-89 by provinces ($ 000's)**

Manitoba

Year	Fluid	Industrial	Total	Per Farm[a]	C.P.I.[c]	Target[d]
1975	45239.32	32304.27	94519.66	N/A[b]	58.50	38.85
1976	44772.66	31680.45	91941.18	N/A[b]	62.90	39.70
1977	43291.61	28871.87	83275.41	47.80	67.90	38.20
1978	41637.35	30587.28	86358.59	54.21	73.90	37.30
1979	40245.35	32604.71	86043.37	56.31	80.70	36.37
1980	42197.90	38299.20	91875.51	65.02	88.90	36.69
1981	43821.00	38764.00	92936.00	67.44	100.00	35.70
1982	42351.90	40368.20	91828.52	71.07	110.80	35.75
1983	40046.10	39360.90	88738.05	72.09	117.20	35.32
1984	42162.70	39928.90	91286.99	73.98	122.30	35.30
1985	43129.00	35748.20	85480.72	71.29	127.10	35.13
1986	42654.10	34660.90	85342.15	73.69	132.40	34.50
1987	40866.10	35293.10	84170.04	74.49	138.20	33.50
1988	40328.93	38363.70	86348.40	N/A[b]	143.80	32.70
1989	41015.23	35845.69	83896.69	N/A[b]	151.00	31.17

Saskatchewan

Year	Fluid	Industrial	Total	Per Farm[a]	Skim milk[e]	Butter[f]
1975	37483.76	8413.68	55488.89	N/A[b]	2.41	3.88
1976	35359.30	9869.63	54459.46	N/A[b]	2.38	3.78
1977	37223.85	10480.12	56677.47	59.04	2.27	3.83
1978	38573.75	11855.21	59155.62	59.45	2.21	3.79
1979	43759.60	10520.45	61426.27	62.05	2.22	3.74
1980	37688.40	15632.00	60132.73	66.08	2.22	3.67
1981	34948.00	19512.00	61360.00	62.80	2.20	3.63
1982	33648.00	21866.40	61677.79	70.89	2.22	3.73
1983	33436.00	21412.10	61113.48	70.89	2.23	3.74
1984	34015.50	25152.90	65378.58	78.39	2.24	3.76
1985	32372.90	21887.50	59751.38	71.99	2.24	3.76
1986	38808.20	26842.10	71092.90	86.49	2.21	3.72
1987	37637.50	25212.00	68103.47	90.08	2.16	3.65
1988	35888.00	28702.30	69730.18	N/A[b]	2.09	3.55
1989	34876.82	27337.75	66849.67	N/A[b]	1.99	3.37

a "Per Farm" figure is calculated as the total amount divided by total numbers of dairy farms (as shown in Table 1.1 in Chapter One).

b "N/A" represents data are not available due to no farm numbers being recorded.

c "C.P.I." represents the Consumer Price Index.

d "Target" stands for the target price for industrial milk per hectolitre.

e "Skim milk" is the federal support price for skim milk powder per kilogram.

f "Butter" is the federal support price for butterfat per hectolitre.

Source: Statistics Canada 1976 to 1990b; The Canadian Dairy Commission 1975 to 1990.

Table A.4 - Continued

Alberta

Year	Fluid	Industrial	Total	Per Farm[a]
1975	77312.82	55524.79	161753.85	N/A[b]
1976	82128.78	50459.46	160023.85	N/A[b]
1977	81331.37	52033.87	158568.48	76.19
1978	83280.11	50855.21	158209.74	78.55
1979	89651.79	52691.45	162402.73	81.53
1980	99125.90	60239.60	176926.88	94.01
1981	102318.00	65479.00	185060.00	91.34
1982	106893.50	76194.90	199285.19	105.44
1983	102977.00	71350.70	189883.96	103.14
1984	100433.30	80952.60	197329.52	112.12
1985	97461.00	69232.90	181321.01	106.22
1986	93682.00	72588.40	180528.70	110.89
1987	86034.70	71696.80	171334.29	106.16
1988	86039.60	77702.30	176961.75	N/A[b]
1989	88157.62	77637.69	174323.18	N/A[b]

British Columbia

Year	Fluid	Industrial	Total	Per Farm[a]
1975	124126.49	51572.65	189174.36	N/A[b]
1976	125976.15	45109.69	183635.93	N/A[b]
1977	126749.63	44661.27	185565.53	139.10
1978	127653.59	41443.84	179477.67	140.88
1979	134736.06	45506.82	189040.89	153.69
1980	144480.31	51294.70	204642.29	174.31
1981	142583.00	52942.00	204965.00	173.26
1982	138056.90	57827.60	203706.60	178.53
1983	132235.50	52820.80	185178.33	163.73
1984	129910.90	56623.10	186549.47	170.36
1985	127411.50	57216.40	192412.27	178.16
1986	121034.70	52703.90	182633.69	171.81
1987	115955.10	51352.30	174849.49	164.79
1988	114020.80	51024.30	172374.13	N/A[b]
1989	110768.21	50067.55	167939.08	N/A[b]

a "Per Farm" figure is calculated as the total amount divided by total numbers of dairy farms (as shown in Table 1.1 in Chapter One).

b "N/A" represents data are not available due to no farm numbers being recorded.

c "C.P.I." represents the Consumer Price Index.

d "Target" stands for the target price for industrial milk per hectolitre.

e "Skim milk" is the federal support price for skim milk powder per kilogram.

f "Butter" is the federal support price for butterfat per hectolitre.

Source: Statistics Canada 1976 to 1990b; The Canadian Dairy Commission 1975 to 1990.

Table A.5 **Annual Commercial Milk Sales, 1975-88 by Province (Hectolitres)[a]**

Year	Manitoba	Saskatchewan	Alberta	British Columbia
1975	101690	78766	174014	248919
1976	104425	84047	185719	249645
1977	104669	87333	197844	256252
1978	103823	87932	214711	271100
1979	104499	93296	234322	280816
1980	104748	94887	249444	290229
1981	103274	91512	260032	291897
1982	103286	97227	261849	292324
1983	102915	98632	253577	281414
1984	103332	98335	249414	279710
1985	104543	96894	247551	280584
1986	107839	97983	249586	286313
1987	109811	99308	253838	286536
1988	110467	98672	254011	289628

[a] Milk sales shown here includes homogenized milk, skim milk, 2% milk, chocolate milk and butter milk.

Source: Statistics Canada 1976 to 1990b.

Table A.6 Annual Commercial Milk Sales per person, 1978-88 by Province (litres)[a]

Year	Manitoba	Saskatchewan	Alberta	British Columbia
1975	99.89	85.92	95.90	101.28
1976	101.94	90.47	98.52	100.44
1977	101.60	92.84	101.15	101.40
1978	101.01	92.85	106.06	105.40
1979	102.15	97.64	111.29	106.51
1980	102.35	98.42	113.19	106.79
1981	100.32	93.96	113.61	105.22
1982	99.23	98.77	112.29	104.30
1983	97.93	99.05	108.48	99.31
1984	97.43	97.75	106.62	97.69
1985	97.88	95.95	104.93	97.31
1986	100.35	96.77	105.29	98.43
1987	101.59	98.05	106.58	96.77
1988	102.05	97.94	105.17	95.62

a Figures are calculated as commercial sales of milk per year divided by the population in each province. Population data are taken from Quarterly Demographic Statistics (Statistics Canada 1982 to 1989c).

Table A.7 **Percentage of Total Canadian Population in each Province**

Year	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	Eastern Canada	Total Population (000's)
1980	11.3%	9.1%	4.0%	4.2%	35.6%	26.6%	9.2%	24153.6
1981	11.4%	9.4%	3.9%	4.2%	35.5%	26.4%	9.1%	24413.2
1982	11.4%	9.5%	3.9%	4.2%	35.6%	26.2%	9.1%	24634.1
1983	11.4%	9.4%	4.0%	4.2%	35.7%	26.1%	9.1%	24823.1
1984	11.4%	9.4%	4.0%	4.2%	35.9%	25.9%	9.1%	25015.8
1985	11.4%	9.4%	4.0%	4.2%	36.0%	25.9%	9.0%	25198.3
1986	11.4%	9.3%	4.0%	4.2%	36.2%	25.8%	9.0%	25417.2
1987	11.5%	9.3%	4.0%	4.2%	36.4%	25.7%	8.9%	25714.7
1988	11.6%	9.3%	3.9%	4.2%	36.6%	25.6%	8.8%	26049.3

Source: Statistics Canada, 1982-1989c

Appendix B A Review of BST Effects on Dairy Cows for Short and Long-Term Trials

Table B.1 Effects of Supplemental Somatotropin on Lactating Dairy Cows, Daily Injection for Short-term Trials

References	No. of Cows	Dosage(mg/day)	Starting day Post-postum	Duration (days)	3.5% Fat Corrected (kg/day)	Increases (%)
Machlin et al (1973)	N/A	33	N/A	10	N/A	25
Fronk et al (1953)	N/A	52	N/A	10	N/A	31
Peel et al (1983)	N/A	52	N/A	10	N/A	15
Peel et al (1983)	N/A	52	N/A	10	N/A	31
French et al (1985)	N/A	30	N/A	8	N/A	26
Pennsylvannis State University (1986)	4	0	258	10	20.7	N/A
	4	27.8	258	10	25.1	21.3
University of Pennsylvannis (1987)	4	0	28	70	33.8	N/A
	4	0	28	70	33.5	N/A
	4	50	28	70	36.9	9.2
	4	50	28	70	40.3	20.3

Sources: Bauman and Eppard 1985; Kalter et al. 1985.

Table B.2 **Effects of Supplemental Somatotropin on Lactating Dairy Cows, Daily Injection for Long-Term Trials**

References	No. of Cows	Dosage (mg/days)	Starting Days	Duration (days)	3.5% Fat Corrected (kg/day)	Increases (%)
Bauman (1985)	6	0	74-94	188	27.9	N/A
	6	13.5	74-94	188	34.4	23.3
	6	27.0	74-94	188	38.0	36.2
	6	40.5	74-94	188	39.4	41.2
	6	27.0[a]	74-94	188	32.5	16.5
Hutchison (1986)	6	0	74-94	188	26.0	N/A
	6	13.5	74-94	188	34.0	30.7
	6	27.0	74-94	188	33.0	26.9
	6	40.5	74-94	188	19.2	19.2
	6	27.0[a]	74-94	188	28.0	7.6
Baird (1986)	8	0	28-35	266	25.7	N/A
	8	12.5	28-35	266	30.6	16.4
	8	25.0	28-35	266	30.4	16.5
	8	50.2	28-35	266	30.3	21.1

[a] Using pituitary bovine growth hormone.

Table B.2 - Continued

References	No. of Cows	Dosage (mg/days)	Starting Days	Duration (days)	3.5% Fat Corrected (kg/day)	Incre. (%)
Chalupa (1986)	8	0	28-35	259-266	24.2	N/A
	8	12.5	28-35	259-266	29.9	18.8
	8	25.0	28-35	259-266	29.5	22.6
	8	50.0	28-35	259-266	33.1	31.6
Soderholm (1986)	9	0	29	259	28.5	N/A
	9	12.5	29	259	31.4	10.2
	9	25.0	29	259	37.2	30.5
	9	50.5	29	259	35.3	23.9
Annexstad (1987)	8	0	29	266	29.8	N/A
	8	12.5	29	266	31.6	6.0
	7	25.0	29	266	36.8	23.5
	3	40.0	29	266	40.5	35.9
Elvinger (1987)	9	0	28-35	273	21.1[b]	N/A
	9	6.3	28-35	273	25.5	20.9
	9	12.5	28-35	273	26.5	25.6
	9	25.0	28-35	273	29.3	38.9

[b] Figures indicate kg. of raw milk per day.

Table B.2 - Continued

References	No. of Cows	Dosage (mg/days)	Starting Days	Duration (days)	3.5% Fat Corrected (kg/day)	Increases (%)
Burton (1987)	9	0	28-35	266	26.7	N/A
	10	12.5	28-35	266	30.5	14.2
	10	25.0	28-35	266	31.5	18.0
	9	50.0	28-35	266	30.8	15.4
Thomas (1987)	80[c]	0	28	259	21.1	N/A
		12.5	28	259	24.6	16.6
		25.0	28	259	26.0	23.2
		50.0	28	259	25.6	21.3
Animal and Grassland Research Institute (1988)	80[c]	0	28	259	19.1	N/A
		12.5	28	259	23.6	23.3
		25.0	28	259	23.7	24.1
		50.0	28	259	24.1	26.2
Pennsylvania St. University (1988)	8	0	35	165	31.2[d]	N/A
	8	0	70	130	32.3	N/A
	8	25.0	35	165	36.2	16.0
	8	25.0	70	130	35.9	11.1

[c] Figure represents total number of cows in the trial.
[d] Figure indicates kg. of 4% fat corrected milk.

Table B.2 - Continued

References	No. of Cows	Dosage (mg/days)	Starting Days	Duration (days)	3.5% Fat Corrected (kg.day)	Increases (%)
University of Georgia (1988)	8	0	75	230	22.5	N/A
	8	5.0	75	230	23.1	2.7
	8	10.0	75	230	27.6	22.7
	8	15.0	75	230	28.3	25.7
	8	20.0	75	230	26.7	18.7
DeBoer et al (1989)	36	0	28-35	224	34.0	N/A
	36	10.3	28-35	224	36.5	7.4
	36	20.6	28-35	224	38.0	11.8

Source: Bauman and Eppard 1985; Kalter et al 1985.

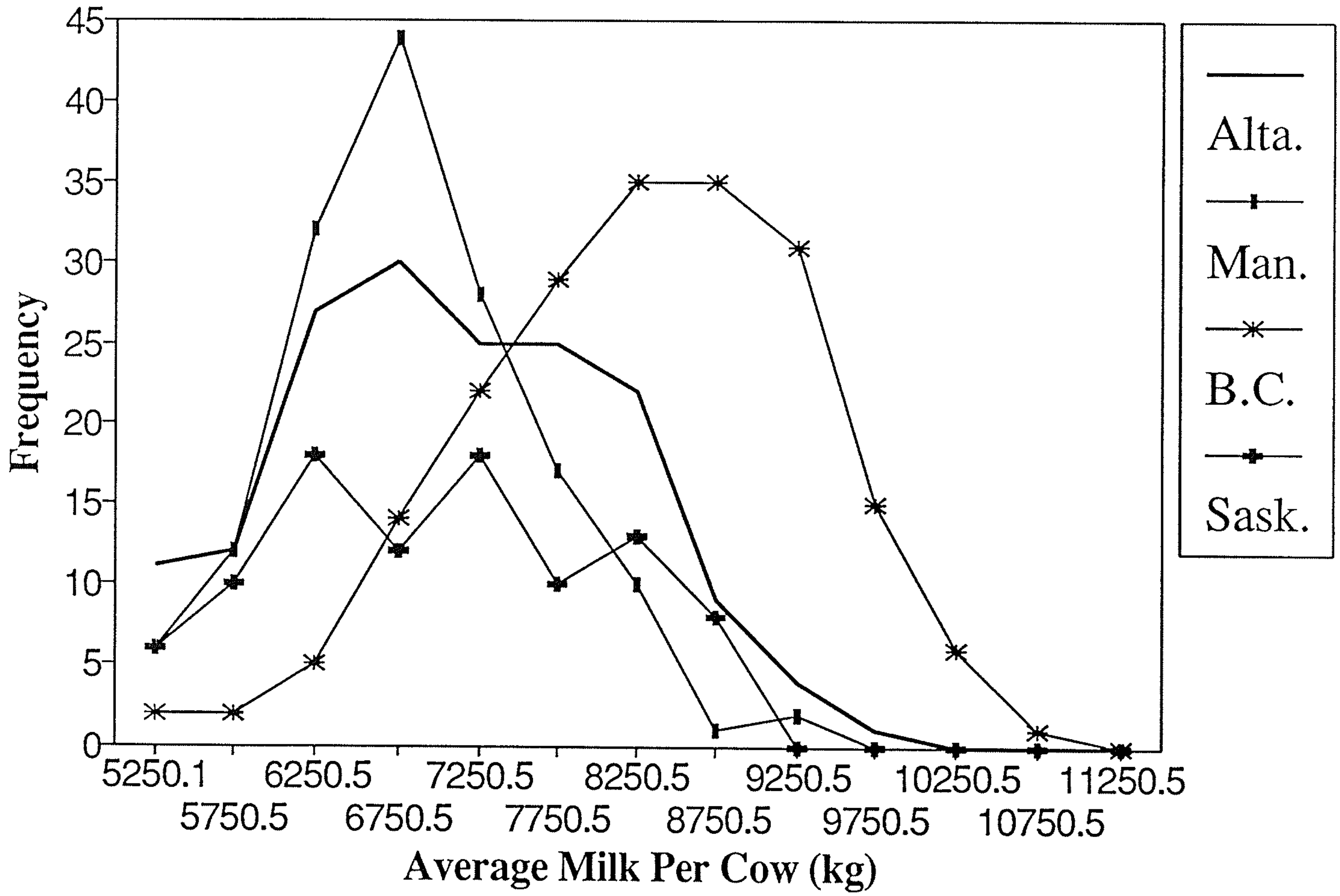
Appendix C Spplementary Information for Representative Farms Classification and Historical Data Used to Estimate Model Coefficients

Table C.1 Percentage Breakdown of Dairy Herds, by Size and Province

Herd Size (Cows)	26-40	51-70	86-105
Farm Numbers	1375	1013	310
Percentage of Total Farm Numbers (%)	29.85	21.99	6.73
Percentage in Each Province (%):			
Manitoba	34.62	20.34	10.65
Saskatchewan	19.27	17.57	11.61
Alberta	29.45	34.85	50.32
British Columbia.	16.65	27.25	27.42

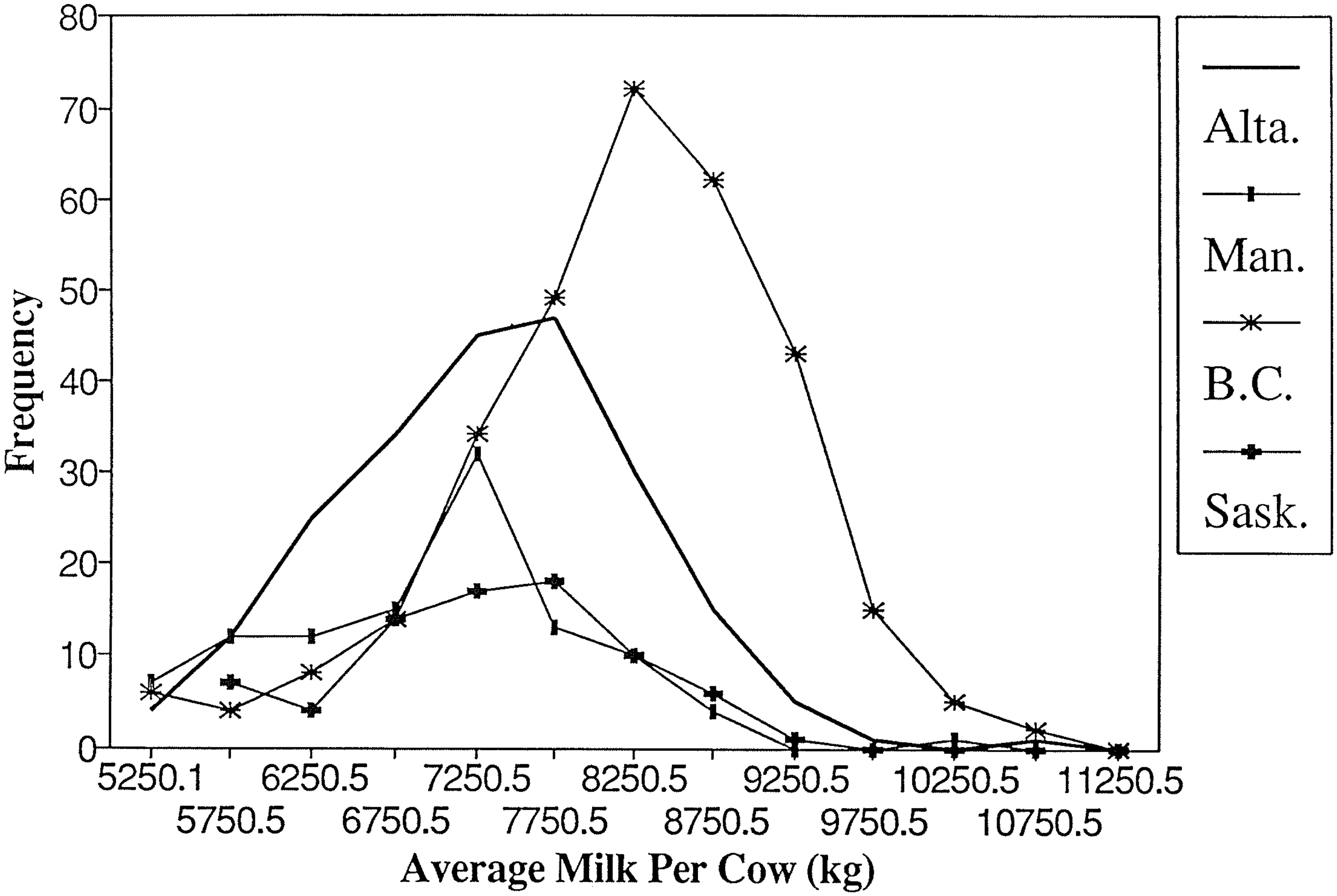
Source: Statistic Canada, 1971-86a.

Figure C.1 Milk Production Frequency Distribution, 26-40 Cow Herd Size by province



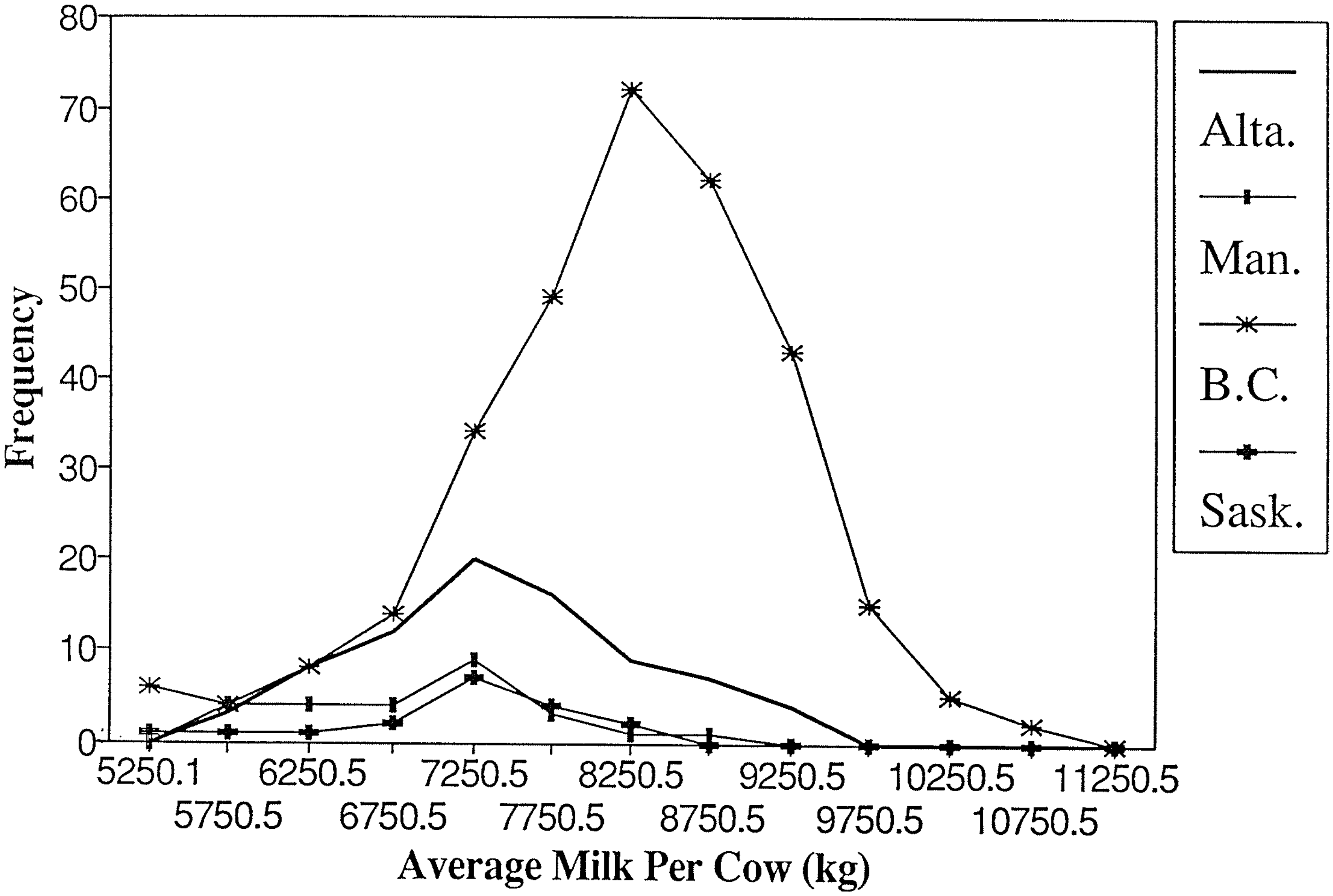
Source: Statistic Canada, 1971-86a.

Figure C.2 Milk Production Frequency Distribution, 51-70 Cow Herd Size by province



Source: Statistic Canada, 1971-86a.

Figure C.3 Milk Production Frequency Distribution, 85-105 Cow Herd Size by province



Source: Statistic Canada, 1971-86a.

Table C.2 **Nutrient Composition of Selected Feeds (as fed basis)[a] and Annual Nutrient Requirements for Dairy Cattle**

Nutrient Composition of Selected Feeds

Nutrient\Feed types	Hay	Barley	F.Barley[a,b]	Oats	F.Oats[a,b]	Wheat	F.Wheat[b]	Soybean	Canola
NE_L (Mcal)	4823.62	1.7072	4589.55	1.5753	3603.09	1.8150	3560.10	1.7266	1.6008
Crude Protein (kg)	643.15	0.1188	319.38	0.1424	270.74	0.1424	279.23	0.3560	0.4441
Calcium (kg)	50.38	0.0004	1.18	0.0006	1.43	0.0004	0.69	0.0027	0.0066
Phosphorus (kg)	7.861	0.0033	8.99	0.0034	7.74	0.0037	7.33	0.0061	0.0105
Dry Matter (kg)	3573.05	0.88	2365.75	0.89	2035.64	0.89	1745.15	0.89	0.92
A. D. F. (kg)[c]	1107.65	0.0616	165.60	0.1424	325.70	0.0712	139.61	0.0890	0
Digest. Energy (kg)	9468.59	3.2560	8753.27	3.0260	6921.19	3.4530	6770.78	3.2930	3.082

a Composition of hay, barley, oats, wheat, canola meal and soybean meal is on a per kilogram. Composition of farm barley, farm oats, farm wheat is on a per hectare of production.

b F. stand for farm grown feed.

c A.D.F. stands for Acid Detergent Fibre.

Source: National Research Council 1988

Table C.2 - Continued

Annual Nutrient Requirements per Animal

Nut. Req't\Prod'n Level	6500 kg	7150 kg[e]	8000 kg	8800 kg	7250 kg	7975 kg[e]	Heifer	Calf
NE_L (Mcal)	9596.55	10130.30	10664.05	11304.55	10130.30	10664.05	N/R	N/R
Crude Protein (kg)	860.20	925.41	990.13	1068.33	925.41	990.13	446.76	192
Calcium (kg)	34.32	36.62	38.92	41.68	36.62	38.92	102.20	6.08
Phorsophus (kg)	22.12	23.54	24.95	26.66	23.54	24.95	7.30	3.84
Dry Matter (kg)	6649.20	6945.58	7207.27	7500.68	6945.58	7207.27	3723	1200
A. D. F. (%)[c]	22	22	22	22	22	22	22	17.5
Digest. Energy (kg)	N/R[d]	N/R	N/R	N/R	N/R	N/R	9774.70	3625.6

[a] Composition of hay, barley, oats, wheat, canola meal and soybean meal is on a per kilogram. Composition of farm barley, farm oats, farm wheat is on a per hectare of production.

[b] F. stand for farm grown feed.

[c] A.D.F. stands for Acid Detergent Fibre.

[d] N/R stands for not required.

[e] The nutrient requirements for 7150 kg and 7975 kg of milk production levels identical to those for 7250 kg and 8000 kg of production levels, respectively, are because of small differences in milk production (i.e., between 7150 kg and 7250 kg, and 7975 kg and 8000 kg) on a daily basis (305 days). Required nutrition to support daily milk production are different by very small amount. The nutrient requirements presented here for the 7150 kg and 7975 kg of milk production levels are based on the requirements for 7250 kg and 8000 kg of production levels, respectively. These requirements slightly above the minimum level (i.e., for 7150 kg and 7975 kg) would not cause significant more feed or higher ration costs than for the minimum levels.

Source: National Research Council 1988

Table C.3 Dairy Machinery And Equipment, by Herd Size

Items\Herd Size	Small	Medium	Large
Milking System	Stall barn milking system, 3 single units & 1 worker with powergate	Parlour milking system, double 6 units, detached powergate	Parlour milking system, double 6 units, detached powergate
Cleaning and Preparation for Milking	2 units Grade A bulk tank	Grade A automatic pipe-washer, hose parlor & pipeline	Grade A automatic pipe-washer, hose parlor & pipeline
Feeding System	Baled hay fed twice a day	Baled hay fed twice a day	Baled hay fed twice a day
	Silage fed by mechanical unloader with cart	Silage fed once a day with unloader to mechanical bunk in upright silos	Silage fed once a day with unloader to mechanical bunk in upright silos
	Grain fed twice a day	Grain fed while the cow is milked	Grain fed while the cow is milked
Waste Handling	Gutter cleaner dry stack	Mechanical scrape stored below the building	Mechanical scrape stored below the building
Bedding the Herd	Baled bedding	All grade A bedding	All grade A bedding
Miscellaneous Machinery & Labour Work	Dairy cattle during dry period are kept in stall	Clean the bulk tank, refreshen the cow for general health, grain grinding at home	Clean the bulk tank, refreshen the cow for general health, grain grinding at home

Source: Fuller 1980.

Table C.4 Cropping Machinery And Equipment For Cereal Grains, Oilseeds and Hay, by Herd Size

Machinery Items\Herd Size	Small	Herd Size Medium	Large
Field Cultivator	100 hp[a], 18 ft	160 hp, 28 ft	250 hp, 50 ft
Grain Drill	60 hp, 16 ft	100 hp, 28 ft	100 hp, 28 ft
Springtooth Drag	75 hp	75 hp	75 hp
Sprayer	40 hp, 30 ft	40 hp, 30 ft	60 hp, 50 ft
Swather	15 ft	20 ft	20 ft
Grain Combine	small size	medium size	medium size
Round Baler	60 hp, 1000 lb	60 hp, 1000 lb	60 hp, 1000 lb
Manure Spreader	100 hp, 225 bu	100 hp, 225 bu	100 hp, 400 bu
Fertilizer Spreader	160 hp	160 hp	160 hp
Rotary Mower/Conditioner	75 hp	75 hp	75 hp
Hydrous Rake	40 hp, 9 ft	40 hp, 9 ft	40 hp, 9 ft
Baled Hay Wagon	40 hp	40 hp	40 hp

[a] hp represent the horsepower. Farms may have more than one machine of the same size.

Source: Fuller et al. 1989.

Table C.5 **Percentages Of Off-farm Work And Hired Labour, by Herd Size**

Items\Herd Size	Small	Medium	Large
Percentage of Farms with Operator Off-Farm Work	12.58	9.48	7.42
Percentage of Farms with Hired Labour	68.53	83.42	80.65

Source: Data are obtained from 1986 Agricultural Census upon requested.

Table C.6 **Owned Cropland and Summerfallow, by Herd Size**

Type of Land	Small	Medium	Large
Average Owned Cropland (ha.)	102.7	163.5	342.8
Average Owned Summerfallow (ha.)	40.1	137.3	237.9
Total	142.8	300.8	580.7

Source: Data are obtained from 1986 Agricultural Census upon requested.

Table C.7 **Farm Product Price Index**

Year\Province	Alberta	Saskatchewan	Manitoba
1981	103.74	110.87	103.07
1982	99.82	103.57	99.21
1983	98.22	101.74	97.45
1984	105.43	107.14	105.00
1985	98.04	98.59	97.19
1986	89.05	82.99	87.80
1987	86.64	77.84	83.49
1988	95.46	94.02	93.24
1989	100	100	100

Source: Manitoba Agriculture, Statistics Branch, 1981-87a and 1988-90b.

Table C.8 Farm Input Price Index

Year	Western Canada
1981	87.64
1982	90.62
1983	90.79
1984	93.08
1985	93.60
1986	94.83
1987	96.06
1988	97.54
1989	100

Source: Manitoba Agriculture, Statistics Branch 1981-87a and 1988-90b.

Table C.9 Historical Cattle Prices ($/100 lb, Adjusted to 1989 dollar base)

Feeder Cows Year	Northern Alberta	Southern Alberta	Saskatchewan	Manitoba	Total
1985	46.27	51.90	48.29	50.13	
1986	53.95	57.36	60.78	59.97	
1987	64.50	65.32	76.93	69.01	
1988	59.17	57.72	61.77	64.97	
1989	59.84	53.94	61.29	59.78	
5 year average	57.25	56.75	61.81	60.77	59.15

Source: Agriculture Canada, Agriculture Development Branch, Livestock Development Division 1985-90.

Table C.9 - Continued

Feeder Heifers Year	Northern Alberta	Southern Alberta	Northern Saskatchewan	Southern Saskatchewan	Manitoba	Total
1985	72.17	75.57	71.77	75.15	71.21	
1986	82.67	89.49	90.42	89.06	80.28	
1987	95.98	102.44	112.41	111.77	96.72	
1988	84.97	91.45	92.38	92.38	83.15	
1989	79.91	87.15	85.85	89.85	81.98	
5 year average	83.14	89.22	90.57	90.84	82.67	87.29

Feeder Veal	Common Grade			Common Grade	Good Butcher	Good Veal	All Grades
Year	Edmonton	Calgary	Winnipeg	Aver. Total	Winnipeg	Winnipeg	Total
1985	60.62	49.72	61.57		74.85	103.01	----
1986	72.68	60.08	68.99		83.64	112.71	----
1987	147.51	----	89.30		109.95	139.37	----
1988	----	----	89.00		107.97	128.88	----
1989	----	----	----		----	110.85	----
5 year average	93.60	54.90	77.22	75.24	94.10	118.96	96.1

Source: Agriculture Canada, Agriculture Development Branch, Livestock Development Division 1985-90.

Table C.10 **Historical Farm-Level Crop Prices (Adjusted $/tonne)[a]**

Year	Spring Wheat	Oats	Barley	Canola
1981	$187.98	$107.78	$118.71	$237.59
1982	$173.80	$98.23	$108.68	$259.17
1983	$168.17	$83.99	$87.33	$249.41
1984	$159.51	$94.85	$107.27	$339.84
1985	$164.04	$107.22	$117.94	$335.37
1986	$163.57	$108.37	$112.58	$295.05
1987	$131.91	$98.55	$82.55	$230.77
1988	$113.70	$108.88	$64.47	$252.34
1989	$169.70	$135.55	$107.09	$276.18
Nine Year Average	$159.15	$104.82	$100.74	$275.08
Fifteen Year Average (1975-89)	$152.47	$84.47	$99.77	$283.77

	Alfalfa Hay		
Year	Manitoba	Saskatchewan	Alberta
1981	58.21	64.94	66.51
1982	55.44	71.45	79.54
1983	56.44	63.89	81.96
1984	59.05	61.60	94.20
1985	64.62	79.12	110.16
1986	69.48	97.60	92.29
1987	53.90	86.07	77.31
1988	84.79	72.33	76.34
1989	52.00	81.00	70.54
9 Year Average	61.55	75.33	83.21
Average of Three Provinces	73.36		

[a] Prices are adjusted using the Saskatchewan Farm Product Price Index to 1989 basis

Source: The Canadian Grain Council 1981-90; Manitoba Agriculture 1981-87a and 1988-90b; Saskatchewan Agriculture and Food 1981-89a; Alberta Agriculture, Statistics Branch 1980-89.

Table C.11 Crop Yields For Selected Regions (tonnes/ha.)

Year	Spring Wheat	Barley	Oats	Alfalfa Hay	Canola
1981	2.20504	2.65542	2.28666	3.91250	1.47310
1982	2.13669	2.64554	2.34676	3.99241	1.33148
1983	2.02723	2.42091	2.17259	4.12533	1.13995
1984	1.66656	2.11963	1.91958	3.71610	1.11548
1985	1.89074	2.26335	2.02400	3.14902	1.22558
1986	2.30667	3.23616	2.72585	4.69333	1.50763
1987	2.04538	3.49407	2.53909	4.25782	1.49556
1988	1.38167	2.68017	2.37978	3.72730	1.20277
1989	1.98756	2.67987	2.19089	4.15663	1.09786
9-year average	1.96084	2.68835	2.28724	3.97005	1.28770

Source: Manitoba Agriculture 1981-87a and 1988-90b; Saskatchewan Agriculture and Food 1981-89a; Alberta Agriculture, Statistics Branch 1980-1989.

Table C.12 Financing Sources For Dairy Farms, by Herd Size

Loan Term\Herd Size	Small	Medium	Large
Short-term	Banks, credit unions	Banks, credit unions	Banks, credit unions
Intermediate-term	Banks, credit unions and supply companies	Banks, credit unions and supply companies	Banks, credit unions and supply companies

Source: Unpublished Survey Report from Farm Credit Corporation, Research and Development Branch 1990.

Table C.13 **Historical Interest Rates for Short and Intermediate Term Financing[a]**

Year	Prime Rate (%)	Five Year Financing Rate (%)
1985	10.50	12.00
1986	10.50	11.25
1987	9.50	11.25
1988	10.75	11.75
1989	13.25	12.00
Five Year Average	11.00	11.65
Rate Used in the Analysis	12.50	13.00

a The interest rate in each year is the simple average of interest rates for each of twelve months.

Source: Bank of Canada, Editorial Board 1985-90; CIBC personnel

Table C.14 **Historical Bond Rate And Consumer Price Index (Used For Calculation Of Discount Rate)**

Year	Corporate Bond Yield (%)	Change in CPI (%)
1984	--	2.89
1985	10.38	4.97
1986	10.16	4.42
1987	10.26	2.64
1988	10.69	3.68
1989	10.85	--
Average	10.46	3.72

Source: Bank of Canada, Editorial Board 1985-90.

Appendix D Supplementary Modelling Results for the Representative Farms

Table D.1 Percentage of Total Crop Acreage Allocated to Individual Crops, Base Solutions (years 2 and 3)

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Hay	38.0	38.0	31.4	31.4	25.4
Barley	5.9	9.5	4.9	7.8	5.0
Wheat	56.0	52.5	38.8	35.8	44.6
Canola	----	----	25	25	25
Percentage of Total Area in Cash Crops	56.0	52.5	63.8	60.8	69.6

Table D.2 Percentage of Total Farm Net Gross Margin Generated by Cropping Enterprises (years 2 and 3)

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Total gross margin from Cash Crops ($)	9252.39	8399.35	31117.64	29551.60	67174.24
Percentage of Total Farm Gross Margin (%)	9.1	6.8	16.7	13.0	19.7

Table D.3 **Interest Expenses for Quota Purchases - Quota Purchase Scenario (13% Interest Rate)**

Herd Size	Small		Medium		Large
Production Level	Low	High	Low	High	
Year 1	$ 1943.76	$ 2393.04	$ 3332.16	$ 4102.80	$ 5887.44
Year 2	$ 1555.01	$ 1914.43	$ 2665.73	$ 3282.24	$ 4709.95
Year 3	$ 1166.26	$ 1435.82	$ 1999.29	$ 2461.68	$ 3532.46
Year 4	$ 777.50	$ 957.22	$ 1332.86	$ 1641.12	$ 2354.98
Year 5	$ 388.75	$ 478.61	$ 666.43	$ 820.56	$ 1177.49
Total for the First Three Years	$ 4665.03	$ 5743.29	$ 7997.19	$ 9846.72	$ 14129.85
Total for Five Years	$ 5831.28	$ 7179.12	$ 9996.48	$ 12308.4	$ 17662.32