CANADA

1/91

Agriculture Canada

Policy Branch

Direction générale des politiques

WORKING PAPER

Canada

[redacted]

BOVINE SOMATOTROPIN AND THE CANADIAN DAIRY INDUSTRY: AN ECONOMIC ANALYSIS

(Working Paper 1/91)

B.K. Stennes[1], R.R. Barichello[2] and J.D. Graham[2]

[1] Research Assistant, Department of Agricultural Economics, University of British Columbia
[2] Associate Professors, Department of Agricultural Economics, University of British Columbia

December 1990

This report was completed under contract with Policy Branch, Agriculture Canada, 1990.

EXECUTIVE SUMMARY

Bovine Somatotropin (BST) is a naturally occurring hormone in dairy cows which affects milk production levels (Chalupa and Galligan, 1988). The effects of BST have been known since the 1930's but limited and costly supplies of this hormone made any large scale commercial use impossible. Recently a low cost source of BST became available through recombinant DNA technology. This low cost availability of the hormone has led to research experiments which show that recombinant BST can significantly increase a cow's ability to produce milk (Peel and Bauman, 1987; Burton et al, 1987; Soderholm et al, 1988; de Boer et al, 1988).

This paper builds upon earlier Canadian studies by examining the impacts of BST at the firm and aggregate industry level, both regionally and nationally. For this analysis a linear programming model of the Canadian dairy industry is used which models the dairy sector for each province. This model is incorporated into the Canadian Regional Agricultural Model (CRAM), (Webber et al, 1986) and includes the production, processing, trade and marketing subsectors.

At the firm level, the main impacts of BST introduction are a fall in marginal costs estimated at $2 per hl and an 18 percent increase in quota values (calculated on the basis of annual rental values), assuming national policy remains as is. While these estimates of firm level changes resulting from BST adoption are not trivial they are much less than would be expected from earlier studies which showed milk yield increases of 25 to 35% accompanied by dry matter feed increases of only 10 to 15 percent (Bauman et al, 1985;

Soderholm et al, 1988).

An issue BST adoption raises for public policy is how the benefits of the innovation, however small, are to be shared. If producers keep the benefits, they enjoy a 5% increase in income. If consumers receive the benefits, their milk prices fall by 4 to 8 percent. If the benefits are channelled to taxpayers, the savings amount to $80 million per year.

In aggregating the firm level impacts to the national industry level, four different scenarios are examined with reference to a no-BST base case situation (1986). These scenarios represent alternative government policy responses to BST introduction, corresponding to these different methods of sharing the benefits of BST.

The first scenario examined represents a "no price change" situation, passing the benefits of BST on to milk producers. Provincial quota levels, producer prices, levies and subsidies all remain unchanged. Adoption rates are assumed by province. In order to maintain existing milk production levels a 5% reduction in the national cow herd would be required. This reduction in cow numbers results in a 5% increase in dairy sector gross margins at the national level.

In the second scenario the impact of BST on quota values is examined. As in the first scenario all dairy policy instruments remain at 1986 base levels. The decrease in marginal costs for a producer who fully adopts BST is then estimated. Using a marginal cost estimate of $32 per hl, the fall in marginal cost is nearly 6% or $2.00 per hl, on average, for Canada. This results in an 18% increase in what these producers could afford to pay for quota. The use of lower marginal cost estimates would result in a greater percentage decrease in marginal costs and a smaller percentage increase in quota values arising from the introduction of BST.

In scenario 3 the benefits of BST adoption are passed on to consumers. Production levels are expanded such that the difference between the farm-gate price and the marginal cost of producing milk (ie, the supply price) remains the same as prior to the introduction of BST. Quota values remain at their base case level. This results in a 2% increase in the national supply of raw milk. In the fluid milk market the supply of standard milk increases by 2% and lowfat milk production increases by approximately 3 percent. In the industrial market cheese production increases by 6%, butter production increases by 2% and skim milk powder production falls by approximately 4 percent.

In the final scenario the benefits of BST adoption are passed on to the taxpayers. This is accomplished by reducing the dairy subsidy by an amount which just offsets the cost savings in each province as a result of BST adoption. This leads to a decrease in the dairy subsidy of $80 million at the national level or approximately 30% of the 1986 subsidy payment.

Finally, it should also be noted that this study assumes consumers do not differentiate between milk produced with and without the use of BST. Furthermore, this study does not deal with other social and economic issues related to the licensing of BST for commercial use.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

The agricultural industry worldwide has been dominated by rapid technological changes of many types for more than 50 years with the effect of dramatically increasing productive capacity (Weersink and Tauer, 1989). One of the more recent developments, the commercial introduction of BST (bovine Somatotropin), has potentially important implications for the dairy industry. Recent advancements in biotechnology have led to a low cost method of synthesizing this key hormone in the lactation cycle of dairy cattle, this allows a dairy cow to more efficiently utilize feed energy for milk production (Shaver and Nytes, 1987).

This study will examine the potential impacts of introducing this new product on the highly regulated Canadian dairy industry. The main emphasis will be on the provincial and national effects of introducing BST. Impacts on the production, processing, trade and marketing aspects of the Canadian dairy industry are examined, and several different scenarios representing alternative policy options are evaluated. These scenarios differ by passing the benefits of BST adoption onto either producers, consumers or taxpayers.

1.1 Background

BST is a naturally occurring protein in dairy cattle, released from the anterior pituitary gland, which affects the production of milk in a cow throughout the lactation cycle. This natural secretion of BST in lactating dairy cows is positively correlated with milk output at different stages of the lactation (Hart et al, 1980; Bines and Hart, 1982). When exogenous BST is subcutaneously injected into dairy cows the result is a significant increase in milk yields (Peel and Bauman, 1987; Burton et al, 1987; Soderholm et al, 1988; de Boer et al, 1988).

BST controls the partitioning of nutrients between tissue synthesis and milk synthesis. By doing so it increases the gross lactational efficiency (milk per unit energy consumed) of a dairy cow (Bauman et al, 1985). As the animal's nutrient requirements are partitioned, a higher proportion of the feed consumed goes toward the production of milk (Chalupa and Galligan, 1988). This increased ability to partition nutrients towards milk synthesis is also present in genetically superior cows (Bauman et al, 1985, Peel and Bauman, 1987).

Initially, when BST is injected into a dairy cow, the nutrients required for increases in milk yields are provided by body stores of fatty acids, proteins and glycogen (Chalupa and Galligan, 1988). After this initial phase in which the cow is in a negative energy position, feed uptake must be increased to maintain the higher milk yields.

The effects of BST were first discovered in the 1930's when crude extracts from the pituitary glands of slaughtered dairy cattle were injected into cows (Shaver and Nytes, 1987). In 1937 Asimov and Krouze discovered that increases in milk yields were possible with the injection of this crude form of BST into dairy cows. Until recently these pituitary extracts remained the only source of the hormone. This research was difficult and expensive because pituitary glands from approximately 200 cattle are required to produce enough BST for a single animals daily injection (Trelawny, 1986).

In the early 1980's recombinant DNA technology provided a lower cost source of this hormone. Using bacteria as hosts and introducing the gene responsible for BST production this technology has led to large scale synthesis of BST. The first experiments with this recombinantly derived BST were conducted in 1982. These experiments resulted in milk yield increases similar to earlier studies using pituitary BST (Bauman et al, 1982). Several, large, private sector chemical companies have become interested in the commercial potential of this hormone (Kalter et al, 1985).

Previous Canadian economic studies on BST have shown this product to be profitable at the firm level. Trelawny (1986) found increases of between 5 and 15% in short term net returns; excluding the cost of the drug. Tabi and Stonehouse (1988) found that dairy enterprise profitability would be increased for all 3 different representative farms in their model. Oxley et al (1989) calculated an average decrease in marginal cost of 8% with the introduction of BST to the Ontario dairy industry. Based on their assumption of no change in milk prices this would imply an increase in dairy enterprise profitability as well.

1.2 Dairy Policy Setting

The dairy industry has experienced the effects of technological advancements perhaps more than any other sector of the modern agricultural industry. Increasing yields per cow, changes in feeding regimes, and labour-saving innovations such as milking parlours have resulted in capital intensive, large scale, dairy operations and steadily falling producer numbers. These changes have resulted from many different advancements such as bulk milk handling systems, high-tech closely monitored feeding systems, rigid breeding programs accelerated by artificial insemination and embryo transplantation.

These technological advancements were partially responsible for the surpluses and low prices of milk in the late 1950s and early 1960s. Relatively low prices and depressed producer incomes led to the introduction of the Canadian Dairy Commission Act in 1966 (Lavigne and Biggs, 1985). As a result the dairy industry has been effectively split into two separate markets, the industrial milk market under the jurisdiction of the federal Canadian Dairy Commission (CDC), and the provincially controlled fluid market.

The fluid (fresh) milk market is under provincial control with internal pricing and quota levels controlled by provincial marketing boards (Barichello, 1987). The markets are spatially isolated with no significant movements, interprovincially or internationally. Any milk produced under fluid quota but surplus to the fluid market requirements is diverted to industrial uses, but this may require adequate industrial milk quota (MSQ) in some provinces.

Industrial milk or cream is used in the production of manufactured dairy products such as cheese, butter, skim milk powder, yogurt and many others. The industrial market is supplied by producers holding market share quota (MSQ), who may or may not also hold fluid quota. MSQ is allocated to each province by the Canadian Milk Supply Management Committee (CMSMC). Incentives to produce over quota are removed through the use of a large levy on over quota milk deliveries by industrial producers.

Support prices for butter and skim milk powder (SMP) are set by the CDC. Butter and SMP that processors cannot sell on the domestic market at or above the support price are purchased by the CDC. The support price is operative at the wholesale level, so it incorporates a processors' margin which is set by the CDC. The combination of these support prices and the processing margin effectively sets the minimum farm gate price for industrial milk.

The support prices for butter and SMP are set to balance the national supply and demand for butterfat (Short and Côté, 1986). However, the support price for SMP is well above the level that would allow the domestic market to "clear", leading to a surplus in the solid nonfat (SNF) constituents of milk. Residual SNF goes largely into SMP which is surplus to domestic demand and is exported. Because world prices of skim milk powder are often well below this support price, disposal on the world market usually entails a loss to the CDC which is financed through a levy on MSQ producers.

This policy setting is important to this study as any changes in the farm cost structure resulting from the introduction of BST could possibly impact upon it's functioning and it's structure. Any substantial increase in production would have to be marketed and hence both the fluid and industrial markets would be affected.

1.3 Problem and Objectives

BST is different from many past products and innovations which have been introduced to the dairy industry. An immediate yield response is possible and this combined with low capital requirements make this technology commercially attractive to producers in the dairy industry. However, a new technology such as this, which has been used only in research settings, raises a great deal of uncertainty both for farm managers and for national policy makers.

At the aggregate level there is uncertainty about the 'best' policy response to an expected lowering of industry marginal costs. Should producers be allowed to capture all of these rents through increases in the value of quota? Alternatively, some of the benefits could be passed onto consumers by allowing an expansion in quota levels associated with lower milk and dairy product prices. Taxpayers could also capture some of the benefit through reductions in the industrial milk subsidy to offset the benefit to the industry from the introduction of this product. These are important questions facing the industry and those that set policy for the industry. One of the first issues to be addressed when a new product enters an industry is acceptance by existing producers. In order to establish aggregate level impacts of BST some insight into the economics of technology adoption must be gained. The proportion of farms which adopt BST is as important as the firm-level effects in determining industry-level results. It is likely that there will be a group of producers who will not find BST profitable because there is a high degree of managerial ability required to realize the efficiency gains related to BST. Producers with greater managerial and technical skills may view this as an opportunity to expand production profitably with given overhead structures. Both groups of farmers face uncertainty about the impacts of BST adoption on their own costs, product prices, quota values and consumer acceptance issues.

If milk yield increases due to BST do in fact lower unit costs, adoption with fixed quotas and price levels will increase milk profitability and quota values. Some measure of the expected increase in the value of quota is necessary if the impacts of BST on potential entrants to the dairy sector and existing producers looking to expand the scale of their operations are to be analyzed.

Consumer groups have also expressed concern about the effect of BST on dairy products. The possible movement of consumers away from dairy products is a real concern to the entire industry and will dictate whether BST is eventually licensed for commercial use. Although the issue of consumer acceptance and licensing are critical, they are not addressed in this study which assumes BST is licensed and has no impact on consumer demand.

If U.S. producers were to adopt BST and those in Canada did not, this would further increase the difference in dairy product prices between these two countries. This may increase cross-border purchases of dairy products, reduce domestic demand, and perhaps elicit further criticism by consumer lobby groups. This is another issue not addressed directly in this study, but can have implications in regions such as the Fraser Valley in British Columbia.

The major objective of this study is to assess the potential impacts of introducing BST to the Canadian dairy industry and examining a number of different policy responses. This is an analysis at both the national and provincial levels which includes an examination of changes in the production, processing and marketing sectors. To accomplish this several sub-objectives are stated:

1. research data is assessed related to increases in both milk yields and feed concentrate requirements associated with the use of this technology at the firm level to determine the resultant drop in unit cost;

2. the number of farmers who will adopt this technology, by region for Canada is estimated;

3. the aggregate output effects of this technology on the Canadian dairy industry with the current policy structure is measured; and

4. several different government policy options that may be followed by the industry are examined and conclusions reached based upon the results of this analysis.

1.4 Research Procedure

In order to achieve these given objectives the following research procedure has been followed:

1. Experimental data from a full lactation study on the effects of using recombinantly derived BST from the University of British Columbia Research Farm, Oyster River will be analyzed (de Boer et al, 1988). Average changes in concentrate feed utilization and milk production levels between a group of control animals and cows receiving daily injections of 20.3 mg BST will be estimated based on this data. These animals are at different stages of maturity ranging from first lactation heifers to mature cows in their final lactation. These data together with that from other studies provide the basis for firm level changes expected with the adoption of BST.

2. A review of theory on the adoption of technology and discussion with industry experts has provides a basis on which to make assumptions about the adoption rates of BST, by province, in Canada. Yield, feed use and cost coefficients are modified to reflect regional variation in estimated adoption rates.

3. In order to establish impacts of this adoption at the national and provincial levels an existing national level dairy model developed by Short and Cote (1986) is modified. The original model had fixed national supplies of fluid and industrial milk, a single national level processing subsector and national level demands for several final dairy products. This model is expanded to a provincial level model and updated to a 1986 base year. This dairy processing and marketing model is then incorporated into the Canadian Regional Agricultural Model (CRAM), (Webber et al, 1986). CRAM already has provincial level dairy production activities to supply milk to the new provincial processing and marketing subsectors. Trade links are added to transport industrial products interprovincially and internationally.

4. Four scenarios representing three different government policy options and a base case are analyzed. The first scenario involved no policy changes. The second scenario assesses the impact on quota values if the current policy remains unchanged. The final two scenarios pass the benefits associated with BST adoption on to other groups: consumers and taxpayers.

1.5 Report Outline

The second chapter outlines theory relevant to this analysis, including firm level effects of a new technology, a discussion of the economic theory concerning technology adoption, and finally a theoretical model of a supply controlled industry with a shifting supply curve.

The third chapter presents the data used in this study from the results (de Boer et al, 1988) of an experiment at the University of British Columbia Research Farm at Oyster River. The assumptions on the cost of BST and the adoption rates to be used in this study are also presented.

Chapter 4 details the dairy model in CRAM, including data relevant to this study and the format of certain files.

The fifth chapter details the scenarios to be examined in this study and the results of this analysis are noted. These scenarios are compared to a 1986 base year. Finally, chapter 6 presents the summary and conclusions of this study. Policy implications are discussed along with the limitations of the study and recommendations for further research.

Chapter 2

THEORETICAL CONSIDERATIONS

The purpose of this chapter is to examine economic theory on the adoption and impact of new technology. Basic production economics at the firm level will be reviewed and combined with the economics of technology adoption. Adoption rates at the firm level based on this theory are then used to examine industry level effects of the adoption of a new technology by the firms in that industry.

2.1 Related Studies

A large number of biological studies on the effects of BST on milk yields and feed requirements of dairy cattle have been undertaken. For example, Bauman et al (1985) reported an experiment with both pituitary and recombinantly derived BST. With 20.6 mg per day of BST, milk yields increased 16% with the pituitary derived BST and by 36% with the recombinantly derived BST. Net energy intake for the recombinantly derived BST group was 16% greater than for a control group. Burton et al (1987) with a 25 mg per day dosage over 266 days had a yield increase of 18% combined with an increase in dry matter uptake of 5%. Soderholm et al (1988) had a yield increase of 25% with a group of cows receiving 20.6 mg per day while dry matter uptake increased by 10% over the control group. de Boer et al (1988) had an overall increase in milk yields for a group of dairy cows and first lactation heifers of 11.8% with an increase in the uptake of feed concentrates (not dry matter uptake) of 12.5%. This study used a much larger sample size with 35 control animals and 37 receiving the 20.6 mg per day dose of BST (the next largest of the studies mentioned had 10 cows per group). These studies show that BST significantly increases a cow's milk yields and this is accompanied by an increase in feed intake. However, feed consumption in most of these studies increases by less than milk yields on a percentage basis.

There have been three economic studies in Canada on the effect of BST. Trelawny (1986) measured changes in variable returns from BST on three different types of dairy farms categorized by different levels of capital and management inputs. The short-term net farm returns from adoption, excluding the cost of administering the hormone, ranged between 5 and 15% depending on the combination of farm resources and yield response. These results suggested that BST use would not favour either small, medium or large farms but would favour a manager with superior feeding skills.

Tabi and Stonehouse (1988) estimated the impacts of BST on the amount a farmer could afford to pay for quota for three categories of farms. The main result is that the amount farmers could pay for additional quota would increase between 8 and 29% depending on the type of quota (fluid or MSQ) and the farm's level of technology. Likewise, Oxley et al (1989) attempted to measure the impacts of BST on quota values for dairy producers in Ontario. The rental value of quota was found to increase by 23 percent. BST also resulted in a 5% decrease in the number of dairy producers.

An aggregate level analysis on the impacts of BST on the US dairy industry by Fallert et al (1987) examined the changes in cow numbers, milk prices, production, product use government expenditures, by region, under different scenarios representing different support prices to the industry. The main finding of this study was that under each of the scenarios increases in revenues exceeded the cost increases associated with BST. The regional location of milk production and the relative size of farms did not change as a result of BST adoption. The number of dairy farms in the U.S. would decrease as a result of BST.

2.2 Production Effects of BST

The principal effect of BST is to increase the technical efficiency of a dairy cow's milk production through an improvement in the animals feed:milk conversion ratio. As outlined in the previous section, most previous studies estimate that the consumption of feed increases proportionally less than the increases in milk yields. The study by de Boer et al (1988), with a large sample group, determined that the increase in the "concentrate" portion of an animal's total feed intake is as great as the increase in milk production. If BST does in fact increase an animals feed:milk conversion ratio the increase in forage consumed will be proportionally less than milk production increases.

The effect of this new technology on milk production per cow is hypothesized in Figure 2.1. Holding other factors constant, more milk can be produced for a given level of total feed inputs, or a given increase in milk can be achieved with a smaller increase in total feed input (forages and concentrates). Prior to the adoption of BST the output level y_1^0 is produced using x^0 units of feed. After BST is adopted x^1 units of feed produce y_2^1 units output at the profit maximizing point. The production function has thus shifted upwards as a result of this new technology.

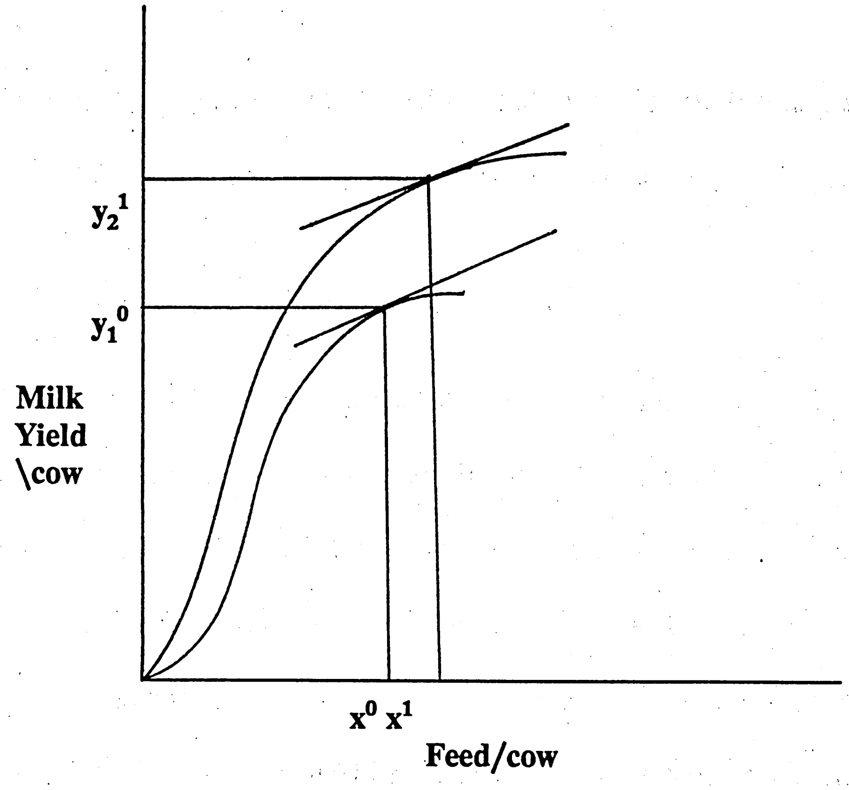

Figure 2.1: Effect of BST Adoption on Milk Production Function, Input/Output Price Ratio Constant

Analogous to maximizing profit, the firm can minimize cost subject to a given level of output. The effect of introducing BST is illustrated in factor space (Figure 2.2). Prior to the new technology the icocost line A^0B^0, representing the price ratio line of two factors $(- px_2 / px_1)$, is tangent to the isoquant y_1^0 at point A. The marginal rate of substitution (dx_1 / dx_2) between feed (x_1) and other factors (x_2) given as $- (\partial y / \partial x_2) / (\partial y / \partial x_1)$ is equal to the ratio of the prices of the two factors $(- px_2 / px_1)$. At this point x_1^0 units of feed and x_2^0 units of the other factor represent the minimum cost combination to produce a given output level, (y_1^0) which would also be the profit maximizing level of output from Figure 2.1 given factor and product prices remain constant.

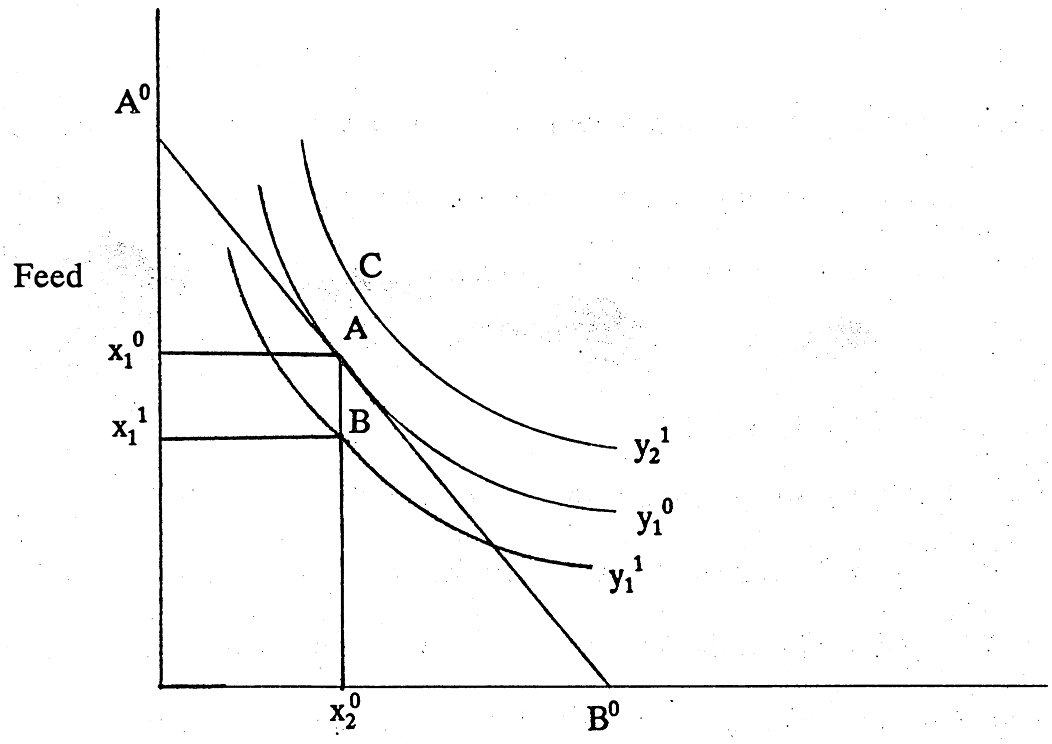

Figure 2.2: Effect of BST Adoption in Two Factor Space, Herd Size Constant

The effect of introducing BST, shifting out the production possibility frontier, is to shift y_1^0 toward the origin to y_1^1. The new cost minimizing point to produce output y_1^0 is B. To produce the previous level of output, less of both x_1 (feed) and x_2 is used (assuming factor prices remain constant), equivalent to point B in Figure 2.1. However, point B is the optimal point of production only if farmers are constrained by non-tradeable output quotas. This current production level could be maintained using smaller herd sizes and less of all other inputs (although herd feed levels would fall the least).

However, in maximizing profits at given prices, farmers would want to increase production from point B to point C in Figure 2.1 (or equivalently minimize cost on y_2^1 in Figure 2.2). Point C lies on a higher isoquant that did not exist prior to the introduction of BST, and it features higher output levels and some new combination of x_1 and x_2 which will minimize cost (maximize profits) given p_1 and p_2. With tradeable quotas imposed, as in the case in most of Canada, adopting farms would expand by buying more quota, while non-adopters would find it more profitable to sell quota and eventually leave the industry.

2.3 The Economics of Technology Adoption

A key assumption in this study concerns the rate of adoption of BST by dairy farms and the impact of adoption on the dairy sectors in each province. Previous Canadian studies have addressed the effects of BST at the firm level. However, to analyze regional effects some attention to farm-level adoption in various regions in Canada is important.

It was suggested by Mansfield (1968) that a firm's probability of accepting a new technology is a function of the firm's size, the proportion of firms in the industry already using it, the profitability of the technology and the size of investment required. Coombs et al (1987), referring to the "epidemic" model of diffusion, suggested these same explanatory variables, but added variables relating to management quality and rate of industry growth.

The adoption of a new technology by an industry over time is referred to in the literature as the diffusion process. The generally accepted shape of a new technology's adoption by an industry is a sigmoid curve (Waterson, 1984; Coombs et al, 1987) as shown in Figure 2.3. Adoption is generally quite slow as a product first enters an industry. As more producers use the product and have success with it the rate of diffusion enters the take-off stage, the very steep portion of the curves in Figure 2.3. This rate slows as adoption reaches the point of maximum diffusion given as the level A, which may or may not represent 100% of producers in the industry.

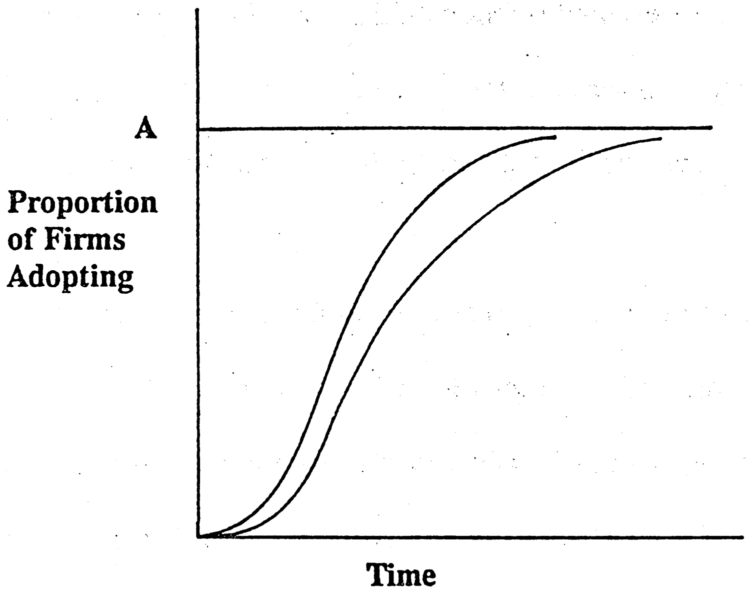

Figure 2.3: Sigmoid Curve Representing the Diffusion Process of a New Technology into an Industry

For this study level A in Figure 2.3 is critical. This represents the maximum adoption for the new technology over the long run. In theory, if the benefits associated with a new technology are greater than the costs for all firms, the proportion of firms adopting this technology will equal 100 percent. In the dairy industry with BST, the level A, needs to be estimated. There is a high degree of managerial skill required to make use of BST profitable. Hence, it is hypothesized that some segment of the industry would not adopt BST, at least in the medium term. Assumptions concerning adoption rates for this study will be further detailed in chapter three.

2.4 Industry Level Effects of BST Introduction

The effects of a new technology which lowers the cost of production (thus shifting the industry supply curve to the right) are reasonably straightforward in a competitive industry.

The industry would expand production levels, and prices would fall until a new equilibrium is reached where the new supply curve intersects the demand curve. For those milk products with inelastic demand, consumers would capture the bulk of the benefits through lower milk product prices.

Under supply management with production limited by quotas, the dairy industry is expected to increase net returns by using BST through a lowering of unit costs. The use of BST allows for increases in economic efficiency by allowing more output to be produced from a given valued bundle of inputs. This implies a lower marginal cost at all output levels and assumes the cost savings are not all dissipated through the administrative pricing mechanism.

The introduction of this new technology into a supply managed industry, assuming no change in consumer preferences[1], is shown in Figure 2.4. Prior to the new technology the supply curve is S^0, the demand curve D and the quota level is set at Q. The farm-gate price for the product will be 0a with a supply price[2] equal to Ob. This implies profits equal to the area of the rectangle abef. The marginal benefit from an extra unit of quota is the distance ab. Assuming a competitive market for quota this will be the annual rental value of a unit of quota.

[1] If consumers decrease their consumption of milk as a result of BST this would result in a downward shift in the milk demand curve. This would negatively affect the profit function having an offsetting affect on the cost savings associated with BST.

[2] Where supply price is equivalent to marginal cost at the final unit of output.

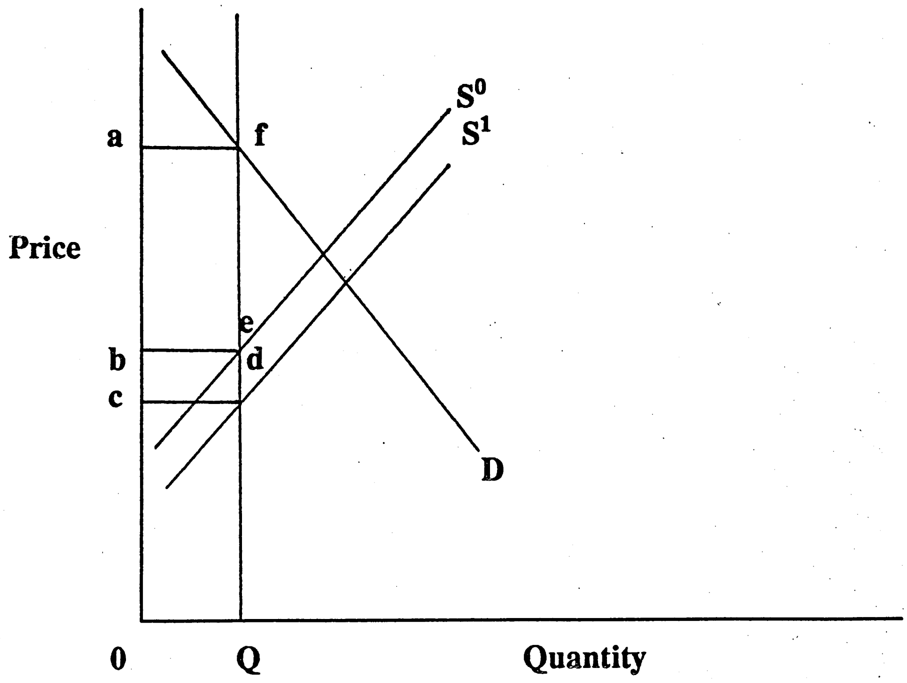

Figure 2.4: Effect of a New Technology Entering a Supply Managed Industry, No effect on Demand

With the introduction of the new technology the supply curve shifts down to S^1. If Q and price are held constant by policy (exogenous), the supply price falls from Ob to Oc. The result of this is an increase in profits equal to the area bcde. The marginal value of an extra unit of quota will now have increased to ac.

If a supply managed industry acted as a profit maximizing monopolist, quota levels (Q) will be set such that MR = MC, at Q^0 in Figure 2.5. With a downward shifting supply curve the new profit maximizing output level will involve an increase in Q (to Q^1) and a decrease in farm-gate price from P^0 to P^1. Even if the institutional framework inhibited such profit maximizing behaviour, pressures to move in this direction are predicted by this model if Q^0 is less than the quantity determined by equating MR to MC.

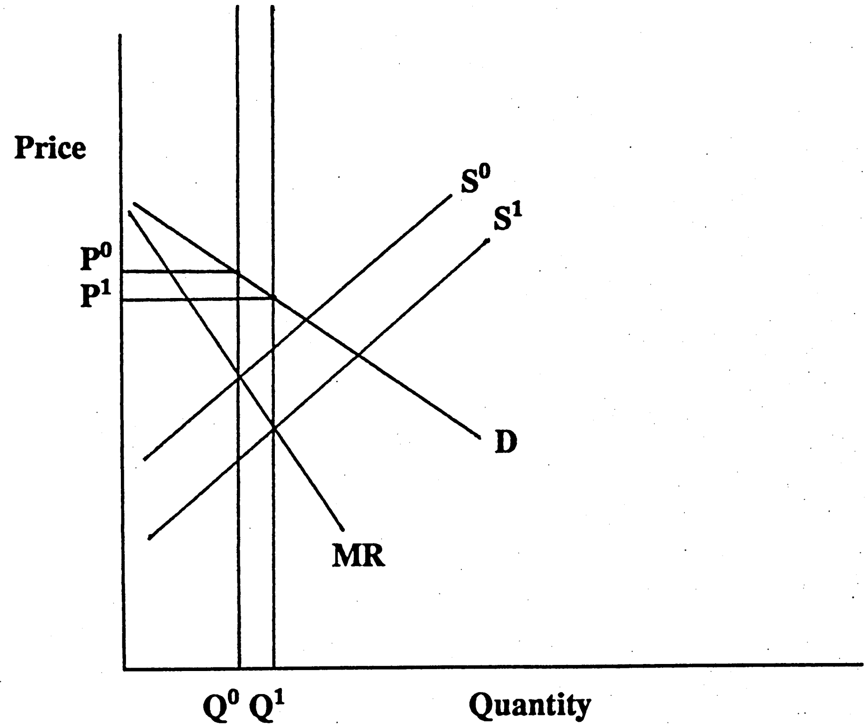

Figure 2.5: Monopoly Industries Profit Maximizing Points Before and After the Introduction of a New Technology

2.5 Summary

This chapter has presented economic theory explaining the firm and industry-level effects of the introduction of a new technology, and how it would affect a supply managed industry.

There have been a number of technical studies on the biological effects of BST showing significant increases in a cow's milk yield. Most firm-level economic studies in Canada show BST's benefits to outweigh its costs. The main conclusion from the firm-level studies is that it would be profitable for most producers to adopt BST in Canada. Net farm returns would increase and this increases the amount farmers would be willing to pay for additional quota. There have been few industry level studies on the impacts of BST adoption, and none for the Canadian dairy industry.

Chapter 3

IMPACT OF ADOPTING BST ON FARM PERFORMANCE

This chapter will present data specific to BST to be used in this study. This includes a description of a BST research experiment conducted at the University of British Columbia Research Farm (de Boer et al, 1988) which provides biological data on milk yield and feed use changes with this product. Assumptions regarding the cost of BST and the costs of additional dairy feed concentrate requirements are also detailed. Rates of adoption assumed for each province in this study are also discussed.

3.1 Oyster River Experiment

Data on changes in milk yield and the intake of feed concentrates used in this study for dairy cattle injected with BST were obtained from research results of an experiment conducted at the University of British Columbia Research Farm, Oyster River. This study by de Boer and Kennelly is based on research by Shelford, Peterson and Holbek of University of British Columbia.

Data for this experiment covered 108 Holstein cows, over a complete lactation, comprising of 79 mature cows and 29 heifers. These animals were assigned to one of three different treatment categories. The control consisted of 35 animals which received injections of 2 ml sterile saline per day. The low dosage category consisted of 37 animals receiving 10.3 mg per day of recombinantly derived BST in 1 ml sterile saline. The high dosage category received 20.6 mg of the BST per day in 2 ml sterile saline and contained 36 animals. Injections began at between the 28th and 35th day of lactation and continued for 266 days.

Feed concentrates were fed via a computer feeding system. Cows producing in excess of 28 kg of milk per day were fed 1 kg of concentrate per 2.5 kg of milk produced. Lower yielding cows received 1 kg of concentrate per 3 kg of milk produced. The concentrate ration consisted of 40% barley, 30% mill run, 21% canola meal balanced with salts and minerals. All of the cows in this experiment received the same ration.

Forage consisted of hay, grass and corn silage, and pasture. Forage was freely available to all cows and no measurement of the amount consumed was taken.

Cows were milked twice per day and the milk yields for each animal were recorded. The milk composition including fat content, lactose and somatic cells, were analyzed for two consecutive milkings each week. This data on the milk yield along with the consumption of feed concentrates were averaged for each four week period. Also recorded, on a per animal basis, were the body weights and body condition scores.

The Oyster River experiment began with 108 cows but this number fell to 102 as six cows had early health problems. These health problems were not necessarily associated with BST. Data from these six animals were not included in the results on milk yields and feed consumption but were included in the results pertaining to health and reproduction.

Summary results on milk yield and feed use changes are given in Table 3.1. Heifers showed very little change in either feed intake or milk yields with either the low dosage or high dosage levels of BST. With the lower dosage of 10.3 mg per day BST, and increases in concentrate feeds of approximately 11%, mature cows showed increases in milk yields of

11 percent. With 20.6 mg per day and increases in concentrates fed of approximately 18% milk yields were 18% higher.

Table 3.1: Results from Oyster River on Concentrate Feed Uptake and Milk Yield Changes Using BST, kg/day

	Concentrate Feed Level Dose of BST (mg/day)			Milk Yields Dose of BST (mg/day)		
	0	10.3	20.6	0	10.3	20.6
	(---------- kg/day ----------)			(---------- kg/day ----------)		
Cows	14.2	15.8	16.8	35.4	39.3	41.7
Heifers	12.2	12.3	11.7	29.9	30.5	28.6
Total	13.6	14.7 (8.1)[a/]	15.3 (12.5)	34.0	36.5 (7.4)	38.0 (11.8)

Source: de Boer et al, 1988
[a/] % changes from control group in parenthesis

Overall, for the mixed herd, including both cows and heifers, milk yields were 7.4% greater with daily injections of 10.3 mg BST and 11.8% greater with 20.6 mg per day. Concentrate feed increases with BST were 8.1% greater with the low dosage group over the control and 12.5% greater with the high dose category for the mixed herd. The composition of the milk did not change across the three groups.

Table 3.2 shows that body weights and condition scores were not significantly changed by either dose of BST. The overall average body weight was 3 kg less with the low dosage and 2 kg less with the high dosage. Condition scores were also nearly identical between the groups.

Table 3.2: Results from Oyster River on Body Weight and Condition Scores for Cows Using BST

	Body Weight (kg) Dose of BST (mg/day)			Condition Score Dose of BST (mg/day)		
	0	10.3	20.6	0	10.3	20.6
Cows	632	633	641	3.1	3.1	3.1
Heifers	549	549	526	3.0	3.0	2.9
Total	611	608	609	3.1	3.0	3.0

Source: de Boer et al, 1988

There were no noticeable changes in reproductive performance or in the health of cows treated with BST in the Oyster River experiment during this single lactation period. Likewise, the weights of calves born to cows treated with either dose of BST were not different than those born to the control group.

Results from the Oyster River experiment used in this study include the changes in milk yields and concentrate feed consumption between the control group and the 20.6 mg per day BST treatment group. This higher dosage of BST is the closest to the optimal found in clinical trials of 25 mg per day (Oxley et al, 1989).

The Oyster River experiment differs from previous studies primarily in the size of the different groups receiving BST. The average number of animals in the previous Canadian studies was from 8 to 12 per group. The Oyster River study also used a mixed herd of both mature cows and heifers. Careful attention was paid not to overmanage the Oyster River herd, thus simulating more closely actual commercial conditions. This adds to the credibility of the results when attempting to utilize them to model dairy producers in the industry. The herd at Oyster River is a high yielding herd compared to commercial dairy herds or even other Canadian experimental herds.

3.2 Cost of BST

Another difficult question with a new technology is at what level the pharmaceutical companies will price BST. The assumption about the cost of BST used in this study is similar to that used by Tabi and Stonehouse (1988). The cost of BST is based on a Cornell study which indicated the production costs to the pharmaceutical companies for the hormone to be equivalent to a range of $0.06 to $0.15 US per cow per day depending on the scale of production (Kalter et al, 1985). Using the upper end of this cost scale results in a BST cost of approximately $50.00 CDN per cow per year. The upper end of this production cost range is used in this study to include any additional charges for marketing, distribution and manufacturers profit.

3.3 Adoption Rates

In attempting to measure the aggregate level economic effects of a new technology on an industry an assumption is required on the rate of adoption by existing producers. With BST this is difficult as there are no previous data on the commercial acceptance of this product. Survey studies in New York State (Kalter et al, 1985) and California (Zepada, 1989) yield some information but as in all surveys they are subject to error. The New York survey showed a willingness by producers to try BST of 66% in 1 year and 85% over 5 years.

The California study found 43% of producers polled would not be willing to try BST.

Table 3.3 outlines the adoption levels selected for this study, based on the studies mentioned in the previous paragraph, discussion with industry experts and a review of the literature. As previously outlined in chapter 2 the rate of adoption for a new technology is generally a function of a firm's size, the profitability of the technology, the proportion of firms who have already adopted it, the level of investment required and other variables (Mansfield, 1968; Coombs et al, 1987). Available data which are useful for developing assumptions on rates of adoption are average provincial yields and the distribution of farm herd sizes within each province. Two sets of adoption levels are calculated, one based on each of these criteria. The choice of two different measurements reduces the significance of the regional differences based on a single criteria and reduces the risk of reporting unreasonable results based on a single assumption.

The first set of adoption levels outlined in Table 3.3 are based on average provincial milk yields (Criterion A). These yields are used as a proxy for dairy farm profitability. Based on personal communication with specialists in the industry, the rates chosen for B.C. were as follows: 75% for large farms (> 77 cows), 65% for medium size (48 - 77 cows) and 55% for small operations (< 48 cows). Based on weights for the proportion of cows in each category an overall adoption level of 68% for B.C. dairy farms resulted. Farms with under 18 cows are not included in these calculations.

The B.C. dairy industry is characterized by having both the largest average herd size and the highest average yields per cow of any of the provinces. It is therefore assumed that B.C. would have the highest provincial adoption level. The level for the other provinces are adjusted downwards with criterion A based on the percentage that their yields are lower than yields in British Columbia.

The second set of adoption levels in Table 3.3 (criterion B), is based on provincial farm herd size distributions. Categories for herd size are the same as for criterion A with the large farms having an adoption level of 65%, medium size farms 55% and the small farms 45%. These levels are held constant across each province and multiplied by the proportion of animals in each classification.

Using the first criterion the adoption levels ranged from a low of 33% in Saskatchewan to a high of 68% in British Columbia. The national average adoption level is 48%. Under criterion B the lowest rate is in Quebec at 49% and up to 58% in British Columbia. This results in a national average of 52%.

These assumed levels represent a medium term time horizon implying that over five years dairy farmers will adopt this new technology up to these levels. The results presented in chapter 5 are sensitive to these chosen adoption rates and should be interpreted within this context.

Table 3.3: Projected Levels of Adoption for BST, by Province Based on Average Yields (Criterion A) and Herd Size (Criterion B)

Province	Large	Medium	Small	Total
	(------------------- % --------------------)			
British Columbia				
Criterion A	75	65	55	68.4
Criterion B	65	55	45	58
Alberta				
Criterion A	52.5	42.5	32.5	45.1
Criterion B	65	55	45	58
Saskatchewan				
Criterion A	43.5	33.5	23.5	32.8
Criterion B	65	55	43	54
Manitoba				
Criterion A	51	41	31	38.2
Criterion B	65	55	43	52
Ontario				
Criterion A	63.5	53.5	43.5	49.9
Criterion B	65	55	43	51
Quebec				
Criterion A	62.5	52.5	42.5	46.2
Criterion B	65	55	43	49
Maritimes				
Criterion A	64	54	44	54.3
Criterion B	65	55	45	55
Canada				
Criterion A	60.9	51.4	41.8	48.1
Criterion B	65	55	45	52.0

3.4 Summary

In summary, this chapter has presented information on a large full lactational experiment on the use of BST on dairy cows. The biological data specific to BST, the assumed cost of BST and the rates of adoption assumed for each province are presented. In interpreting these results, it should be noted that the feeding regime was not altered in response to BST introduction, so the feeding levels may not be fully optimized. Nevertheless, it was still clear that BST increased milk yields significantly.

Chapter 4

THE EMPIRICAL MODEL

The purpose of this chapter is to detail the empirical model developed in this study. This begins with an overview of the Canadian Regional Agricultural Model (CRAM) followed by more detail on the production, processing, shipping and demand subsectors of the dairy sector in this model. A more complete description of the conceptual dairy model in CRAM is presented in the Appendix.

4.1 Overview of CRAM

CRAM is a regional-level mathematical programming model of the Canadian agricultural industry (Webber et al, 1986). The major production activities and final demands, linked by transportation between regions and with the rest of the world, are all modelled making CRAM a sector-wide model. It is a single period model with the original base year 1984, updated to a 1986 base.

Briefly, the CRAM modelling system (Graham et al, 1989) is composed of:

1) A set of data files that contain regional specific resource, production and demand information;

2) A fortran matrix generator which has the flexibility of generating linear programming matrices with different structures depending on the nature of the problem being tackled;

3) An optimizing or simulating feature;

4) A report writer that helps to interpret output; and

5) A set of spreadsheets that generate the comparative static information that is reported.

The underlying strength of the model is the specification of production responses at the regional level and the linking of output with provincial demand and world markets through a transportation matrix.

The model represents Canada's agricultural sector with 29 crop regions producing wheat (4 grades), barley and other coarse grains, flax, canola, corn, soybeans, hay, pasture and "other crops". Livestock production is modelled at the provincial level for beef, dairy, hogs and poultry. Shipments of livestock, livestock products and grains occur to meet provincial demand levels, with excess domestic demand or supply being met by import or export activities. Demand for beef, pork and grains are endogenized using stepped functions. Opening inventories of livestock are adjusted through incorporation of retention functions responding to own price, feed grain price and other effects. Trade requires that export and import prices be established; a domestic floor and ceiling price is specified. A small country assumption is adopted which means that Canadian trade will not affect world prices. Additional features of the model are summarized as follows:

Model Characteristics:

- Static, spatial, partial equilibrium linear programming model focused upon the major agricultural sectors.
- Contains 5 major geographical levels - national; east and west; provincial (combining the Maritime provinces); crop region, and export or shipping points.
- Contains 29 crop regions - 22 in the Prairies and one for each of the remaining provinces.

- Grains, oilseeds, dairy, beef, pork, eggs,and poultry are included. Fruit and vegetables are excluded.

- Fairly detailed production input relationships are included in the model, allowing examination of both the direct and indirect effects of changes in government policy.

- Unit costs, opening grain stocks, livestock inventories, and certain import and export levels are exogenously specified.

- Models supply and demand relationships for all major commodities.

- Uses elasticities of supply and demand, based on the literature, which represent the expected responsiveness of supply/demand to price changes.

- Shipments of livestock, livestock products and grains occur to meet provincial demand levels, with excess demand/supply met by import/export activities.

- Trade activities respond to export and import prices, specified in the model as domestic floor and ceiling prices.

- The model assumes Canadian trade will not affect world or North American prices.

The Crop Block:

- Crops modelled include wheat (4 grades), barley (including other coarse grains), flax, canola, corn, soybeans, hay, pasture and other crops.

- The model permits choice among the various crops, given the constraints of soil and climate on yield.

- Choice also occurs between grain crops, hay, pasture and fallow (using a set of fallow ratios).

- Crop rotations are very important, since yields will vary when planted on fallow vs. stubble. Crops are grown in 29 geographic regions, differentiated primarily by soil and climatic zones.

- Crops produced in these regions are transferred to the provincial level to meet the demand for livestock feed and domestic consumption, or transferred to port for export.

The Livestock Block:

- Beef, pork and dairy production activities are modelled in detail, while the poultry sector is modelled as single activities for each of broiler, egg and turkey production.

- Feed sources include stored forage, pasture and barley for beef and dairy animals; barley for hogs; and wheat for poultry. Protein supplement feeding is not accounted for at this time. Grain input substitution is possible.

- Opening stocks, input requirements (including diet and cash costs), and replacement ratios are all specified to determine yield, closing stocks and price.

- Livestock inventories, prices and government payments are set at 1986 levels, and the demand functions are calibrated to replicate prices and consumption in that year.

- Livestock inventory retention functions specified are based on econometrically estimated relationships.

Government Programs:

- Programs explicitly modelled are:
  - Western Grain Stabilization Act
  - Agricultural Stabilization Act
  - Crop Insurance
  - Federal and Provincial Red Meat Stabilization Programs
  - Two Price Wheat Program
  - Input Subsidies
  - Special Canadian Grains Program
  - Western Grains Transportation Act
  - Dairy levies and subsidies
  - Feed Freight Assistance

- Expected payouts under each of the various programs are used to supplement market returns.

- The benefits of supply management for the dairy and poultry sectors are captured.

- The model assumes farmers view government payments as equivalent to market receipts.

This section has given a brief outline of the CRAM model. In the next section the dairy subsector of the CRAM model will be discussed in much more detail, including the production, processing, trade and demand subsectors.

4.2 Dairy Sector in CRAM - Conceptual

The general structure of the dairy industry model, as specified in CRAM, is based on the approach followed by Short and Côté (1986). Their model balanced butterfat (FAT) and solid-not-fat (SNF) from milk supplies with the demand for these milk components as specified by national level demand functions for dairy products. It was a national level model and assumed supplies of fresh milk, industrial milk and industrial cream were fixed.

In the dairy sector of CRAM, milk is supplied from a provincial level production subsector, given the opening stock of dairy cows in each province. Milk produced is shipped to provincial dairy processing subsectors where it is divided between the fluid and industrial markets. Balance equations similar to those used by Short and Côté split the raw milk into FAT and SNF which is used to manufacture seven final dairy products: whole milk, low fat milk, creams, cheese, skim milk powder, butter, and other dairy products. The processed products then move through to the demand subsector, net of any interprovincial or international trade.

4.3 Matrix Coefficients

The following section of this chapter outlines the matrix coefficients in the dairy sector of CRAM. The basic format is the same as in section 4.2 detailing the data for the production, processing, trade and demand subsectors of the CRAM model.

4.3.1 Dairy Production Subsector

Provincial herd sizes and the average yields per cow assumed in this analysis are presented in Table 4.1. The yields are derived by dividing the provincial production (including industrial cream) by the number of dairy cows to arrive at a provincial average. The dairy herd also includes dairy calves. Cash costs and use of barley, pasture, and forage as well as the yields of beef as a byproduct associated with the dairy sector are presented in Table 4.2. These data form the coefficients or right hand sides of activities and rows associated with production activities in each of the provinces.

Table 4.1: Provincial Dairy Herd Sizes, Supplies of Raw Milk and Yields, 1986

	Dairy Cow[a] Numbers (000'head)	Replacement[a] Heifers (000'head)	Milk[b] Produced (000'hl)	Yield/cow (hl)
British Columbia	83	30	4,888	58.89
Alberta	130	44	5,897	45.36
Saskatchewan	59	16	2,244	38.03
Manitoba	71	27	2,913	41.03
Ontario	503	244	24,387	48.48
Quebec	615	251	28,401	46.18
Maritimes	86	36	4,320	50.00
Canada	1,547	648	73,050	47.21

Source: a/ Statistics Canada, Cat. No. 23-008, Nov. 1988
b/ Dairy Farmers of Canada, 1987

Table 4.2: Feed Use and Cash Costs for Provincial Dairy Production Regions, Per Animal, 1986

Province	Category	Cash Cost ($)	Barley (bu)	Forage (tons)	Pasture (tons)	Fed Beef	D Beef	Veal
B.C.	Cows	1398[a]	44.09	1.42	0.58	0	576.3	0
	Replacements	270	16.70	0.88	0.44	513.7	0	0
	Heifer Calves	100	8.35	0.33	0.33	513.7	0	0
	Veal Calves	100	20.90	0	0	0	0	169.2
Alta.	Cows	1249	30.00	1.59	0.80	0	547.0	0
	Replacements	239	16.70	1.19	0.60	533.8	0	0
	Heifer Calves	100	8.35	0.33	0.33	533.8	0	0
	Veal Calves	100	20.90	0	0	0	0	151.1
Sask.	Cows	1063	21.30	1.81	0.91	0	554.3	0
	Replacements	253	16.70	1.37	0.56	516.0	0	0
	Heifer Calves	100	8.35	0.33	0.33	516.0	0	0
	Veal Calves	100	20.90	0	0	0	0	149.5
Man.	Cows	987	27.60	1.59	0.80	0	532.0	0
	Replacements	253	16.70	1.19	0.60	515.1	0	0
	Heifer Calves	100	8.35	0.33	0.33	515.1	0	0
	Veal Calves	100	20.90	0	0	0	0	0
Ont.	Cows	1149	33.70	1.55	0.78	0	553.7	0
	Replacements	251	16.70	1.16	0.58	551.8	0	0
	Heifer Calves	100	8.30	0.33	0.33	551.8	0	0
	Veal Calves	100	20.90	0	0	0	0	202.0
Que.	Cows	1096	33.20	1.48	0.74	0	513.2	0
	Replacements	234	16.70	1.10	0.55	524.3	0	0
	Heifer Calves	100	8.35	0.33	0.33	524.3	0	0
	Veal Calves	50	15.00	0	0	0	0	110.8
Mar.	Cows	1356	39.01	1.33	0.66	0	531.7	0
	Replacements	238	16.70	1.00	0.50	500.9	0	0
	Heifer Calves	100	8.35	0.33	0.33	500.9	0	0
	Veal Calves	50	15.00	0	0	0	0	118.9

Source: CRAM data base, 1987

a/ This coefficient includes the cost of the mill run and meal portions of dairy ration (Canadian Livestock Feed Board Prices)

4.3.2 Dairy Processing Subsector

The coefficients used in the dairy processing subsector are categorized into three sets: ratios for the split of milk into fluid and industrial; a set dealing with the different subsidies and levies; and, information for the processing of milk into final dairy products (FAT and SNF contents, processing margins, etc.) . Three data files are used to specify these values for each provincial processing subsector. The breakdown of raw milk into the fluid and industrial milk supplies is given in Table 4.3.

In 1986 Canada produced a total of 73.05 million hectolitres of milk which was commercially sold (Dairy Farmers of Canada, 1987). Of this total production approximately 36% was produced for the fluid (fresh) milk market. The balance, 64%, was produced for the manufacturing of industrial milk products.

At the centre of the dairy processing model as defined by Short and Côté are the four balance equations for FAT and SNF in the fluid and industrial markets. The provincial level balance equations in this study are somewhat modified versions having fewer processed products and a single "sink" product known as other dairy products to nationally balance FAT and SNF.

1. Fluid Market:FAT

$$-3.6\ FLM + TRAN + 3.604\ STRD + 1.956\ LFAT + 15.72\ FCRM \leq 0$$

2. Fluid Market:SNF

$$-8.6\ FLM + 8.52\ STRD + 8.719\ LFAT + 6.142\ FCRM \leq 0$$

Table 4.3: Breakdown of Total Farm Supplies of Milk into Fluid and Industrial, by Province, 1986

Province	Total Milk Sales	Fluid Milk Sales	Industrial Milk Sales	Industrial Cream Sales	Ratio of Fluid/ Industrial	Ratio of Production/ Industrial Cream
	(----- 000'hl -----)					
B.C.	4,888	3,119	1,760	10	1.77	488.8
Alberta	5,897	2,577	3,096	224	0.83	26.33
Sask.	2,244	976	1,106	164	0.88	13.68
Manitoba	2,913	1,139	1,477	294	0.77	9.91
Ontario	24,387	9,950	13,462	951	0.74	25.64
Quebec	28,401	6,873	21,528	0	0.32	0
Maritimes	4,150	2,002	1,960	188	1.02	22.07
Canada	73,050	26,636	44,389	1,831	0.60	39.90

Source: Dairy Farmers of Canada, 1987.

3. Industrial Market:FAT

-3.6 INDM - 3.6OQM - 3.6 INDC + .871 CHZ + .82 BTR

+ .007 SMP + .2250 TDP ≤ 0

4. Industrial Market:SNF

-8.6 FLM - 8.6OQM - .669 INDC + .871 CHZ + .126 BTR

+ .965 SMP + .78 OTDP ≤ 0

where:

FLM	=	Fluid Milk	(thous hl)
INDM	=	Industrial Milk	(thous hl)
0QM	=	Over Quota Milk	(thous hl)
INDC	=	Industrial Cream	(thous hl)
TRAN	=	Skim Off Fat Transfers	(tonnes)
STRD	=	Standard Milk	(thous hl)
LFAT	=	Low Fat Milk	(thous hl)
FCRM	=	Fluid Cream	(thous hl)
CHZ	=	Cheese	(tonnes)
BTR	=	Butter	(tonnes)
SMP	=	Skim Milk Powder	(tonnes)
OTDP	=	Other Dairy Products	(tonnes)

The coefficients used in these balance equations are the same as those used by Short and Cote with the exception of the butterfat coefficient on industrial milk which is changed from 3.7 tonnes butterfat per hectolitre to 3.6, and the coefficients on Other Dairy Products as in its current form it did not exist in Short and Côté's national level model.

The subsidy on butterfat for industrial milk and cream along with the skim-off levy for fluid milk, the in-quota levy on industrial milk and the over-quota levy are given in Table 4.4.

The final set of coefficients used in the dairy processing subsector are those associated with marketing margins on the different processed dairy products. For fluid products the only available prices were at the retail level so the margins are farm gate-retail margins. Wholesale prices are available for industrial market products so farm gate-wholesale margins are used. These margins, as well as farm gate values and retail/wholesale prices, are given in Table 4.5.

Table 4.4: Subsidies and Levies Associated with Canadian Dairy Program, 1986

Province	Butterfat[a/] Subsidy	Skim-Off Levy	In-Quota Levy	Over-Quota Levy
	(------ $/hl ------)			
B.C.	5.77	0.30	5.13	38.00
Alberta	5.69	0.30	5.13	38.00
Sask.	5.68	0.30	5.13	38.00
Manitoba	5.99	0.30	5.13	38.00
Ontario	5.95	0.30	5.13	38.00
Quebec	6.09	0.30	5.13	38.00
Maritimes	6.70	0.30	5.13	38.00

Source: The Dairy Review, Statistics Canada, January 1987, except, [a/] Maryse Côté, Commodity Coordination, Dairy Unit, Agriculture Canada

Table 4.5: Farm Gate Values, Retail or Wholesale Prices and Marketing Margins for Processed Dairy Products Used in CRAM, 1986

Produce	Farm Value	Price[a/]	Marketing[b/] Margin
Fluid Market			
Standard Milk	50.45	98.13	47.68
Low fat Milk	42.64	98.13	55.49
Cream	104.47	247.10	142.63
Industrial Market			
Cheese	3.90	5.05	1.15
Butter	4.57	4.97	0.40
Skim Milk Powder	2.46	2.95	0.49

Source: Prices from FARM data base.

a/ Retail price for fluid market products, wholesale price for industrial market products.

b/ Farm gate-Retail margin for fluid market products, farm gate-wholesale margin for industrial market products.

The farm gate values for these products are based on the shadow prices of FAT and SNF resulting from the current dairy program. Butter and skim-milk powder are essentially joint products of milk. The CDC guarantees a price to processors on these two products through an offer-to-purchase program. A processing margin (per hectolitre of milk) is also negotiated between the CDC and the processors. The value of the skim milk powder and butter which can be manufactured from a hectolitre of milk less the processors' margin is taken as the farm gate value (prior to subsidies and levies) of industrial milk is. This system is shown in Figure 4.1.

This is based on the assumption that when milk is processed into these joint products, 30 percent of the processing costs go to butter production and 70 percent to skim milk powder production. The farm gate value of these two products can then be calculated. The calculations are shown below:

1) 1 hl milk yields 4.32 kg butter

2) (.3)(5.76) = 1.728 of assumed processors margin to butter,
and 1.728/4.32 = 0.40;

3) 1 hl milk yields 8.24 kg skim milk powder

4) (.7)(5.76) = 4.032 of assumed processors margin to skim milk powder, and 4.032/8.24 = 0.49.

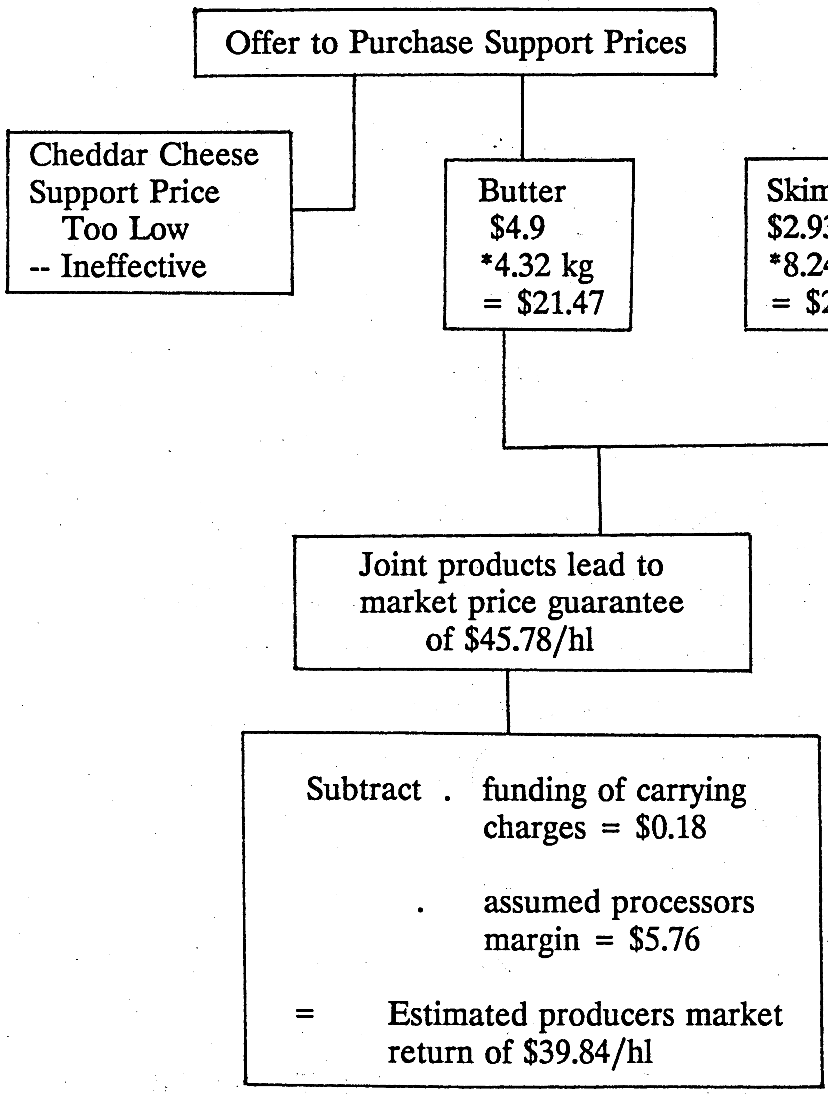

Figure 4.1: Calculation of Producers Market Return Based on Offer to Purchase Scheme by CDC Prior to Subsidy and Levy Adjustments.

Source: Prices, Farm Model Database, 1986.
Based on Table 26, Dairy Facts and Figures at a Glance, Dairy Farmers of Canada, 1987

The calculated processors' margins on butter and skim milk powder are $0.40/kg and $0.49/kg respectively. If these are subtracted from the support prices the farm gate values are $4.57/kg on butter and $2.46 on powder. A 2 x 2 linear program (LP) can be formulated with these farm gate values in the objective function and quantities of FAT and SNF in butter and skim milk powder as the constraints to calculate the shadow prices on these milk constituents under this policy. This LP is shown in Figure 4.2.

The solution of this LP yields a shadow price on FAT of $5.19/kg and SNF of $2.51/kg. Using these shadow prices and the amounts of FAT and SNF, in cheese, the farm value of cheese can be calculated, and thus the farm-gate wholesale margin (Table 4.5).

	Butter	Skim Milk Powder
OBJ	4.57	2.46
FAT	.8198	.007
SNF	.1264	.965

Figure 4.2: Linear Program Tableau to Determine Shadow Prices on Butterfat and Solid Not Fat from Industrial Milk.

To calculate the shadow prices for the fluid market milk the assumption is made that the FAT component will have the same value in both markets. This assumption follows from the fact that there is surplus FAT in the fluid market from producing low fat fluid milks which is transferred to the industrial side. Once a value for FAT is determined it is quite simple to calculate the shadow price of SNF in the fluid market. Given a weighted average price of $50.73 (Graham et al ,1989) for fluid milk, the shadow price on SNF comes out to \$3.726/kg. Again, using the amounts of FAT and SNF in the fluid market products and these shadow prices the farm value and farm gate-retail margins can be calculated (Table 4.5).

4.3.3 Dairy Trade Subsector

The transport rates to be used in the dairy trade subsector are based on shipping costs supplied by a contractor who hauls dairy products for one of the major cooperatives in BC. The total cost of shipping butter, skim milk powder and cheese to and from several Canadian cities is averaged to yield shipping costs per tonne per mile. The final values are, \$0.0564/tonne/mile for butter, \$0.0703/tonne/ mile for skim milk powder and \$0.0549/tonne/mile for cheese. The shipping costs are given in Table 4.6.

The shipping activities for exports to, and imports from, the world are based on distances to a specified large urban centre in the United States. For the east the city chosen is New York and for the west Los Angeles.

Table 4.6: Transport Costs for Dairy Products Used in CRAM Model, 1986

Shipping Route	Distance (Miles)	Cheese	Butter	Skim Milk Powder
		(----- $/tonne -----)		
B.C. to Alberta	650	35.70	36.70	45.70
B.C. to World	1,290	70.80	72.70	90.60
Alberta to B.C.	650	35.70	36.70	45.70
Alberta to Sask.	450	24.70	25.40	31.60
Alberta to World	1,860	102.10	104.90	130.70
Sask. to Alberta	450	24.70	25.40	31.60
Sask. to Manitoba	400	22.00	22.60	28.20
Sask. to World	2,200	120.80	124.10	154.70
Manitoba to Sask.	400	22.00	22.60	28.10
Manitoba to Ontario	1,300	71.40	73.30	91.40
Manitoba to World	2,570	141.10	145.00	180.70
Ontario to Manitoba	1,300	74.40	73.30	91.40
Ontario to Quebec	400	22.00	22.60	28.10
Ontario to World	500	27.50	28.20	35.20
Quebec to Ontario	400	22.00	22.60	28.10
Quebec to Maritimes	500	27.50	28.20	35.20
Quebec to World	360	19.90	20.50	25.60
Maritimes to Quebec	500	27.50	28.20	35.20
Maritimes to World	710	39.10	40.20	50.10

Source: Personal communication with Hauling Manager of a Major Cooperative in British Columbia

4.3.4 Dairy Demand Subsector

The prices used in the demand functions are given in Table 4.5. These prices are at the wholesale level for industrial products and the retail level for fluid market products. Domestic disappearances are given in Table 4.7 and the own price elasticities of demand are given in Table 4.8.

Table 4.7: Domestic Disappearances of Dairy Products Used in CRAM by Province, 1986 (Calendar Year)

Province	Standard Milk	Lowfat Milk	Cream	Cheese	Butter	Skim Milk Powder
	(----- thous hl -----)			(----- tonnes -----)		
Western Canada	1926.6	5398.2	400.6	71623.1	24820.4	13145.7
British Columbia	847.7	1995.3	202.7	28649.2	11169.2	5126.8
Alberta	558.7	1889.4	112.2	23635.6	7694.3	4206.6
Saskatchewan	231.2	755.7	36.1	8594.8	2730.2	1840.4
Manitoba	289.0	755.7	48.1	10743.5	3226.7	1971.9
Eastern Canada	5634.1	12661.2	872.0	167901.8	74506.1	32184.3
Ontario	1915.6	7723.3	505.8	83950.9	41723.4	16042.2
Quebec	2817.1	3671.8	313.9	67160.7	16822.2	11908.2
Maritimes	901.5	1266.1	52.3	16790.2	5960.5	4184.0

Source: Fluid Disappearances, Dairy Market Review, 1986
Industrial Disappearances, Dairy Commodity Coordination Unit, Agriculture Canada

Table 4.8: Own Price Elasticities of Demand for Processed Dairy Products Used in CRAM model, 1986

Product	Elasticity
Fluid Market:	
Standard Milk	-0.33
Low fat Milk	-0.34
Cream	-0.50
Industrial Market:	
Cheese	-0.73
Butter	-0.80
Skim Milk Powder	-0.39

Source: FARM data base, 1986

4.4 Summary

In summary, this chapter has presented a model of the Canadian dairy industry including the production, processing, trade and marketing subsectors. The conceptual model is presented in further detail in the appendix.

Chapter 5

Results

The purpose of this chapter is to present the results of the introduction of BST into the Canadian dairy industry based on the model assumptions noted earlier. This analysis compares a 1986 "base case" of the industry to several scenarios representing government policy alternatives.

The base case represents the status of the dairy industry in 1986 prior to any adjustments resulting from the introduction of BST. This solution is meant to represent the Canadian agricultural industry including the dairy sector as it existed in 1986. This is presented to allow a comparison of scenarios representing government policy alternatives with the "status quo" situation.

The first scenario represents a "no price change" situation[3]. Current provincial quota levels, producer prices, levies and subsides remain unchanged in this scenario and it is assumed farmers adopt BST. Adoption rates as specified in Table 3.3 are assumed for each province and the aggregate effects on supply, producer incomes and herd size adjustments are analyzed. The second scenario attempts to predict the effect of BST on quota values. Representative farms in each province are assumed to adopt BST and the change in supply price and subsequent annual returns to quota are calculated. This scenario differs from scenario 1 in that 100% adoption is assumed. As in scenario 1 it is assumed dairy industry regulations remain unchanged.

[3] In the context of Canada's cost of production milk pricing formula, a "no price change" scenario shows what would happen if the pricing formula was suspended, if sampled farms are drawn heavily from non-adopting farms, or if the cost of production data are inaccurate in other respects.

The third scenario passes some of the benefits of BST adoption on to consumers. Instead of allowing producers to capture the expected benefits of BST adoption through increased quota values consumers could capture some of the benefits if prices are allowed to fall to reflect lower production costs. Production is increased until annual quota rents (farm-gate minus supply price) are equivalent to those in the base case.

The final scenario addressed would pass the benefits of BST on to the taxpayers. This is accomplished by decreasing the dairy subsidy at a national level by the amount that supply prices fall under scenario 1.

5.1 BST and No Price Change

The first scenario is meant to represent the Canadian dairy industry after the introduction of BST and assuming no accompanying change in administered prices. It is assumed that farm gate prices remain fixed, implying any fall in supply price is not captured in the cost of production formulas used to set price for the industrial and fluid markets. This implies quota levels, levies, subsidies and farm gate prices are all left unchanged. If production per cow is increased then the number of cows in each of the provinces will need to be reduced since overall Canadian production remains constant under supply control in this scenario. This scenario represents the situation of passing the full benefit of the adoption of BST on to producers.

This scenario is examined with both of the assumed levels of adoption in Table 3.3. The first situation assumes adoption is a function of average provincial milk yields (scenario 1A). The second assumes adoption is a function of the distribution of provinces' farm herd size (scenario 1B).

The changes in herd size for this scenario as compared to the base case are presented in Table 5.1 These numbers are for the dairy cow herd including first lactation heifers. At the national level the reduction in herd size is 5.3% under Scenario 1A and 5.7% under scenario 1B. Ontario faces a herd reduction of 5.6% in both cases and Quebec's herd size falls by just over 5% under each adoption rate criteria. British Columbia has the greatest decrease in provincial herd numbers assuming either set of adoption rates. Under scenario 1A the herd size falls by 7.3% and 6.4% under scenario 1B. The Prairies face the lowest reduction at 4.4% under scenario 1A. Under scenario 1B the herd reductions in the Prairies are greater than the national average at 6.1%. These differences are based upon the different assumptions regarding adoption levels by province.

The main effect of these changes on the dairy production sector are given in Table 5.2. By the definition of this scenario gross returns are unaffected. Any changes noted result from differences in variable costs and the returns from beef as a byproduct produced by the provincial dairy herds. Savings in variable costs of milk production, which at the national level amount to about 3%, can be attributed to several sources. Although the concentrate feed used to produce a hectolitre of milk with BST increases slightly, the forages fed would fall substantially. The total costs for items such as replacements, energy, veterinary and overhead will also fall as cow numbers are decreased. Offsetting these cost savings would be the cost of the hormone itself. On a provincial basis these costs, including the cost of BST, fall by approximately 3% in each province. The province experiencing the greatest decrease in variable costs is Ontario, at 3.7 percent. The Prairies have the lowest decrease at just over 2% in scenario 1A.

Table 5.1: Herd Size Changes with the Introduction of BST, by Province (thousand head)

Province	Base	Adoption Based on	
		Ave. Yields	Herd Size
B.C.	83.0	76.9 (-7.3)	77.7 (-6.4)
Alberta	130.0	123.5 (-5.0)	121.9 (-6.2)
Sask.	59.0	56.8 (-3.7)	55.4 (-6.1)
Manitoba	71.0	67.9 (-4.4)	66.8 (-5.9)
Ontario	503.0	475.5 (-5.6)	474.6 (-5.6)
Quebec	615.0	583.4 (-5.1)	582.2 (-5.3)
Maritimes	86.4	81.2 (-6.0)	81.1 (-6.1)
Canada	1547.4	1465.2 (-5.3)	1459.7 (-5.7)

(percentage changes from base in parentheses)

Source: CRAM model results

Falling herd sizes would mean a lower return from beef produced by the dairy herd. The total low quality (LQ) and high quality (HQ) beef returns fall by 5% under the first set of adoption levels and 6% under scenario 1B due to the smaller herd. These numbers do not include veal or the transfers of animals to the beef sector (feedlot), which are expected to fall as a result of the smaller herd.

The reductions in variable costs lead to an increase in dairy production sector gross margins[4] of over 5% in this scenario. Ontario experiences an increase of 5% and Quebec has a slightly higher increase of 6% in net sector earnings. British Columbia has the lowest increase in net sector earnings at 3.6% under scenario 1A and 3% under scenario 1B. The greatest percentage increase is on the Prairies where dairy sector gross margins increase by over 7% with this scenario.

Along with the changes to the dairy production subsector, movements of calves to the beef sector will be affected. The decline in dairy calves moving to the beef sector feedlots, as herd size falls, are given in Table 5.3, assuming calf slaughter remains at its current level to maintain domestic veal production.

In conclusion, in this scenario representing "no price change", herd size falls by approximately 5 percent. This smaller herd size results in a decrease in variable costs of just over 3 percent. The fall in variable cost with no change in milk price or production levels results in approximately 5% increase in dairy producer gross margins. At the national level the assumption on whether adoption is a function of average yields or herd sizes makes little difference in variable costs or the resulting dairy producer gross margins. The only appreciable differences shown are in British Columbia where producers fare better when the assumed adoption level is based on average yields. The Prairies benefit more when adoption is a function of the herd size.

---

[4] Dairy production sector gross margins are defined as total sector gross revenue less all cash costs.

Table 5.2: Changes in Dairy Production Subsector Earnings with Introduction of BST and No Price Change, by Province (mil $)

Province	Fluid Market Gross Returns	Industrial Market Gross Returns	HQ and LQ Beef Gross Returns			Variable Costs			Dairy Producer Gross Margins		
			BASE	SCEN 1A	SCEN 1B	BASE	SCEN 1A	SCEN 1B	BASE	SCEN 1A	SCEN 1B
B.C.	161.9	77.7	19.1	17.8 (-7)	17.9 (-6)	147.6	142.3 (-3.6)	143.1 (-3.0)	111.1	115.1 (3.6)	114.4[a/] (3.0)
Alberta	124.0	108.2	25.0	23.9 (-4)	23.5 (-6)	205.4	200.1 (-2.6)	198.9 (-3.2)	51.8	56.0 (8.1)	56.8 (9.7)
Sask.	51.3	41.9	10.2	9.8 (-4)	9.6 (-6)	81.2	79.6 (-2.0)	78.5 (-3.3)	22.2	24.5 (10.3)	24.3 (9.5)
Manitoba	56.4	59.7	15.4	14.7 (-5)	14.4 (-6)	94.9	93.0 (-2.0)	92.3 (-2.7)	36.6	37.8 (3.3)	38.2 (4.4)
Ontario	516.1	530.8	159.3	150.6 (-6)	150.3 (-6)	795.5	766.8 (-3.6)	765.9 (-3.7)	410.7	430.7 (4.9)	431.3 (5.0)
Quebec	334.4	809.2	137.0	129.9 (-5)	129.5 (-5)	898.0	868.5 (-3.3)	868.1 (-3.3)	382.6	405.4 (6.0)	405.0 (5.9)
Maritimes	114.1	68.5	21.1	20.0 (-6)	19.9 (-6)	150.0	145.2 (-3.2)	145.0 (-3.3)	53.7	57.4 (6.9)	57.5 (7.1)
Canada	1358.2	1696.0	387.1	366.7 (-5)	365.1 (-6)	2372.2	2295.5 (-3.2)	2291.8 (-3.4)	1068.8	1125.4 (5.3)	1127.5 (5.5)

(percentage changes in parentheses from base case)

[a/] The low percentage change in B.C. dairy producer income with the adoption of BST, compared to the other provinces, is due to the unusually large gross margins in that province compared to variable production costs.

Source: CRAM model results

Table 5.3: Changes in Transfers of Dairy Calves to Beef Sector, Scenario 1

	Dairy Calf Transfers		
Province	Base	Scenario 1A	Scenario 1B
B.C.	8990	5760 (-36)	6210 (-31)
Alberta	88290	83650 (-5)	82440 (-7)
Sask.	29950	28360 (-5)	27360 (-9)
Manitoba	40750	38560 (-5)	37810 (-7)
Ontario	45140	31660 (-30)	31210 (-31)
Quebec	92060	72900 (-26)	72180 (-22)
Maritimes	34540	31960 (-7)	31880 (-8)
Canada	339720	292850 (-14)	289090 (-15)

(percentage changes in parentheses)

Source: CRAM model results

5.2 Change In Quota Values

Scenario 2 is used to measure what impact the introduction of BST would have on quota values in the Canadian dairy industry. This scenario is identical to the first scenario except that 100% adoption is assumed. It is also assumed that the representative farm in each province produces a blend of fluid and industrial milk and receives a blended price for this milk. The difference between this blend price and the supply price of milk will be the annual returns or 'rental value' of quota.

Producers who tend to purchase quota are most often those in the low cost category who wish to expand production levels. These producers would be in a position to bid for quota above what less efficient producers could pay. The market price of quota is determined by the present value of a stream of returns available to efficient producers in the dairy industry. These same producers would also be able to capture the greatest benefit from the adoption of BST. It is assumed in this analysis that 100% of these producers adopt. The difference between product price and marginal cost for these efficient producers is used to determine the changes in annual returns to quota with the introduction of BST.

The situation in this scenario is portrayed in Figure 2.5. The supply curve for the efficient producers in the industry shifts from S^0 to S^1 as illustrated in Chapter 2. This curve shifts down as a direct result of the lower average costs necessary to produce a given level of output (Q) with the adoption of BST. With a fall in marginal cost, but constant product price and quota production levels, in the annual returns to quota increase.

The blend prices of milk, supply prices and resultant annual quota returns, before and after BST is introduced, are given in Table 5.4. As in scenario 1 the assumption made is that all relevant policy instruments such as levies, subsidies, quota levels and farm gate prices remain unchanged. In Table 5.4 supply price and quota returns change, the blend price remains the same before and after BST is utilized.

The supply price falls by 5.6% at the national level. This leads to a 17.8% increase in the annual returns to the blended fluid-industrial quota for Canada. Oxley et

Table 5.4: Supply Prices Average Milk Prices and Annual Returns to Quota Before and After BST Introduction, by Province ($/hl)

Province	Supply Price		Average Milk Price[c/]	Annual Returns to Quota	
	Before[a/]	After[b/]		Before	After
B.C.	30.20	28.50 (-5.6)	49.55	19.35	21.05 (8.8)
Alberta	34.80	32.65 (-6.2)	41.90	7.10	9.25 (30.3)
Sask.	36.20	33.90 (-6.4)	44.81	8.61	10.91 (26.7)
Manitoba	32.60	30.70 (-5.8)	42.47	9.87	11.7 (19.3)
Ontario	32.60	30.70 -(5.8)	43.95	11.35	13.25 (16.7)
Quebec	31.60	30.00 (-5.1)	40.25	8.65	10.25 (18.5)
Maritimes	34.70	32.80 (-5.5)	44.33	9.63	11.53 (19.9)
Canada	32.40	30.60 (-5.6)	42.69	10.29	12.09 (17.5)

(percentage changes in parentheses)

Source: a/ Model results calibrated to Graham et al (1989) supply prices.
b/ Model results
c/ Graham et al (1989) showed a decrease in supply price for Ontario of 8% resulting in a 23% increase in quota values. Tabi and Stonehouse calculated an increase in what farmers could pay for quota ranging from 8 to 29% depending on the farm technology level.

5.3 Quota Values Constant

This scenario is designed to represent a situation in which some of the benefits of BST adoption are passed on to the consumers. Quota values are held constant before and after BST introduction, by allowing expansion in production to keep the distance between supply price and farm-gate price the same. This expansion leaves producers at least as well off with BST introduction, and benefits some producers by allowing an expansion in production through more quota.

The main concept to be examined in scenario 3 is portrayed in Figure 5.1. The dairy industry prior to the introduction of BST produces at the level Q^0. This implies a farm gate price of PD^0 and a supply price of PS^0. The difference between these prices will be the annual rental value of quota. The introduction of BST causes a shift in the supply curve down to S^1 from S^0. In order to keep the rental value of quota and thus the capitalized price of quota constant after the introduction of BST the level of quota must be increased to Q^1. At this level the farm gate price is PD^1 with a supply price of PS^1. The difference between these prices is equivalent to the previous PD^0 less PS^0. As more milk is produced, marketed product prices to consumers are lower.

The increases in production levels required to keep quota values the same as in the base case are given in Table 5.5. This analysis is on a provincial level treating the milk market as a single market producing both fluid and industrial milk. The ratio of fluid to industrial milk was kept constant in each province as the total supply was allowed to increase. At the national level production was increased by over 1.5 mill. hl which is a 2% increase over the base case. Fluid market milk production increased by 2.1% and industrial market milk production increased by 1.9%. To bring about the consumption of this increased production, consumer prices would have to fall and the model predicts the following changes in prices:

- 8% fall in the prices of standard milk in the west and 4% in the east
- 4% fall in the price of lowfat milks in the west and 8% in the east
- 12.5% fall the price of cheeses in the west and 9% in the east
- no change in western butter prices and a 2% fall in the price of butter in the east

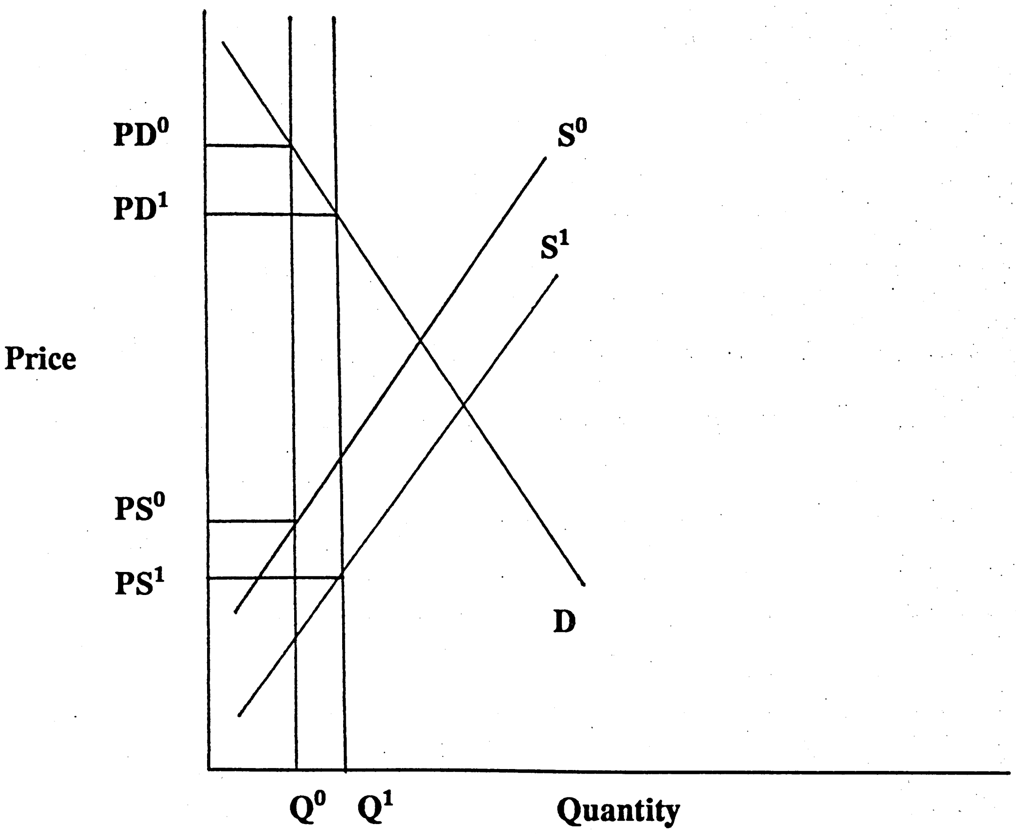

Figure 5.1: Expansion in Milk Output to Keep Quota Values Constant Before and After the Introduction of BST

The final processed dairy product mix which results from the new supplies of raw milk are listed in Table 5.6. For standard milk, the western provinces increased production levels by slightly less than 3%, and in the east by 1.5% for an overall increase of 2% for Canada as a whole.

Lowfat milk production was up by slightly less than 3% in the western provinces and almost 3.5% in the east. At the national level this results in an increase of 3.2%. Cream production does not change as the demand is essentially fixed for this product. In the industrial market, cheese production increases substantially more than the other products. At the national level, production increases 6.4%. Butter production also increases by slightly less than 2%. Skim milk powder is the only product which has a decrease in production under this scenario.

Table 5.5: Milk Production for Scenario 3 Compared to Base, by Province (thous. hl)

Province	Fluid Production		Industrial Production		Total Production	
	Base	Scen 3	Base	Scen 3	Base	Scen 3
B.C.	3119	3172	1770	1800	4889	4972 (1.7)
Alberta	2579	2637	3324	3399	5902	6036 (2.3)
Sask.	974	997	1268	1298	2242	2295 (2.4)
Manitoba	1139	1163	1772	1808	2911	2971 (2.1)
Ontario	9920	10165	14475	14726	24396	24891 (2.0)
Quebec	6871	6996	21542	21935	28413	28931 (1.8)
Maritimes	2173	2216	2147	2189	4320	4405 (2.0)
Canada	26775	27346 (2.1)	46298	47155 (1.9)	73072	74501 (2.0)

(percentage changes in parentheses)
Source: CRAM model results

Table 5.6: Increases in Processed Dairy Products for Scenario 3, by Province

Province	Standard Milk		Lowfat Milk		Cream		Cheese		Butter		Skim Milk	
	Base	Scen 3	Base	Scen 3	Base	Scen 3	Base	Scen 3	Base	Scen 3	Base	Scen 3
	- thous hl -						- tonnes -					
B.C.	842	866	1877	1928	209	209	11036	11407	4785	4881	5107	5107
Alberta	555	571	1776	1823	115	115	23135	25942	6883	7075	4190	4190
Sask.	230	236	710	729	37	37	8453	8852	2971	3042	1833	1833
Manitoba	287	295	710	729	49	49	10569	11427	4051	4131	1964	1964
Ontario	1874	1905	7589	7843	518	518	84661	89746	34715	37298	40014	38046
Quebec	2755	2801	3608	3729	322	322	77484	84294	39640	39195	53082	51057
Maritimes	882	896	1244	1286	54	54	14112	14602	5381	5515	4170	4167
Canada	7425	7570 (2.0)	17514	18067 (3.2)	1304	1304 (0)	231450	246270 (6.4)	98326	10026 (1.8)	110360	106364 (-3.6)

(percentage changes in parentheses)
Source: CRAM model results

Nearly all of the increased industrial milk production is used for increased cheese production. The reason for this is that cheese has a much greater farm-gate/wholesale margin than butter or skim milk powder. A great deal of the butterfat required for this cheese production is skim-off from increased fluid lowfat milk production, while the solid-not-fat comes from actual decreases in skim milk powder production. The increases in industrial milk production along with the transfers from the fluid market lead to a small surplus of butterfat. This is used for the modest increase in butter production.

The changes in movement of dairy products for scenario 3 over the base case are given in Table 5.7. At the national level cheese trade is fixed by import and export quotas, so these do not change. Canada is still self-sufficient in butter with no movement in or out of the country in this scenario. Skim milk powder exports fall by 6% at the national level.

At the provincial level movements of butter from Quebec to the western provinces fall by approximately 4%. The other significant interprovincial movement, cheese into British Columbia from Alberta falls by 39%.

5.4 Reduction In Butterfat Subsidy

The final scenario to be addressed in this study is meant to pass the benefit of BST introduction to the taxpayer. This is accomplished by reducing the aggregate butterfat subsidy per province by an amount which will exactly offset the net cost savings resulting from the use of BST. In other words, gross margins in the industry will be held constant and the cost savings from BST adoption will be transferred to the federal government. The subsidy is then calculated on a per hectolitre basis for industrial milk. The decrease in cost,

Table 5.7: Changes in Dairy Shipping Activities with BST and Expansion of Quota Levels, tonnes

Province		Cheese		Butter		Skim Milk Powder	
		Base	Scen 3	Base	Scen 3	Base	Scen 3
B.C.[a/]	Exports	0	0	0	0	0	0
	Imports	17148	18636	6475	6378	0	0
ALTA	Export	1883	1156	6475	6378	0	0
	Imports	0	0	7348	7060	0	0
SASK.	Exports	0	0	7348	7060	0	0
	Imports	0	161	7129	6770	0	0
MAN.	Exports	0	161	7129	6770	0	0
	Imports	0	0	6330	5892	0	0
ONT.	Exports	0	0	6330	5892	23986	22018
	Imports	0	0	11975	11664	0	0
QUE.	Exports	12248	12497	12602	12157	41221	39196
	Imports	2492	0	0	0	0	0
MAR.	Exports	0	0	0	0	0	0
	Imports	2821	3347	628	495	0	0
CAN.[b/]	Exports	12248	12238	0	0	65107	61214
	Imports	20578	20578	0	0	0	0

a/ includes both interprovincial and international movements
b/ only international movements with cheese quotas in place

source: CRAM model results

per province, will be the value from scenario 1 with its assumed adoption rates for the two different criteria on adoption rates. Scenario 4A will have adoption rates as a function of average provincial yields and scenario 4B will have adoption rates as a function of the provincial farm herd size distributions.

The results of these taxpayer savings are presented in Table 5.8. Total production is multiplied by the cost savings per hectolitre to come up with the total savings for the industry after adoption of BST. This value will be the total reduction in subsidy to offset this savings. The subsidy is only paid on industrial milk so the actual decrease in the subsidy per hectolitre must be calculated from the provinces' production of industrial milk.

The butterfat subsidy has traditionally been set at the national level then applied to the provinces equally. The decrease in the subsidy would be 1.80 per hectolitre at the national level for either scenario. This would represent a savings to the taxpayers of over $80 million, or approximately 30% of the current subsidy payments.

The smallest decrease in the butterfat subsidy necessary to offset the gains from using BST would be in Quebec at $1.30/hl. The reason for this is the high proportion of industrial milk produced. In Ontario the subsidy would fall by $2.00/hl.

The largest decrease in the subsidy to offset the producer benefits of BST use would be in British Columbia in scenario 4A at $3.30/hl and both B.C. and the Maritimes in scenario 4B at $2.70/hl. The main reason for the large reduction in subsidy is the low proportion of industrial to fluid milk produced in these provinces.

The Prairie provinces would require a $1.60/hl reduction in the subsidy under scenario 4A and a $2.10/hl reduction in scenario 4B to offset the fall in marginal costs as

Table 5.8: Savings by Taxpayers if Butterfat Subsidy Fell to Offset Cost Savings with BST

Province	Total Production	Industrial[a] Production	Decrease in MC ($/hl)		Total Offset Savings (mill $)		Fall in Subsidy ($/hl)	
	(----- thous hl -----)		Scenario 4A	Scenario 4B	Scenario 4A	Scenario 4B	Scenario 4A	Scenario 4B
B.C.	4889	1614	1.1	0.9	5.4	4.4	3.3	2.7
ALTA.	5902	2765	0.9	1.1	5.3	6.5	1.9	2.3
SASK.	2242	1078	0.7	1.2	1.6	2.7	1.5	2.5
MAN.	2911	1771	0.7	0.9	2.0	2.6	1.1	1.5
ONT.	24396	14475	1.2	1.2	29.3	29.3	2.0	2.0
QUE.	28413	21542	1.0	1.0	28.4	28.4	1.3	1.3
MAR.	4320	1930	1.1	1.2	4.8	5.2	2.5	2.7
CANADA	73073	45167	1.1	1.1	80.4	80.4	1.8	1.8

[a] net of overquota production

Source: CRAM model results

a result of BST adoption.

5.5 Summary

In this chapter the results of the introduction of BST to the Canadian dairy industry based on the model and assumptions stated in chapter 3 were presented. To facilitate this analysis a "base case" was compared to several scenarios representing different dairy policy options. The summary results of this analysis and conclusions are presented in the final chapter.

Chapter 6

Summary and Conclusions

In this chapter a summary of the study and some conclusions are presented. The first section will briefly outline the first five chapters including the problem to be addressed, the objectives, the model and the important results from the 4 scenarios. The next section presents conclusions drawn from these results and implications for policy. Limitations of the study and recommendations for further research are also discussed.

6.1 Summary and Conclusions

Bovine somatotropin (BST) is a naturally occurring hormone in dairy cattle which when administered to dairy cows allows for significant increases in the production of milk. The introduction of this product into an industry with production levels fixed through production quotas raises uncertainty with respect to its quantitative effects and the appropriate response by policy makers on matters of price and quota levels. The matter is further complicated by the possibility of a change in consumer preferences for milk produced in BST-using herds, whether supply management is involved or not. This aspect is not addressed in this study.

Several scenarios representing policy alternatives are considered for the introduction of BST and are compared to a "base case" situation (1986) with no BST. The first scenario analyzed involves no administrative price change in response to the introduction of BST. Quota levels, levies, subsidies and prices remained at their "base" levels. This situation was analyzed based on two different sets of adoption rates. The first based adoption rates on average provincial milk yields and the second on the distribution of provincial herd size.

In this first scenario the number of dairy cows in Canada decreased by 5% under both sets of adoption rates. British Columbia had the largest reduction at approximately 6.5 percent. Ontario and Quebec reduced their herd size by 5 percent. With falling herd numbers and cows producing the same total amount of milk, an increase in dairy producer sector gross margins of between 5.3 to 5.5% is predicted by the model.

The second scenario measured the change in quota values with the introduction of BST. Again, all policy instruments stayed the same as in the base case. At the national level the average annual returns to quota increase by 17.5 percent.

In scenario 3 some of the benefits of BST adoption are passed on to consumers by allowing production to expand, and retail prices to fall with the difference between farm-gate price and supply price remaining the same after BST introduction as in the base. This means quota values would remain at their base case level. This results in a 2% increase in the supply of milk (both fluid and industrial) at the national level. In the fluid milk market the production of standard milk increased by 2% and production of the lowfat milk by 3% at the national level. In the industrial market the manufacturing of cheese increased by over 6%, butter production increased by approximately 2% and skim milk powder production fell by almost 4 percent. These increases in supplies, for both fluid and industrial milk products, were accompanied a reduction in prices.

In the final scenario the benefits of the introduction of BST are passed on to the taxpayers. This is accomplished by decreasing the industrial market dairy subsidy by an amount which just offsets the cost savings to each province as a result of BST adoption. This results in a decrease in the dairy subsidy of $80 million, or approximately 30% of the current amount paid out. Producers in this scenario are in the same position as the base case in terms of gross margins and protection levels.

In conclusion, under the assumptions made in this study, the impacts of BST adoption are quite moderate. At the firm level it is estimated that BST adoption would reduce a producers marginal costs by approximately $2.00 per hl on average in Canada. With the supply prices used in this study this represents a 5.5% reduction in marginal costs. Alternatively, if supply prices for an efficient producer are closer to $25.00 per hl this would represent a larger reduction, at almost 8 percent. Using the supply price in this study of $32.40 as an upper bound and $25.00 as a lower bound, quota values are estimated to increase between 10% and 17.5% with the introduction of BST. These are smaller effects than measured in previous studies on the firm level effects of BST.

The overall aggregate impacts of BST on the Canadian dairy industry are further moderated by the assumption that not all producers would utilize the hormone. The important results are a 5% decrease in dairy herd size and a 5% increase in dairy sector producer incomes if prices remain at 1986 levels. These are both quite small.

The high degree of managerial skill required to profitably utilize BST, combined with early adoption of this technology by certain producers, would encourage high cost producers to leave the dairy industry. Early adopters of BST, facing reductions in cow numbers of approximately 10% to maintain current production levels, could be expected to purchase more quota to ensure full utilization of fixed resources. This is likely to accelerate the ongoing rationalization process of fewer but larger dairy farms with higher yields per cow.

Regulatory bodies responsible for dairy policy could direct any benefits resulting from BST in different directions. If production levels were to be expanded such that quota values didn't change, consumers would capture some of the benefit of BST. This would involve a moderate production increase and an accompanying decrease in dairy product prices. These price changes would be quite small but it can be argued that any lowering in the price of dairy products is important. Alternatively, if all of the increased rents associated with BST were passed on to taxpayers, through a reduction in the dairy subsidy, a burden on the Canadian taxpayers would be reduced.

At the international level, if the US adopts BST and Canada does not, this would increase the price differential between dairy products in these countries. In these Canadian urban areas in close proximity to the US border where a considerable quantity of dairy products moves into Canada through consumer purchases, these consumer imports would be expected to increase, reducing the demand for Canadian produced dairy products.

With no accompanying change in Canadian dairy policy BST would only accelerate the ongoing trends in the Canadian dairy industry. Dairy industry rationalization, with decreasing producer numbers would be temporarily accentuated, and quota values would increase.

6.2 Limitations and Recommendations for Further Research

The preceding sections have presented the major findings of this study and the conclusions based on these findings. These results must be interpreted bearing in mind the simplifying assumptions used to model the dairy industry and the introduction of BST to that industry in this study. Some of the major concerns follow.

A major concern of this study relates to the assumptions on adoption rates. There is wide ranging speculation among industry experts on acceptance of this technology by producers in Canada. However, if full adoption of a new technology is assumed, and the resulting impacts noted, an upper bound on the estimated effects of the product is achieved. Under full adoption, as modelled in scenario 2 of this study, the impacts of BST are not large. Although the assumptions on adoption of BST are a source of uncertainty for this study, utilizing them with the upper bound mentioned above reduces this uncertainty about the anticipated effects.

The analysis in this study assumes consumer preferences would not change with the introduction of recombinant BST into dairy herds. Given the relatively moderate gains associated with the introduction of BST estimated in this study, any offsetting reduction in dairy product demand could conceivably erase the net benefits to the industry. Assessing consumer response is required. The supply prices for milk are critical to the analysis of the situation representing consumers capturing some of the benefit associated with BST. The collection of more accurate data on quota values and the methodology used to estimate supply prices needs further examination.

The shortage of long-term large scale experiments on BST leaves some unanswered questions with respect to the overall effects of this hormone. The effect of this hormone on the useful life of a cow still remains to be determined. If a cow does, on average, lose a lactation from her useful life this would entail a cost to dairy producers not covered in this study. Another related issue is the possibility of three milkings per day with the use of BST. It is anticipated that this will result in larger milk yield increases. As field experiments with BST yield more information on these problems this study should be updated.

BIBLIOGRAPHY

Asimov, G.J., Krouze, N.K. "The Lactogenic Preparations from the Anterior Pituitary and the Increase in Milk Yield in Cows", Journal of Dairy Science. 20 (1937): 289

Barichello, R.R. "The Economics of Canadian Dairy Industry Regulation". Ottawa: Economic Council of Canada, Technical Report E/12, 1981.

Barichello, R.R. "Analyzing an Agricultural Marketing Quota". Paper presented at the IV European Congress of Agricultural Economists, Kiel, Federal Republic of Germany, September 1987.

Barichello, R.R., Cunningham-Dunlop, C. "Quota Allocation and Transfer Schemes In Canada". Ottawa: Agriculture Canada Working Paper 8/87, 1987.

Bauman, D.E., Eppard, J.E, DeGeeter, M.J. and Lanza, G.M. "Responses of High Producing Dairy Cows to Long Term Treatment With Pitiutary Somatotropin and Recombined Somatotropin", Journal of Dairy Science. 68 (1985): 1352-1362

Bines, J.A. and Hart, I.C. "Metabolic Limits to Milk Production, Especially Roles of Growth Hormone and Insulin", Journal of Dairy Science. 65 (1982): 1375-1389

Bollman, R. "Farm Financial Stress and the Ability of a Farm to Sustain a Family". Paper Presented at 7th World Congress on Rural Sociology, Bologna, Italy, 1988.

Burton, J.H., Mcbride, B.W., Bateman, K., McLeod, G.K., Eggert, R.K. "Recombinanant Bovine Somatotropin: Effects on Production and Reproduction in Lactating Cows", Journal of Dairy science. 70, Supplement (1987): 175

Chalapa, W. and Galligan, D.T. "Nutritional Implications of Somatotropin For Lactating Cows", Journal of Dairy Science, 71, Supplement (1988): 123

Coombs, R., Saviotti, P., Walsh, V. "Economics and Technological Change". London, Macmillon Education, 1987.

Dairy Farmers of Canada. "Dairy Facts and Figures at a Glance". Ottawa: Dairy Farmers of Canada, 1987.

de Boer, G., Kennelly, J., Shelford, J., Peterson, R. and Holbek, N. "Efficacy and Safety of Recombinantly Derived Bovine Somatotropin for Dairy Cows", Final Report for Experiment B-86-49. Department of Animal Science, University of Alberta, Edmonton, Department of Animal Science, University of British Columbia, Vancouver, 1988.

Eppard, P.J., Bauman,D.E. and McCutchian,S.N. "Effect of Dose of Bovine Growth Hormone on the Lactation of Dairy Cows", Journal of Dairy Science. 68 (1985): 1109-1115

Fallert, R., Mcguckin, T., Betts, C.and Bruner G. "BST and the Dairy Industry: A National, Regional and Farm-Level Analysis". Washington: United States Department of Agriculture, Agricultural Economic Report Number 579, October 1987.

Forbes, J.D., Hughes, R.D. and Warley, T.K. "Economic Intervention and Regulation in Canadian Agriculture". Ottawa: Economic Council of Canada, 1982.

Graham, J.D., MacGregor, R.J., Mielke, K.D. and Stennes, B.K. "Multilateral Trade Liberalization: Implications for Supply Controlled Industries in Canada". Paper presented at the Pacific Economic Cooperative Conferences Meeting, Seoul Korea, May 1989.

Graham, J.D., Meilke, K.D., Moschini, G., and Stennes, B.K. "The Effects of Trade Liberalization on the Canadian Dairy and Poultry Sectors". Contract Report to Policy Branch, Agriculture Canada, June 1989.

Lavigne, B., Biggs, E. "Report of the Review Committee on a Long-term Dairy Policy for Canada". A Report to the Honourable John Wise, Minister of Agriculture, 1985.

Mansfield, E. "Industrial Research and Technological Innovation: An Econometric Analysis". New York, W.W. Norton and Company, 1968.

Moschini, G. and Meilke, K.D. "Sustainable Rates of Return for Milk Quotas in Ontario". Canadian Journal of Agricultural Economics, 36 (1988): 119-126

Oxley, J., Fox, G.and Moschini, G. "The Potential Impact of Bovine Somatotropin on the Ontario Dairy Industry" Department of Agricultural Economics and Business, University of Guelph, Guelph. Working Paper WP89/6, 1989.

Puu, T., Wibe, S. "The Economics of Technical Progress". London, The Macmillon Press Ltd, 1980.

Reel, C.J., Bauman, D.E., "Somatotropin and Lactation", Journal of Dairy Science. 70 (1987): 474-486

Shower, R.D., Nytes, A.J. "Overview of Bovine Somatotropin for Dairy Cattle". Proceedings of the Pacific Northwest Nutrition Conference, 1987.

Short, C., Cote, M., "Dairy Policy Simulation and Evaluation". Ottawa: Marketing and Economics Branch. Agriculture Canada Working Paper 3/86, 1986.

Soderholm, C.G., Ollerby, D.E., Linn, J.C., Ehle, F.P., Wheaton, J.E., Hanson, W.P., and Annestad, R.J. "Effects of Recombinant Bovine Somatotropin on Milk Production, Body Composition and Physiological Parameters", Journal of Dairy Science. 71(1988): 355-365

Statistics Canada. "The Dairy Review". Catalogue 23-001. 1987.

Statistics Canada. "1986 Census of Canada". Catalogue 96-102, Agriculture: Canada.

Statistics Canada, Livestock and Animal Products Section, Agriculture Division. "Livestock Report". Catalogue 23-008, Vol.9. Jan. 1988.

Stonehouse, D.P., "Government Policies for the Canadian Dairy Industry", Canadian Farm Economies. 14 (1979): 1-11

Tabi, J. and Stonehouse, D.P. "Effects of Adopting BST on Quota Values in a Supply Managed Dairy Industry: A Case Study for Ontario". Department of Agricultural Economics and Business, University of Guelph, Guelph. Working Paper WP88/12, 1988.

Trelawny, P. "A Preliminary Assessment of the Short-Term Economic Effect of Bovine Somatotropin". Ottawa: Farm Development Policy Directorate, Policy Branch, Agriculture Canada, 1986.

Waterson, M., "Economic Theory of the Industry". Cambridge, Cambridge University Press, 1986.

Weersink, A.J. and Tauer, L.W. "Dairy Farm Investment Models", American Journal of Agricultural Economics. 71 (1989): 136-145.

Zepada, L. "Attitudes of California Milk Producers Toward Bovine Somatotropin", California Agriculture, 43 (1989): 11-12

APPENDIX:

The Dairy Sector in CRAM,

Conceptual Model

1. Dairy Production Subsector

The basic supply of raw milk for the dairy processing and marketing activities in CRAM is from farms specified in the dairy production subsector of the model. These production activities are provincial-level with three categories of dairy animals being specified and fed combinations of pasture, forage and barley.

The general equations for this subsector of the model may be grouped into eleven sets of equations which are specified for each provincial producing region in the model, i.e., for each province:

(1) Provincial Cash Costs

O/S of cows, heifers and calves times cash costs per animal of each	+	Number veal animals fed times cash costs per animal	-	Total provincial dairy production sector cash costs	≤ 0

(2) Provincial Crop Balances

O/S of cows, heifers and calves times the forage, pasture, and barley usage per animal of each category	+	Number veal animals fed times barley usage per animal	-	Total provincial feed usage by dairy production sector	≤ 0

(3) Dairy Balances

-	O/S of cows adjusted for culling and death loss	-	O/S Heifers adjusted for death loss	-	Culled heifers	+	C/S of cows		≤ 0

-	number calves produced by O/S	-	number calves produced by O/S heifers	+	C/S dairy calves	+	Veal animals fed	+	Transfer of calves to beef sector		≤ 0

-	Calf O/S numbers for death loss	+	Heifers killed	+	C/S heifers		≤ 0

(4) Dairy Slaughter

Dairy calf, heifer and cow slaughters	-	Bounded activities for net provincial (beef and dairy) animal slaughter	≤ 0

(5) Yield/Demand Transfer

-	O/S numbers of cows times LQ beef and milk yields and yields from slaughters (calves, heifers, veal) times slaughter numbers	+	Quantities demanded for beef and veal (net of trade) and amount of milk processed products demanded (net of trade)	≤ 0

(6) Retention Functions

O/S Numbers of dairy cows, heifers and calves	-	Retention activity numbers of cows, heifers and calves times coefficients adjusted for changing herd size for different arguments	≤ 0

(7) Input Accounting

O/S numbers of cows, heifers and calves times coefficients for costs and feed use	-	Activities to account for provincial cash costs and and feed use	≤ 0

(8) Yield Accounting

O/S cows and slaughters of heifers and calves times yields milk and HQ and LQ beef	-	Activities to account for provincial yields of milk, HQ and LQ beef	≤ 0

(9) Government Payments

- O/S numbers of cows, heifers and calves times payment/ animal	+	Provincial government payment to dairy activity	≤ 0

In this section an explanation for each of the equations in the model follows:

Cash costs and feed accounting activities for pasture, stored forage and barley (through provincial crop balance rows) are defined and these are associated with opening stock activities on cows, heifers and calves (equations 1 and 2). The veal activity draws from a calf balance row and includes activities for cash production costs and the provincial barley balance row.

The herd size for each province is set by specifying right hand sides on opening stock numbers for the cow, heifer and calf categories. Balance rows for these three categories determine how opening stock numbers are accounted for or transferred through the time period to other categories in the provincial herd. A typical herd transfer equation is followed in which opening stocks + purchases + transfers in are greater than or equal to closing stocks + sales + transfers out. This includes adjustments for loss due to natural death rates and culling of the various categories, as well as allocating calves to veal feeding, transfers to the beef sector, or rejoining the dairy herd as heifers (equations 3, 4 and 5).

Milk production is associated with the opening stock of dairy cows (equation 5). A provincial yield row accounts for total milk production and is used to transfer milk to the processing sector where it is allocated between the fluid and industrial markets.

Aside from milk three types of byproducts from the dairy herd are produced in the dairy production sector. High quality (HQ) and low quality (LQ) beef results from the slaughter and culling activities of cows, heifers and calves. These are aggregated, along with HQ and LQ beef from the beef sector, into provincial beef production accounting rows, which transfer these outputs to the demand sector. A number of the dairy calves are also transferred into the production of veal. This enters a national veal yield row along with the veal produced in the other provinces.

The model allows for herd size changes through the use of retention functions (equation 6). The retention rows allow for a ratio of the closing stock numbers to the opening stock to simulate responses to changing arguments for this function such as own price, feed price or other important variables. Current prices, expected future prices and an estimate of the associated elasticity are required to calculate the coefficients for this function (Graham et al, 1988). For long run analysis the opening stock activities use these coefficients to increase or decrease opening stocks. Closing stock numbers are equated to O/S in a long run situation.

The input accounting rows are used to keep track of the dairy herd's cash costs and feed use. Likewise, yield accounting rows are used to tally the dairy herd contribution of LQ and HQ beef to the provincial totals, and the supply of raw milk to the processing sector (equations 7 and 8). There are rows that account for government payment to the provincial dairy sectors (equation 9). Currently the subsidy payments, as well as levies are calculated on milk as it enters the processing subsector.

2. Dairy Processing Subsector

Raw milk produced at a provincial level in the production subsector is transferred via the milk yield row to a provincial dairy processing subsector. Raw milk is split into the fluid and industrial needs, processed into fresh milk and the industrial milk is manufactured into final products. Products specified include: lowfat and whole milk, fluid cream, cheese, butter, skim milk powder and other dairy products. The equations for this subsector are:

(10) Provincial Cash Costs

Processing costs +	Levies - Subsidies -	Provincial dairy processing sector cash costs	≤ 0

(11) Processing Costs

Activity for processing dairy product times unit processing cost -	Total provincial processing costs	≤ 0

(12) Levies

Fluid market milk production times skim-off levy +	Industrial market milk production times in-quota levy +	Over quota milk production times over quota levy -	Provincial levy total	≤ 0

(13) Subsidy

- Industrial market milk production times subsidy -	Industrial cream production times subsidy +	Provincial subsidy total	≤ 0

(14) Milk Balance

Fluid market milk production +	Industrial market milk production +	Overquota milk production +	Industrial cream production -	Total provincial supply raw milk	≤ 0

(15) Fluid:Industrial Ratio

Fluid market milk production -	Industrial milk (including overquota) production times proportion of total which goes to industrial	≤ 0

(16) Industrial Cream Ratio

Total raw milk production -	Industrial cream production times proportion of production which goes to cream production	≤ 0

(17) Market Share Quota

Industrial market milk production times amount of butterfat per hectolitre +	Industrial Cream production times amount butterfat per hectolitre	$\leq$	Provincial MSQ level in tonnes butterfat

(18) Milk Component Balances

(a) Fluid Butterfat

- Fluid Market Milk Production times amount butterfat per unit (hl) +	Transfer (tonnes) of butterfat to industrial market +	Production of fluid market final products times amount of butterfat per unit	≤ 0

(b) Fluid Solid Non Fat

- Fluid market milk production times amount of SNF per unit (hl) +	Production of fluid market final products times amount SNF per unit (hl)	≤ 0

(c) Industrial Butterfat

-	Industrial Milk Production times amount butterfat per unit (hl) -	Over Quota milk production times amount butterfat per unit (hl) -	Industrial cream production times amount butterfat per unit (hl) +	Production of industrial market final products times amount butterfat per unit (hl)	≤ 0

(d) Industrial Solid Nonfat

-	Industrial milk production times amount SNF per unit (hl) -	Over quota milk production times mount SNF per unit (hl) -	Industrial milk production times amount SNF per unit (hl) +	Production of industrial market final products times amount SNF per unit (hl)	≤ 0

Associated with the processing activities are processing costs (equation 11). These costs are summed up and transferred to the provincial cost row, which in turn negatively enters the objective function (via equation 10).

The butterfat subsidy along with the skim-off, in-quota and overquota levies are associated with activities for the four basic milk supplies (equations 12 and 13). These equations represent part of the government policy component of the model. The fluid market milk has a skim-off levy to cover the movements of butterfat to the industrial sector. The industrial milk (within MSQ) is charged an in-quota levy, but receives the butterfat subsidy. Over-quota milk production is charged an over-quota levy. And, finally, industrial cream receives the butterfat subsidy but is not charged a levy.

In the milk balance equation (equation 14), raw milk from the production sector is allocated to one of four uses, fluid market milk, industrial market milk, overquota milk and industrial cream. A ratio of fluid to industrial (per province) ensures the fluid quota levels for each province are not exceeded (equation 15). The remainder of the milk, after fluid use is accounted for, is allocated to one of the three industrial uses.

The industrial cream supply is also controlled through the use of a ratio on total milk production (equation 16). This, along with the remaining milk in a province, draws from the row for market share quota (equation 17). Once the MSQ is totally used for a province excess production is allocated to overquota milk. This overquota production is charged a large levy. A milk balance row insures these four activities use all raw milk supply for a given province (ie: total use $\leq$ total supply).

Fluid and industrial supplies of milk are broken down into their butterfat and SNF components in the four milk component balance rows (equations 18 a,b,c and d). Fluid milk components enter the fluid balance rows and industrial supplies enter the industrial balances. On the demand side the final products draw from their respective market balance rows. This ensures the amounts of butterfat and SNF used by the fluid or industrial products don't exceed the amounts available given the supplies of milk.

3. <u>Dairy Trade Block</u>

Only industrial milk products are shipped in the CRAM model. These may be shipped either interprovincially or internationally. The equations for this sector are:

(21) <u>National Transport Costs</u>

Interprovincial movements of product times shipping cost per unit	+	Province - World trade movements times the shipping cost per unit	-	Total Shipping costs for the given product	≤ 0

(22) <u>**Demand Transfers**</u>

Exports of product from province	-	Imports of product into province	≤ 0

(23) <u>**Provincial Trade Accounting**</u>

Imports to province (exports from province)	-	Total provincial imports (exports)	≤ 0

(24) <u>**Canadian Exports**</u>

–	Summation of province to world movements of product	+	Total Canadian exports of product	≤ 0

(25) <u>**Canadian Imports**</u>

Summation of world to province movements of product	-	Total Canadian imports of product	≤ 0

Only industrial dairy products in this study are shipped either interprovincially or internationally in the CRAM model, however the model structure also allows fluid milk movements. Any imports are added to supplies and exports drawn from the demand transfer row ensuring only production for domestic consumption goes through to the demand subsector (equation 22). These movements also enter accounting rows to track provincial imports and exports (equation 23).

Total exports from each province to the world and imports to each province from the world are tallied in a Canadian export row and a Canadian import row (equations 24 and 25). These totals are then transferred up to the objective function row where the value of the imports enter as a cost and the value of the exports a revenue.

4. Dairy Demand Subsector

The processed dairy products, net of trade, supply domestic demand functions specified on a regional level for western or eastern Canada. The regional demands are split down to the provincial level by the use of ratios representing a provinces share in regional demand. The general equations for this subsector are:

(26) Objective Function

Maximize:

Area under demand curve corresponding to step chosen for west	+	Area under demand curve corresponding to step chosen for east	-	Production costs

(27) Revenue (Price) Accounting Row

Revenue (price) associated with demand function step times 1 if step chosen and times 0 otherwise	-	Activity for revenue (price) of product	≤ 0

(28) Demand Row

Summation of production from provinces making up region	+	Net eastern or western demands associated with step times 1 if step chosen, times 0 otherwise	≤ 0

(29) Covexity Constraint

1 times activity of choosing step	-	Activity representing amount which consecutive steps most add up to in value	≤ 0

Using Duloy and Norton (1975) type demand functions the activity associated with a step on the demand curve which maximizes consumer plus producer surplus will be chosen. A convexity constraint ensures that only one step will be chosen, or some combination of two adjacent steps which add to one (equation 29). Accounting rows keep track of the revenue, price and quantity demanded for the chosen step (equations 27 and 28).